



OPINION ARTICLE

# A new paradigm for the scientific enterprise: nurturing the ecosystem [version 1; referees: 2 approved, 1 approved with reservations]

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**Abstract**

The institutions of science are in a state of flux. Declining public funding for basic science, the increasingly corporatized administration of universities, increasing “adjunctification” of the professoriate and poor academic career prospects for postdoctoral scientists indicate a significant mismatch between the reality of the market economy and expectations in higher education for science. Solutions to these issues typically revolve around the idea of fixing the career “pipeline”, which is envisioned as being a pathway from higher-education training to a coveted permanent position, and then up a career ladder until retirement. In this paper, we propose and describe the term “ecosystem” as a more appropriate way to conceptualize today’s scientific training and the professional landscape of the scientific enterprise. First, we highlight the issues around the concept of “fixing the pipeline”. Then, we articulate our ecosystem metaphor by describing a series of concrete design patterns that draw on peer-to-peer, decentralized, cooperative, and commons-based approaches for creating a new dynamic scientific enterprise.

**Keywords**

academia, higher education, independent scholarship, careers, science studies, politics of science, systems-thinking, peer-to-peer science, collaboration



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**Introduction**

The institutions of science are in a state of flux. Declining public funding for basic science<sup>1,2</sup> has led academic institutions to change their business models<sup>3,4</sup>; the administration of universities is becoming increasingly corporatized<sup>5</sup>. With increasing “adjunctification” of the professoriate<sup>6</sup>, continued use of outdated funding models for research science in academia, and dwindling academic career prospects for postdoctoral scientists<sup>7-10</sup>, it is clear that there is a mismatch between the reality of the market economy and expectations in higher education.

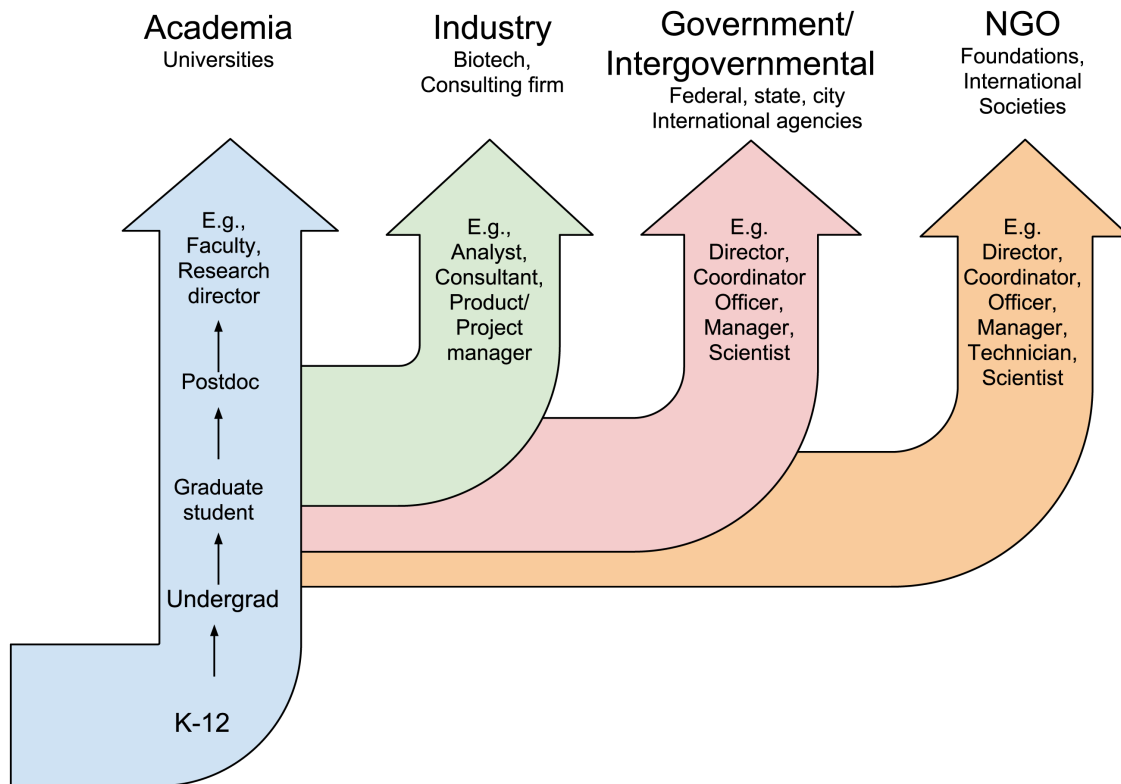
The evolving funding landscape at academic and research institutions has had a major impact on career opportunities for scientists, particularly those who are early-career. As a result of grant dollars being increasingly awarded to a disproportionately small number of established investigators and institutes<sup>11</sup>, intellectual discovery has become captured by a privileged few<sup>12</sup>, leading to greater bias in scientific research, diminished scientific productivity<sup>13</sup>, and less potential for breakthrough discoveries<sup>14,15</sup>. Such a lack of social diversity and equity is a major challenge in science, technology, engineering, and mathematics (STEM)<sup>16,17</sup>. Solutions are often sought out by proposing adjustments to the “career pipeline”, but these issues in STEM continue to be unresolved.

The career pipeline envisions a straight career path, from higher-education training to a coveted permanent position, and then up

a career ladder until retirement (Figure 1). While such a direct path to success may be optimal for some, it does not reflect the reality of typical career development (Box 1). In today’s economy, permanent positions are becoming rarer across all industries, including universities, which are as more contract positions that are short-term and require no employee benefits are offered<sup>18</sup>.

The limitations of the pipeline as a conceptual model for education and careers is being recognized in both the tech industry<sup>19</sup> and science<sup>20</sup>. The consequences of continuing to apply this outdated model is stalled career development in science, underemployment of some of the most highly educated people in our society, and overall loss of STEM professionals as they seek out career alternatives<sup>21-23</sup>. In 2016 \$3 billion were invested into federal agencies to support STEM education programs<sup>24</sup>. Considering the governmental and individual investment that is made into higher STEM education each year, this is not just an academic conundrum—it is a societal problem.

By persisting with the assumption of the pipeline, we also miss engaging in conversations that address the fundamental cultural change that is occurring in science today. A new conceptual model is needed to help guide both early-career scientists and those who care about the scientific enterprise towards a more sustainable and resilient professional future. In this paper, we propose and describe the term “ecosystem” as a more appropriate



**Figure 1. The standard scientific career “pipeline”.** The pipeline includes formal scientific training and different scientific career paths. The pipeline is characterized as a set of distinct streams with little flow between each stream, and a career ladder within each sector.

**Box 1. The PhD “path” to a tenure-track position**

The alarming disproportion between the number of people with PhDs and the number of university-based academic positions available for PhDs has become a major preoccupation in the trade science press and beyond<sup>25</sup>. Indeed, training models for graduate students, and particularly for PhDs, in STEM often focus on delivering them to a tenure-track faculty position. Decades-long reliance on graduate students and post-doctoral researchers as cheap labor contributes to today’s unsustainable academic models and underemployment of academic scientists. Such a system has become a poverty trap for many graduate students and early PhDs, as they work long hours for low wages under the expectation that their participation in the pipeline will eventually lead to a permanent position in academia. The reality is that only 8% of postdocs are able to land a tenure-track job within 6 years of being awarded a PhD<sup>26</sup>.

Much of the discussion around career prospects for PhDs assumes that they must find a traditional position in a university in order to continue pursuing their scientific goals<sup>27</sup>. Funding changes have also produced an academic structure that provides limited prospects for early-career scientists to advance their careers within academia<sup>9</sup>. Postdoctoral training periods also continue to expand. While the increasing complexity of research may require longer training periods, it is unlikely that longer postdoc positions result in better researchers; many postdocs rarely get the appropriate direct training and mentoring to start an independent lab<sup>28</sup>. It is unknown how many promising, early-career scientists become trapped in postdoctoral limbo, as the morass of titles given to postdocs disguises the scale of the scientific workforce that exists in this state<sup>29</sup>. The ever-lengthening apprenticeship time for scientists has created a Red Queen’s Race: scientists must run twice as fast to stay in the same place with their point of “independence” postponed almost indefinitely<sup>30</sup>.

Additionally, an outdated mentality still persists that the path to faculty tenureship requires putting science ahead of all of life’s other priorities, and this can have a severely negative effect on the mental health of those who try to conform (e.g., 31). While this model may have worked decades ago for those (mostly male) scientists that could rely on compliant spouses to raise families and perform domestic duties, it does not work in today’s world. By presenting it as such, the pool of tenured faculty is limited to those who have the means to commit to such a lifestyle: typically young, male, unencumbered with children and geographically unconstrained. This demographic is steadily decreasing proportionally across the whole scientific research community, so career advice solely targeting this group is increasingly irrelevant.

Even after gaining a tenure-track position, the mechanics of gaining tenure can be just as rigid and unforgiving<sup>32</sup>. The intense pressure on faculty to be “productive” (i.e., larger grants, publications in “high impact” journals), as well as the race to achieve institutional measures of “excellence”<sup>33</sup>, all divert attention from scholarship<sup>2,28,34,35</sup> and undermine the creativity that nourishes scientific progress<sup>36–38</sup>. There have been serious concerns that such hypercompetition has led to a drop in scientific quality, especially in the biomedical field, as labs vie to publish their papers in the limited number of “slots” in high profile journals<sup>39,40</sup>. Indeed, the existence of fairly accurate predictive models<sup>41</sup> of one’s chances of “becoming a principal investigator” based on affiliation, publication, and grant metrics, is itself a symptom of a profoundly narrow view of “success” in science.

way to conceptualize today’s scientific training and the professional landscape of the scientific enterprise. First, we highlight the issues around the concept of “fixing the pipeline”. Then, we articulate our ecosystem metaphor by describing a series of design patterns that draw on peer-to-peer, decentralized, cooperative, and commons-based approaches to science. We finish by describing the related cultural shifts underway that can hasten a more diverse and fluid scientific enterprise into the 21st century.

**Fixing the pipeline**

Much effort has gone into improving the efficiency of the scientific “career pipeline” (Figure 1). Proposed solutions tend to fall into one of three categories: adjusting the rates of flow in the pipeline, modifying oneself to fit the pipeline, or switching to an “alternative” pipeline. These solutions focus primarily on accessing tenure track faculty positions, as this issue has received the most attention in literature regarding the challenges facing the “pipeline” for scientists (Box 1). Here, we highlight some of the main issues facing these proposed solutions.

**Adjusting flow in the pipeline**

Alberts *et al.*<sup>35</sup> proposed that the supply of the pipeline (i.e., the number of trainees) should be adjusted to match the demand (i.e., the number of tenure-track positions). Increasing the number of tenure-track-style positions, as desirable as that might be, seems unlikely given the current trends in

science funding. By addressing the demand end, it has also been suggested that the size of individual labs should be decreased to reduce the number of trainees that must be moved into faculty positions<sup>10,42</sup>. While these proposed reforms are thoughtful and well-intentioned, they do not address the problems of an oversupply of talented researchers and funding models that rely on large numbers of low-paid trainees to get work done. Such a solution could certainly lead to fewer scientists with more career stability, but is this the future that we envision for science and our society?

**Adapting to the pipeline**

Today’s search for a tenure track position is often a multi-year process as many open positions are saturated with candidates<sup>43</sup>. Many candidates must go to great lengths to make themselves more competitive. Recognizing this need, academic departments, as well as for-profit companies<sup>44</sup>, now assist with academic “survivorship” to help potential candidates prepare CVs, develop interview skills, and write research statements. This is leading to a system that is even less accessible to those with lesser means<sup>45</sup> and may contribute even further to a bias towards hiring candidates from elite institutions<sup>46</sup>. It also contributes to the ever-lengthening time period before a scientist can “fledge” as a professional in academia. Much of the energy, currently being devoted to preparing individuals to adapt to the system, could be redirected towards more collaborative and collective solutions.

### Finding another pipeline

The paucity of traditional academic jobs has led to increased career advice about alternatives to academic careers, and there are encouraging indications that many PhDs are finding employment outside academia<sup>47,48</sup>. Although most of these efforts are entirely well-meaning, they sometimes have the unintended consequence of reinforcing the same tendencies as “pipeline-thinking”. For example, a recent *Nature* editorial discussed the ability of PhDs or postdocs to “stay in touch with science” by working in a “related function such as administration, outreach or publishing”<sup>48</sup>. While these career options suit many people, the possibility of doing any future self-directed science outside of an academic or research position is rarely considered. Such a narrative is disempowering overall, as junior researchers are encouraged to “take a hard look at their job prospects” rather than question the nature of institutions or the pipeline<sup>25</sup>. Other discussions of the STEM pipeline are framed by discussions of “workforce needs” and the production of workers that are “globally competitive”<sup>49,50</sup>, reinforcing a business approach to science<sup>51</sup>, rather than on doing science as a public good or for its own sake<sup>52</sup>.

### Thinking outside the pipeline

Much of the career advice on how to be successful in the academic science pipeline reflects the values and dynamics present in the job market when many senior scientists obtained their first positions (e.g., that outlined by Diamandis<sup>53</sup>), instead of the realities of today<sup>54,55</sup>. As many of these scientists’ career experiences are often limited to academia, their perspectives may not be relevant to early-career scientists who are open to other career options. Academics often fail to recognize the broad applicability and value of PhD degrees, or encourage their trainees to work outside the traditional academic pipeline.

By framing solutions in terms of “fixing the pipeline”, the underlying career structures for scientists remain largely unchallenged. As such, early-career scientists occupy a passive role, waiting for change to come from the top, such as through institutional reform driven by senior leaders. Likewise, the scarcity of research positions is accepted as a given, limiting how much science can be done. There is, no limit on society’s need to address complex challenges, the number of research questions that can be asked, or the amount of scientific *work* that can be done. New models are needed to help identify different ways for scientists to continue their work outside of a standard academic or agency job.

### The science ecosystem

We propose an ecosystem as a conceptual model that is relevant both to the training of a scientist and their role as a professional (Figure 2). The two most inner circles in the Figure depict the basic necessities, training, and professionalism of science. Here, traditional scientific labs may still have a role, but the networks of peer-to-peer collaborators that span both within and outside of institutions are emphasized. The two outermost circles are the impetus behind the changing context of science today. It is becoming more evident that a new systems-based approach is needed to allow science to adapt more quickly to the

complex socio-political and biophysical context of today (the outermost circle). There are, however, now new resources, tools, and infrastructure (courtesy of STEM advances), such as lab space, journal access, and high-performance computing, either publicly available, or available for rent, that allow science to thrive outside of traditional institutions (the orange, next outermost circle)<sup>56</sup>. In addition, bottom-up changes are already being driven by early career scientists themselves in many different ways<sup>57–60</sup>.

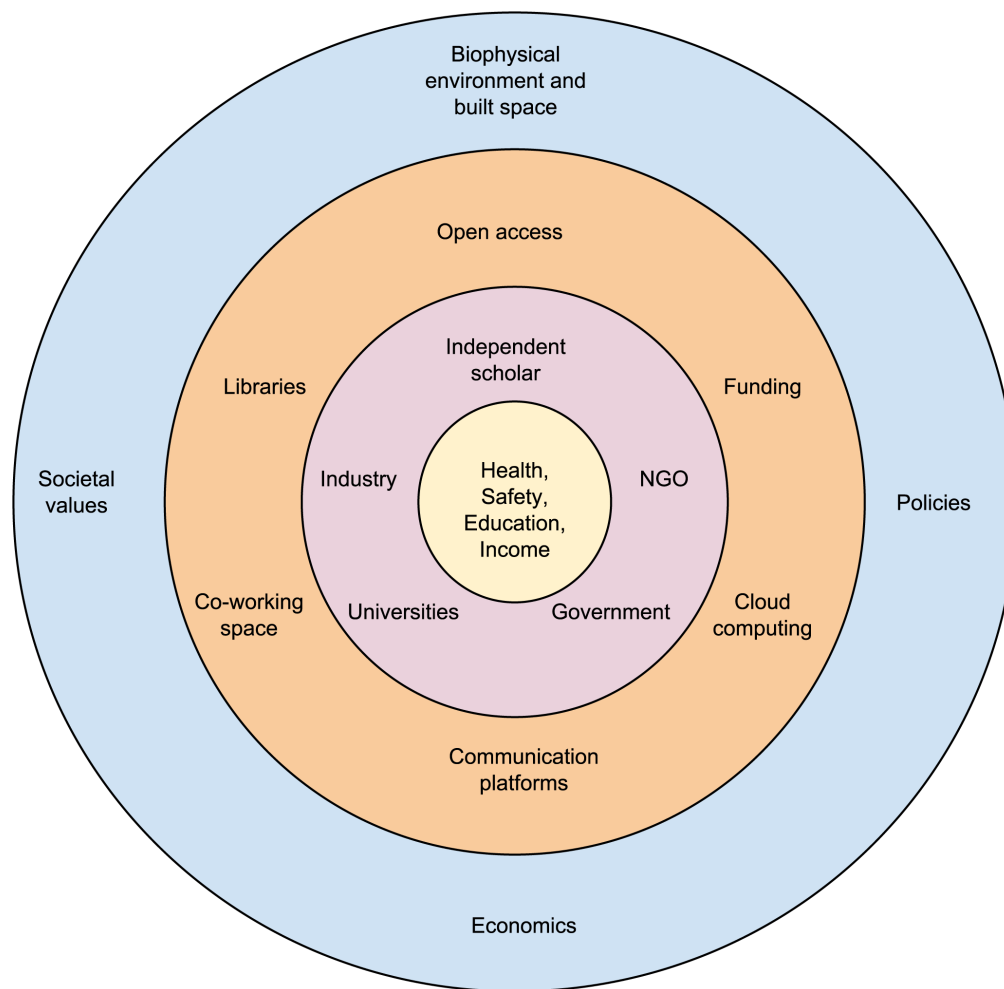
Many postdocs and adjunct scientists already have the majority of tools that they need to do independent science, such as deep training and understanding of their field, a body of work that demonstrates their scientific ability, pre-existing networks of colleagues with similar intellectual interests, and the Internet to collaborate and share. By moving beyond the existing pipeline model of academic science, the ecosystem vision provides the space, flexibility, and diversity that science needs to be more responsive to both local and broader complex scales affecting science.

To demonstrate how an ecosystem model would work in practice, we present a set of conceptual design patterns loosely inspired by commons-based approaches<sup>61–63</sup>, systems-thinking approaches<sup>64</sup>, and the sustainable livelihoods framework<sup>65</sup>. We acknowledge specific social movements and grassroots changes that are occurring today, and demonstrate how science now has the means to be more egalitarian, inclusive, and diverse by being less dependent on their institutional settings. We recognize, that major institutional reforms are needed to realize this vision to its fullest, so we also address the changing role of institutions within this vision. We deliberately chose the term “ecosystem” to resonate with many of the phenomena that exist in biological ecosystems: diversity, resilience, multiplicity of scales, dynamic feedback loops, etc., and we use some of these concepts when framing each of the design patterns. That said, we do not claim a one-to-one correspondence with biological ecosystems.

#### 1. Fundamental development of the scientist

Basic necessities (i.e., Maslow’s hierarchy of needs) are fundamental to any human livelihood, and certainly for a scientist to be able to flourish. To truly allow independent scientists to develop, a strong set of progressive social policies, such as universal health care, basic income, and high-quality free education, are needed to strengthen the core of the ecosystem<sup>66,67</sup>. The ecosystem concept recognizes that the journey of a scientist through training is often an indirect path with many more career development influences than the direct path that a “pipeline” implies (Figure 1). Instead, an individual learns foundational knowledge, explores ideas, and gathers experience through a journey that is influenced by a broad range of interests, a balance of personal and professional goals, and adaptation to the challenges of life overall.

Such a student might attend the traditional classes expected in their field, explore other fields of interest (e.g., fine arts, social activism), and gather experience through interactions with



**Figure 2. The scientific ecosystem.** The inner circle (beige) represents the basic necessities needed to be a functioning member of society, as well as a scientist. The next circle (purple) shows the different groups that are often involved in the pursuit of knowledge and scientific progress. Because the circle can be rotated there is no 'up' in this representation; no one type of institution is privileged in this representation and there is exchange in all directions. In addition, the borders between the different institutes are highly porous—there is collaboration, reflection, and sharing of resources between them. The next circle (orange) represents different kinds of resources and infrastructure needed to support science. The outermost circle (light blue) represents the environmental context, including biophysical limitations, and the socio-political and economic landscape, that science and scientists must function within, adapt to, and seek to understand and affect.

others, work, internships, and volunteering, both within their field and outside of it. Along the way, they might explore other career (or life) choices, and perhaps return to academia completely, or explore specific scientific questions from a new perspective in another career choice outside of traditional academic institutions. Overall, the ecosystem model emphasizes that there is no right way to become a scientist. The diversity of experiences and perspectives are key to advancing STEM development in novel and more inclusive ways.

## 2. Multiplicity of niches

Most importantly, the ecosystem model recognizes that every scientist is a person, meaning that people are more than their jobs and must balance a myriad of responsibilities, goals, and limitations that change as they move through life. While the conventional academic scientist pipeline assumes that individuals are functioning within a protected static environment (i.e., male

scientists who serve as the breadwinner for their family in a generally unchanging environment), the ecosystem model encompasses the diverse and dynamic roles that individuals (both men and women) take on, particularly as they move through the household lifecycle (i.e., people's needs and resources change throughout their life and most notably when they raise a family<sup>68</sup>). Indeed, sustainable livelihood strategies<sup>65</sup> further emphasize this point by recognizing that people must be constantly making decisions to most efficiently use their resources (human, natural, financial, physical, and social capital) to meet their livelihood needs, and such decisions are often made within the context of the changing biophysical and socio-political conditions of the system that they live in.

Furthermore, people must balance both non-monetary activities (i.e., child-rearing, house-keeping) with income earning activities, and both are equally important to almost all individuals. There

is a lack of recognition of the importance of non-monetary activities in making livelihood decisions within conventional career models, as well as limited supporting economic and political structures to support these activities<sup>69</sup>. The pipeline model simply doesn't consider both career and life balance in such a dynamic environment, nor does it present any opportunities to leverage the social diversity that occurs through such processes. By contrast, the ecosystem model not only presents a flexible model that encompasses the dynamism of the system, it also thrives on social, economic, and experiential diversity.

Income-generating activities in the ecosystem approach can be diverse different, contrasting with the expectation of there being a sole niche, such as tenure-track employment in university settings. Some of these new niches include part-time, or "fractional scholarship"<sup>57</sup>, through virtual institutes such as the Ronin Institute<sup>70</sup> (see [Box 2](#)), small business or consulting companies (either partly or wholly focused on scientific research), and non-traditional start-ups. For example, some independent scholars run consultancies involving their scientific expertise in a commercial setting, but reserve time to pursue their own research; their research and consulting activities help inform the other, resulting in more grounded research and science-informed solutions, respectively. At a larger scale, some independent scientists have obtained venture capital funding to pursue biomedical research<sup>71,72</sup>, such as [Perlara](#) in San Francisco, which operates as a public benefit "B-corporation".

### 3. Open ecosystem flows

Academics often view the abandonment of the search for a permanent tenured university position as a signal that a person is "leaving science", but we argue that this should not necessarily

be a one-way valve. Thus, another step towards building the open ecosystem is to normalize the movement into and out of traditional university positions. The formal system for scientific training must value students, postdocs, or other researchers who leave and re-enter programs or jobs for their professional and diverse experiences, and the unique network of colleagues that they bring to programs or jobs. Such a change will reduce the fear that scientists have in diversifying their career experience. We expect that for some kinds of science (i.e., those that require the use of expensive equipment), employment in a traditional university-based setting may continue to be the most appropriate, but other types of science (e.g., theoretical and computational sciences) can easily be practiced outside traditional academic settings ([Box 2](#)). Normalizing these movements as one of many flows within the overall scientific ecosystem would be a big step in the right direction ([Box 3](#)) for both broadening and diversifying science, and creating new career opportunities for scientists.

### 4. Diversity of scales in pace and budget

The increasingly all-consuming competitive nature of academic life often discourages speculation, innovation, and collaboration<sup>73-75</sup>. Little time and energy is left for the reflection needed to develop original ideas<sup>35</sup>. Interesting and creative science does not necessarily require this intense pace and may even be inhibited by it. The "slow" science movement encapsulates a more deliberative and conscious approach to science ([Box 4](#)). Smaller-scale research projects can have quite modest budgets, and crowdfunding sites such as [Kickstarter](#) and [Experiment.com](#) have supported many such interesting scientific projects<sup>76</sup>. Relative to standard grants, funds raised via crowdfunding might be considered tiny, but with the large overhead required by brick

#### Box 2. Independent institutes and laboratories

Organizations of independent scholars, such as the non-profit [Ronin Institute](#) for Independent Scholarship (of which the authors are all members), the [National Coalition of Independent Scholars](#), the [Institute for Globally Distributed Open Research and Education](#), [CORES Science and Engineering](#), [NeuroInx Research Institute](#) and research consortia such as the [Complex Biological Systems Alliance](#)<sup>2</sup> enable highly trained individuals to contribute to basic science outside the traditional academic setting. Independent labs focusing on more specific research questions or subject areas have also emerged, such as the [Orthogonal Lab](#). The Ronin Institute, in particular, provides support and infrastructure for submitting grants to existing funding agencies, but crucially also provides a home for scientists who may have either a part-time or full-time job, but wish to pursue their scholarship on a part-time or "fractional" basis<sup>57</sup>. Many such scholars also retain joint or visiting status with traditional universities, demonstrating the porousness between institutes as part of the overall scientific ecosystem. Through seminars, virtual meet-ups, and in-person unconferences, the Ronin Institute provides an essential community for independent scholars to trade ideas and identify new collaborations, so that they are not operating within a vacuum. For example, PhD graduates who work in private companies, government agencies, or the non-profit sector do not have to trade their scientific career for a profession. In addition, independent scholars can side-step some of the bureaucracy of the university, while maintaining their scientific identity that can be lost while working in full-time industry jobs.

#### Box 3. Shifting the dominant narrative

A tenure-track job is still the dominant yardstick of legitimacy for a scientist<sup>27</sup>, and such a lack of vision for scientific careers makes institutional and cultural change in science difficult. Benderly (2015) offers one example where non-tenure-track early career scientists have been dismissed in biomedicine<sup>77</sup>. Unfortunately not all in positions of power are good-faith participants in this conversation: beneficiaries of a system built on implicit assumptions of zero-sum competition for attention and prestige are unlikely to welcome change. However, many senior academics recognize the unsustainability of the current system<sup>78</sup>. There are many steps that such sympathetic senior academics can take to support the ecosystem view. Here are just some: (i) Use language more carefully: don't refer to scientists who do not secure a traditional academic job as "leaving the field"<sup>79</sup>; (ii) More visibly reject the journal impact factor prestige system and embrace preprints and other forms of open research<sup>80,81</sup>; and (iii) Include collaborators beyond those who are university-based, when possible. These small shifts will add up, especially if they originate from well-respected senior academics.

**Box 4. The slow science movement**

Today, many grant dollars are awarded to a disproportionately small number of established investigators<sup>11</sup>, due in part to an increasing emphasis on high-budget, complex science. The rise of “Big Institute” science is channelling both philanthropic and federal dollars towards specific industries (e.g., biomedical research, specific diseases) and biotech hubs<sup>52</sup>, leading to fewer large labs working in a limited number of lucrative research areas. Traditional labs in university settings are incentivized to grow in size, partly because the overhead earned through grants helps fund the institution as a whole<sup>42</sup>. “High profile” journals also tend to favor work done at larger, and therefore more expensive, scales. These two factors bend institutional incentives towards funding expensive research questions and hiring faculty with publications in prestigious journals who do such work.

By contrast, the ecosystem model explicitly acknowledges the value of “slower” approaches to scholarship and science, and recognizes that scientific progress is enabled by scientists pursuing questions at all different scales and pace<sup>83–85</sup>. While expensive, big science certainly has an important place, its prioritization over smaller-scale investigator-driven science tacitly and severely constrains the scope and types of questions that can be asked<sup>82,86,87</sup>. The slow science movement emphasizes a more deliberative, less publish-or-perish pace to provide time for scientists to build trust, create more effective and durable collaborations, and invest in more collective approaches for doing science. The presence of the collaborative and reflective personalities required to address complex problems with team-based solutions<sup>88–91</sup> tend to be weeded out in the current system. Moreover, even in traditional academic positions, the conventional narrative of faculty publishing productivity—a peak of publications in early career with a gradual decline—doesn’t fit the actual publication records of many scientists. In computer science, for example, it only describes about one-fifth of tenure-track careers<sup>92</sup>, even though this conventional narrative has a great influence on hiring and tenure decisions.

and mortar academic institutes (often over 50% of a grant), such funds can often go a long way in a research budget. Such monies have been fairly modest to date, but these approaches are still in their infancy and have much more potential for growth. The scientific ecosystem concept explicitly recognizes the value of, and enables, such scientific work at multiple niches and scales.

**5. Peer-to-peer networks**

Researchers in traditional settings operate in a highly hierarchical system, where the usual benchmarks of “success” are controlled by a relatively small number of people at each level. A large number of apprentices are under the control of a small number of masters<sup>93</sup>; this structure can make it difficult for new ideas to gain a toehold<sup>94,95</sup> and can also lead to the exploitation of apprentices<sup>96,97</sup>. While senior investigators occupy important roles in identifying promising research avenues, providing synoptic views and institutional memories of their field, and many are tireless in promoting their trainees and helping them succeed, this success generally assumes continuing within the “pipeline” model. In contrast, we believe that moving towards less hierarchical peer-to-peer ecosystem models, which emphasize more democratic decision-making, cooperativity, and solidarity, will lead to a more dynamic and creative scientific enterprise overall (Box 5).

**6. Fluid communication networks and shared access to resources**

The burgeoning open science movement<sup>15,98</sup> is a key enabler of the scientific ecosystem by bringing data, models, and resources out from behind institutional walls. Initiatives, such as the Center for Open Science<sup>99</sup> and Sage Bionetworks<sup>100</sup>, have developed pioneering tools to enable large-scale sharing, and thus mining of open biological data by any interested parties without the need for the original infrastructure that generated the data. Access to shared resources, such as lab space, are also part of this shift (Box 6). In addition, the citizen science<sup>101</sup> and indigenous research<sup>102</sup> movements reach out to

bright and creative individuals outside the academic system who are eager to contribute skill and time to advance science. The growth of open-access publishing will especially benefit the peer-to-peer model proposed here (Box 6).

**7. Broader distribution of resources**

Self-funding of research can sometimes be sufficient, since many studies, especially in computational, mathematical, and social science fields cost little beyond the time required. Free of arbitrary institutional expectations of “bringing in grant money”, this can be quite liberating. However, many other kinds of research, especially wet lab biology, can be expensive and labor-intensive. The benefit of joining institutes like the Ronin Institute, allows scholars to apply directly for traditional federal grants (e.g., NIH or NSF) with reduced institutional overhead, leading to more efficient use of money for research. However, existing funding agencies, especially federal, are largely geared to favour the already well-funded or those who are working on whatever scientific questions they may be prioritizing that year. More balance is needed to ensure that scientific questions that are valued by society are also represented. Funding solutions outside of the traditional federal agencies and more distributive approaches, whether federally funded or otherwise, must be considered to help fill this gap (Box 7).

**8. Institutional change**

While we have emphasized existing grassroots movements and trends, this is not because we do not need reform of our institutional practice of science—we certainly do. However, we believe that social and structural changes are often initiated outside institutions, and these efforts can catalyze internal reforms. That said, many of the design patterns have clear institutional analogs. The aforementioned peer-to-peer approaches discussed under subheading 5 can be implemented within institutions as well, particularly at the level of individual labs, by giving postdocs greater autonomy outside of individual projects or grants<sup>103</sup>. Some institutions, such as the Santa Fe Institute, have



**Box 5. Beyond the “principal investigator”: new self-organized collaboration models**

The model of academic science that early career investigators are taught to aspire towards (a “principal investigator” directing a large number of apprentices) is essentially feudal in structure; it is a historical product of the structure of academic institutions. This predominant structure dates roughly from Vannevar Bush’s famous 1945 memo, “Science: the endless frontier”<sup>104</sup>, and is not intrinsic to the discovery process itself. The cultural movement of increasing equity and access, which is driven by the ubiquitous presence of the Internet, the rise of peer-to-peer, commons-based production<sup>62,105,106</sup>, and crowdsourcing<sup>107</sup>, challenges this feudal/industrial model of the production of cultural goods<sup>105,108</sup>, including science. This looser, self-organized approach to intellectual production is demonstrated by the free, libre, or open-source software (FLOSS) movement (which has produced operating systems like GNU/Linux), as well as Wikipedia<sup>109</sup>.

Contributors to FLOSS projects also occupy different niches: some developers of open-source software are employed by companies (e.g. Red Hat), others contribute only one or two lines of code as volunteers, and most contribute at levels in between. Some scientific projects are run in similar ways<sup>110</sup>, and there is natural fit with idea of fractional scholarship introduced in our second pattern on the multiplicity of niches (subheading 2): important scientific contributions can be made at whatever time and energy level that an individual can provide. Open-source projects, and peer-to-peer production more generally, are not without structure<sup>62</sup>. Projects still develop leadership and lines of authority, and the need for mentorship does not disappear<sup>111</sup>, but leadership is fluid, often chosen by consensus, and based more on time, energy, and enthusiasm rather than an academic title or pedigree<sup>112</sup>. Consistent with our ecosystem approach, we imagine a multiplicity of solutions whereby the traditional PI structure is but one model within a larger spectrum of more peer-to-peer structures.

**Box 6. Commons-based access to shared resource and open access**

The DIYbiology movement has championed an extremely low-tech, low-cost approach to experimental molecular biology. The emergence of community labs and commons-based co-working spaces (e.g., [manylabs.org](http://manylabs.org)) are making work possible outside university settings<sup>113,114</sup>. Facilities for genome sequencing<sup>115</sup> and “rent-by-the-bench” lab space, such as QB3@953 in San Francisco, CA and LabCentral in Cambridge, MA<sup>116</sup>, can enable lower-cost, lab-based research that might be completely off the radar from more traditional academic labs or large biotech companies. Mathematical and computationally based research is also now well within the reach of many independent scientists. Cloud-based computing servers offered via Google Cloud and Amazon Web Services<sup>117,118</sup> can be done at a fraction of the cost of running a large university-based high-performance computing (HPC) cluster.

Open-access is another strand in an ecosystem model of science. Notably, open-access information now allows many “researched” communities to finally have access to information about their own communities, and take action from a grassroots position (e.g., members of developing countries are now more empowered to take part in science). However, the “author-pays Article Processing Charges” model of many open-access journals will require some rethinking in the absence of institutional support. The incredible uptake of preprints, especially by younger scientists, as a way around the artificial scarcity of the journal prestige system is an encouraging first step<sup>119</sup>. The growth of low-cost non-commercial models of publishing based on “platform co-operativism” principles<sup>120,121</sup> that are owned and run by scientists are likely to be more equitable and sustainable in the long-run for scholars than venture-capital backed experiments<sup>122</sup> ([www.scholarlyhub.org](http://www.scholarlyhub.org)); Open science and open access platforms should be focused on the goal of improving communication, scholarship, and learning, rather than being simply a way to extract commercial value from scientist’s labor<sup>123,124</sup>. New conferences like [OpenCon](http://OpenCon) and [FORCE11](http://FORCE11) are leading the conversation in this area.

**Box 7. Rethink funding**

Various federal agencies have mechanisms to compensate for the bias towards large institutions and senior, male scientists. For example, the R15 grant mechanism of the National Institutes of Health is restricted towards institutions that receive less than an overall amount per year. The National Science Foundation has grants specifically for postdocs and early career faculty, and they may withdraw or extend a deadline if gender is not well-represented among the applicants. These programs help to correct bias, but still assume participation in the pipeline model. In addition, the massive amount of bureaucracy involved in the submission and reporting of such grants is a barrier to applicants with minimal grant administration support. Attempts to be more explicitly redistributive, such as a proposed cap of three concurrent R01 grants, have been met with fierce resistance<sup>125</sup>.

Fundamental rethinking of funding to address the current concentration of resources is needed. Here, we present two ideas. First, we propose the “fail fast” model, which comes from the tech start-up world. In this model, many smaller projects receive 6–12 months of funding to pursue an idea. If the idea works, the next phase receives funding. If the idea does not work, the researchers move on to the next idea. The “fail fast” model would support many smaller groups for a shorter period of time. It also addresses the reluctance of many funding agencies to fund riskier research as well as the need to have nearly all of the proposed work complete before writing a grant to get the funds to do said work. This model is unlikely to support students, however, as they often need 3–4 years of stable funding.

Second, we support experimenting with “collective allocation” models, where each qualified scientist is given a fixed basic grant (somewhat analogous to a “basic income”) and also receives additional funds from other scientists who think they would make good use of the grant money<sup>126</sup>. Each such scientist would also be required to “pay forward” a fraction of the previous years’ grant money to other scientists in the same manner, thus increasing the overall flow of funds through the scientific community. One benefit is that it reduces the time-consuming and costly bureaucratic infrastructure of the grant review system, while still maintaining the positive influence of peer-review. In addition, there could be rules to minimize “gaming” the system by preventing paying it forward to immediate co-authors<sup>127</sup>. Related ideas include allocating a portion of funding via lottery<sup>128</sup>. The new head of Science Europe has expressed interest in trialing these some of these new mechanisms<sup>129</sup>, indicating a growing frustration with the existing grant process and a willingness to experiment with more radical models.

postdocs that are tied directly to the institution, rather than an individual professor. Furthermore, institutions should recognize that researchers work in different styles and at a diversity of scales, as discussed under subheadings 2 and 4, respectively, and avoid monolithic ranking and assessing of scholars by external metrics.

Finally, the ecosystem approach of providing multiple on-ramps and off-ramps to academia (subheading 3) together with distributing resources more broadly (subheading 7), point to a reform of the tenure system itself. The tenure system could be made more fluid, and the benefits of tenure (stability, security) extended to more people, rather than a lucky few. A progressive commons-based economy would be one way to realize this vision (Box 8). Organizations such as Future of Research, which are leading the way in engaging institutions to encourage open-science practices (subheading 6) and shape a more equitable job and funding landscape (subheading 7), should also be vigorously supported<sup>58</sup>.

### Writing a new cultural narrative

Our paper proposes a fundamental change in the way that scientific training and its professional landscape are viewed. In the spirit of our ecosystem concept, we hope to spark discussion, debate, and action rather than offer a complete “turn-key” solution to the current state of careers in science (if such a thing were ever possible). Increased participation and mobilization of scientists and their partners towards such a concept will ultimately determine how the concept evolves in a bottom-up manner. We particularly hope to reach early-career scientists who are making career decisions and developing professional identities, since they will be most actively involved in co-creating this new ecosystem. We envision that scientists at all levels that are seeking to address the challenges faced by scientific institutions may also find inspiration in this paper to help them catalyze change from the inside out.

Up until this point we have focused on the economic, social, logistic, and professional challenges of a new way of conceiving scientific work and careers. These are critical and necessary steps towards creating a more equitable scientific ecosystem. However, even if we demonstrate economically viable and sustainable ways for more scientists to contribute high quality research outside of traditional institutions, we must still

overcome a potentially larger hurdle: the dominant cultural narrative of scientific success based on scarcity, especially of certain kinds of jobs (Box 3). The set of strategies we propose, while highly disparate and pluralistic in approach, are all characterized by a view that success does not need to be a zero-sum game.

The language we use to frame our new narrative is therefore key to cultural change. As Lakoff and Johnson<sup>130</sup> point out, metaphors frame our thinking, as well as shape and constrain the cultural narratives of success. The ecosystem metaphor is our attempt to reframe and expand the discussion of STEM careers and science, beyond what has often become a sterile and arid debate about competition and scarcity within academia, by introducing the concepts of open flows, resilience, diversity, and feed-back loops of ecological systems. To this end, in Table 1, we provide a lexicon that highlights the non-zero-sum and egalitarian aspects of our ecosystem model, illustrating the contrasting language between the pipeline and the ecosystem. We do not assume that the pursuit of prestige or financial rewards will wither away; convivial competition clearly has a proper place in science<sup>131</sup> and will always co-exist with cooperation (existing somewhere on the spectrum between the two columns in Table 1). But we strongly believe that making science better is not just about “creating better incentives”, but a collective cultural shift beyond viewing competition and individualistic success as the sole defining feature of science (i.e., the pipeline model).

The existing socialization process of traditional academic science vastly over values signals of academic capital (title, rank, and institutional affiliation) and economic metrics of productivity (amount of grant funding, high-impact papers, and *h*-index); scholars who do not meet these criteria are often disregarded, limiting diversity in science. The most important part of the shift toward an ecosystem model is cultural and psychological: the essential spirit of science must be re-captured by emphasizing that there are no gatekeepers to the scientific development of knowledge. Academia doesn't “own” science, any more than museums, art schools, or galleries own art. Just as with visual or performing arts or music, the open-ended exploration of scientific ideas is something worth celebrating in itself, regardless of the nature or scale of the question.

#### Box 8. A secure, progressive economic system

As we noted under subheading 1, basic stability and security is a necessary condition for people to flourish. One of the continuing appeals of university-based, tenure-track positions, especially in the United States, is the job security and health-care benefits promised with tenure. Unfortunately in many industries, including academia, job security is going by the wayside; thus, many new progressive economic models are switching from a focus on job security to a focus on income security, and this takes the form of such initiatives as universal health-care and universal basic income<sup>66,67</sup>. With this kind of security in place, the developing flexible “gig economy” in science<sup>132</sup> is more likely to fully enable scientists to pursue their work in whichever part of the ecosystem that fits them best, rather than in predefined and allocated roles in the pipeline. The dark side of exploitation and insecurity in much of the existing mainstream cultural and gig economy<sup>133–135</sup> is very real, so we advocate for a truly progressive economic system that protects and creates security for all. The benefits of the new flexible peer-to-peer approaches to work must be widely distributed and not concentrated into a small number of hands<sup>62,136</sup>.

**Table 1. Establishing a new cultural lexicon for science: comparing the language emphasized in the pipeline and ecosystem metaphors.**

	Pattern	Pipeline metaphor emphasizes	Ecosystem metaphor emphasizes
1	Basic development of scientist	Linear: K-12, grad school, postdoc, "superdoc", tenure-track "What is your job?"	Multiple pathways, life-long learning, multiple jobs, moving into and out of specific roles/industries "What are you working on?"
2	Career model	Single breadwinner in a static environment: singular focus on productivity for a tenure-track job Standardized career ladders defined by a job title in: academia, industry, NGOs Success defined by job title	Diverse family arrangements: dynamically responding to changing needs Multiplicity of niches not restricted to corporate or academic hierarchies: scientific work and identity that transcends job title Self-defined measures of success
3	Academic positions	One-way valve Independence: defined by securing of Assistant Professor position (financial)	Open ecosystem: flows in and out Independence: claimable at any time (conception and pursuit of your own ideas)
4	Budget and pace	One-size fits all, bigger and faster always better "All-or-nothing": singular focus of life	Diversity of scales, both in pace and budgets "Fractional" science/scholarship
5	Working style	Principal investigator + apprentices Hierarchical, top-down, permissions culture Individualistic, competitive	Peers + collaborators Peer-to-peer, collaborative, permissionless culture Solidarity, cooperative
6	Resource access and publishing models	Private or institutionally based, closed to outsiders Closed-access "high prestige" journals, data hoarding for competitive advantage	Commons-based access: community labs, MakerSpaces, DIY Biology Open science, open access, preprints, data sharing
7	Funding	Competitive, winner-take-all. Concentration of resources in high prestige institutions	Collective allocation, experiment with alternative means of proposal evaluation Wider distribution, not dependent on affiliation.
8	Institutional changes	Keep structure: limit access, train fewer PhDs Scarcity, long-term permanent institutional employment accessible to lucky few	Transform institutions: engage ever more scientists Abundance, platform cooperativism, project-oriented work, basic income, universal health care

Changing the cultures of research careers and the scientific enterprise is an experiment itself: actively practicing new a scientific culture can encourage others to be even bolder in their experimentation. The existing institutions that are tasked with supporting basic curiosity-driven inquiry need to be reformed and strengthened, but that alone is insufficient. We must build new structures that are informed by an ecosystem view from conception. The beauty is that science can be made available to everyone and our technologies are making it increasingly so. It is not a scarce resource: we should build our new ecosystem to recognize this truth.

### Data availability

No data is associated with this article.

### Competing interests

Alexander Lancaster is an owner of Amber Biology; Anne E. Thessen is the owner of The Data Detektiv; Arika Virapongse is the owner of Middle Path EcoSolutions.

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# Open Peer Review

Current Referee Status:



Version 1

Referee Report 01 October 2018

doi:10.5256/f1000research.16419.r38436



**Cameron Neylon** 

Centre for Culture and Technology, Curtin University, Perth, WA, Australia

This article offers a way of thinking about the environment of career structures in science. The other two reviewers have noted a series of small issues which I concur would be good to deal with. The paper overall offers some good critical thinking and summary of issues with the way we think about career structures and job roles and provides advocacy for new ways of thinking. It is generally well written and well argued.

I am going to raise two broader issues which I think should be addressed before finalising for indexing:

1. Is the 'ecosystem' concept well defined and expressed?
2. Is this a 'new paradigm'?

There has been much criticism of ecosystem as a metaphor, primarily from ecologists who object that the term is used imprecisely. I think here there is a risk of getting muddled. Words like 'ecosystem' and 'landscape' are used in opposition to the traditional concept of a 'pipeline' but are not explicitly defined or drawn as analogies to true ecosystems.

I was left wondering whether the 'ecosystem' referred to an ecology of job roles, of workers within those roles, organisations that support them or something else? Figure 2 to me does not evoke an ecosystem but a set of roles and organisations. Rather some elements seem to be drawn from Ostrom's Institutional Analysis and Design model, along with specific instances of change, then roles then knowledge (from outside to in). From a different angle it also looks like a social learning model (moving from centre outwards, Lave and Wenger, Situated Learning). In passing I note a tension between the claim the circle 'has no top' with the line above the figure that '....bottom-up changes are already being driven by early career scientists.

The model/figure also does not seem to be used further in the examples below. I think this is a sign that the model and narrative is not quite right. If I understand correctly the goal is to use the ecosystem metaphor to emphasise interdependence of *actors* and the ability to work effectively together (adopting from commons language throughout). However the pipeline model refers to *development* of those actors. My suggestion would be to consider more explicitly how the pipeline model presumes hierarchical institutional forms and how the new model (community/social learning in communities of practice?) would support new, networked and flexible institutional forms.

This happens towards the end in 'Writing a new cultural narrative' to a certain extent but I would like to see this made much stronger. I think the relationship between rhetoric, narrative, social learning/acclulturation and institutional forms could be made much earlier, ideally in 'The science ecosystem' as an answer to the

deficiencies in the pipeline model that are ably described prior to this. This could draw on a range of previous work.

This brings me to the second point. The claim is made that this is a new model. I am not convinced this is accurate. Elements of the ecosystem metaphor, or at least the division of labour and necessary organisation to create value, are found in Merton (many of the papers in Sociology of Science), Lave and Wenger (Situated Learning), Ravetz (Scientific Knowledge and its Social Problems), Latour (Politics of Nature) and in others discussing the broad area of Science and Technology Studies (Collins on expertise, Stilgoe on public policy development, Stirling on engagement and diversity etc etc).

More directly in STEM debates around the formation and solidification of Bioinformatics as a discipline involving new technical workers and skills (and more recently Digital Humanities - I think it would be good for the application of the model to humanities and social sciences to be at least gestured at), the formation of research institutes, and massive authorship in astronomy, high energy physics, and some areas of biology have all pointed in the direction of an 'ecosystem' of interdependent roles to support modern large-scale science.

My primary suggestion is that referring to this earlier literature will strengthen this paper and aid in the development of a stronger narrative, which will in turn hopefully improve the impact of the article in achieving the authors' goals. I would consider re-working Figures 1 and 2:

1. Figure 1 emphasises that the rhetoric of a pipeline leads to a hierarchical structuring of institutions and a necessary conservatism as a result. You might consider adding an 'average age' of each transition, job titles etc to emphasise this. This can then be picked up more strongly in Box 1 as to how the presumed path and hierarchy leads to the negative results described.
2. In Figure 2 I'd invert the sense of the diagram. Start at the outside and show many spiral paths inwards to a range of roles and organisations (can the relationship between organisations and roles be shown). This echoes Lave and Wenger's concept of learning as 'legitimate peripheral participation'. It then becomes important to emphasise that there are many such target diagrams and that various paths can encompass several of them.

I think these two modifications make it easier to refer back to the figures in the examples and cases described in the numbered sections and boxes. That in turn will make the whole narrative stronger.

**Is the topic of the opinion article discussed accurately in the context of the current literature?**

Partly

**Are all factual statements correct and adequately supported by citations?**

Yes

**Are arguments sufficiently supported by evidence from the published literature?**

Partly

**Are the conclusions drawn balanced and justified on the basis of the presented arguments?**

Partly

**Competing Interests:** No competing interests were disclosed.

**Referee Expertise:** I work on the culture of researchers and research organisations. I have expertise in research evaluation, open research, and communication for change.



**I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.**

Referee Report 21 September 2018

doi:10.5256/f1000research.16419.r35293



**Gary S. McDowell** 

The Future of Research Inc., 848 Brockton Avenue, Abington, MA, USA

Overall this is an extremely interesting thesis and lays out a lot of the current issues with “the pipeline” succinctly. I have made a number of suggestions that I hope the authors find interesting or useful in revising the paper, and a request for citations. I have marked the paper as approved but am hopeful the authors are receptive to revising based on comments below.

Major comments:

I would clarify when you are talking about a) biomedicine vs all fields and b) issues in the U.S. vs issues globally, where possible. For example, in the introduction you state: “Declining public funding for basic science” and cite examples that are particularly focused on biomedicine in the U.S. Checking throughout the manuscript to ensure that geographical/field limitations of data cited are highlighted and differentiated would be very helpful to see where issues can be generalized or not, and may lead to further interesting insights where differences do or do not arise. While the biomedical enterprise in the U.S. is certainly useful as the “canary in the coalmine”, it would be interesting to set this in context.

I would suggest looking into the work of Dr. Wayne Wahls<sup>1-2</sup> and Dr. Kenneth Gibbs Jr.<sup>3-7</sup> and also Levecque et al. 2017<sup>8</sup> and Piefer 2017<sup>9</sup> and considering citing/including any reactions to these in your discussions.

In particular the work of Dr. Gibbs may also help inform a discussion throughout of diversity in terms of gender and race/ethnicity; a key strength of the ideas proposed in this paper is that it can tie into making an enterprise that would help people align their interests with the reasons to stay in various parts of the scientific ecosystem, and in particular diversifying academic faculty through a more fluid scientific ecosystem would be very interesting to explore here.

Minor comments:

Introduction:

Suggest deleting “which are” in last sentence of third paragraph in introduction.

“In 2016 \$3 billion were invested into federal agencies to support STEM education programs” - another interesting number would be an estimated amount that is spent by the taxpayer on training writ broadly - i.e. not just training mechanisms and education programs, but also considering that 85% of grads and postdocs funded by NIH (including all foreigners) are not funded from NRSA training mechanisms. Or could it be approximated what proportion of NIH’s budget is linked to trainees in some way? It may also be worth mentioning the previous interest Congressionally in the sustainability of the training enterprise, which led to the creation of the NRSA (see p6 in Addressing the Nation’s Changing Needs Report<sup>10</sup>) - which contains, again, only 15% of its trainees.

**Box 1:**

“Postdoctoral training periods also continue to expand” - please provide a citation, or points of comparison i.e. specific lengths in specific years, also again specifying countr(y/ies) and field(s). One place to look for data that addresses that talking points may be the recent National Postdoc Survey<sup>11</sup>.

In the discussion of the default faculty path it might be useful to include Dr. Paula Stephan’s analysis of NSF data showing the proportions of U.S. biological sciences PhDs entering particular job sectors 5 years post-PhD (only published in The Atlantic in <https://www.theatlantic.com/business/archive/2013/02/the-phd-bust-americas-awful-market-for-young-sci/>) and also Figure 2-1 in the NASEM “Breaking Through” report could be of interest too<sup>12</sup>. Dr. Stephan’s analysis in particular shows that tenure-track faculty positions have not been the principal (let alone majority) destination for PhDs for the lifetime of most Millennials, which allows you to qualify how outdated this mentality is.

“unencumbered with children” - it may be worth looking further into this - in our analysis with the U.S. Census Bureau in <http://sjscience.org/article?id=570> and the related Nature Comment piece<sup>13</sup>, The New Face of US science - the latter in particular points out specifically that men in their 30s are 7x more likely to have a non-working spouse, and many who are married tend to have children, and in fact there may be some discussion to be had about whether being married is beneficial. Men are more likely to be married than women, but women are more likely than men to be married to someone who is \*also in the biomedical workforce\*. Combining these factors with the advantage that tenure clock interventions designed for women actually confer on men (<http://sjscience.org/article?id=570>) it may be that the “unencumbered with children” comment requires qualifying, or at least some rethinking/citations to show that being childless does confer an advantage. Again the National Postdoc Survey could be useful to check into here.

Figure 1: I would suggest with industry also breaking out not only into academic/non-academic but also research/non-research. In preparing the National Academies report, Breaking Through you see in Figure 2-1 a representation of the phenomenon that many industry jobs are not bench-based, but are sales or managerial positions. Consultancy should also be a large group. This would be useful to illustrate the need for the ecosystem even more, as even “industry” is complicated. It might also be worth looking at the taxonomy work that has been going on nationally<sup>14</sup>.

**Fixing the pipeline:**

I was somewhat confused by the angle the authors were coming from in the last sentence in the “flow in the pipeline” discussion. Why would fewer scientists with more career stability be a bad thing in the tenure-track path? Are they proposing instead more scientists with more career stability, in a diverse range of careers? The authors should be careful not to fall into the “more scientists are better for society” argument, as data about the labor market and PhD outcomes is scarce but points to a massive gap in the labor market with supply far exceeding demand, across all jobs<sup>15</sup>. If however they are trying to make the argument that fixing flow is too restrictive a view/the issues that arise in focusing only on flow, I believe all but the last sentence support this view. Some expansion here to clarify what is meant would be helpful. Having read through the rest of the Fixing the Pipeline section I am satisfied that clarification is all that is needed here, because I get a strong sense of the line of argument in the other sections.

The adapting to the pipeline argument is very well made. It could also be worth pointing out that this is causing pressure to extend the length of postdoc positions, because it is taking longer to get a position, rather than changing the system so that postdoc positions are not so long i.e. by evaluating metrics other

than high IF publications in competition with other applicants. I am glad to see the argument being made about for-profit services, it might be worth considering also asking why institutions are not providing such services when they receive federal funds to train these trainees.

In the thinking outside the pipeline section it could also be worth pointing out the lack of access to alumni networks, or the poor communication between academics and non-academics, and also the simple inability of mentors, no matter how well-meaning, to advise on careers they themselves do not know about. It is also worth considering that many trainees do not feel comfortable bringing up that they may wish to leave academia, even though the PI may be receptive to this idea. This is largely due to over-arching cultural expectations, which also include the idea that “to leave is to fail”, which could also be mentioned somewhere in here.

Box 3 - It may also be worth suggesting a vital role professional societies can play in ensuring that “the field” is not synonymous with academia.

There was a lot of excellent content in the description of the scientific ecosystem: I would suggest considering a way of placing key elements of this discussion in a figure, as there was a lot of information, and it was sometimes difficult to appreciate all the points being made. Some way of parsing out the information in a slightly more digestible format would be very helpful, to really draw in readers and highlight some of the excellent points made.

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**Is the topic of the opinion article discussed accurately in the context of the current literature?**

Yes

**Are all factual statements correct and adequately supported by citations?**

Yes

**Are arguments sufficiently supported by evidence from the published literature?**

Yes

**Are the conclusions drawn balanced and justified on the basis of the presented arguments?**

Yes

**Competing Interests:** The article suggests that the organization I am affiliated with should be supported.

**I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

Referee Report 25 June 2018

doi:[10.5256/f1000research.16419.r35295](https://doi.org/10.5256/f1000research.16419.r35295)



**Jonathan P. Tennant** 

Open Science MOOC, Berlin, Germany

Herein is my response to the manuscript entitled “A new paradigm for the scientific enterprise: nurturing the ecosystem”, by Alexander Lancaster and colleagues to F1000 Research.

The authors present a criticism of the concept of the ‘academic pipeline’, and instead introduce a new ecosystem model that includes more dimensions and scope for understanding the complexity of academic culture. My relevant ‘expertise’ in reviewing this manuscript comes from being a researcher interested in developments in scholarly communication. As this is an opinion piece, the only real substance I can offer is that of my own opinion, as well as attempt to help improve the clarity and argumentation style of the article. I hope the authors find the comments useful and know that this was an enjoyable and provocative read for me.

### Figures

Figure 1. The arrows in the green academia arrow seem to be misaligned. Yes, I am making this comment. Do you by any chance have statistics that could help to quantify this flow diagram? I know the Royal Society have a very similar one for the UK, but would be cool (but not obligatory) to get some

numbers on this. Great figure though, and very easy to interpret.

Figure 2. Given that this is an open peer review, it should perhaps come as no surprise that I think Open Access should be changed to Open Science. So I found this a little annoying flicking between the caption and the image to interpret it. Is it possible to put a very simply coloured legend on the side as well to help maintain focus?

### **Abstract**

The abstract is concise, interesting and impactful, and conveys the context and main findings of the article.

### **Introduction**

The first paragraph of the Introduction is basically identical to the Abstract, which seems a bit odd to me. Can one be rephrased, or is there a different way of introducing the issue?

Second paragraph, can early career be defined. And does every country use dollars? Here, I think it would be worth mentioning that it is not just a funding issue, but that this has been exacerbated by the incentive/reward system, which has become virtually divorced from the issues raised here (i.e., anything vaguely scientific). The final sentence of this paragraph needs a couple of citations to support too, or to be stitched to the beginning of the following paragraph.

Third paragraph. Do you think there are phases between training and permanent positions? I'm thinking of short-term contract postdocs, for example.

Box 1. Can it be mentioned here that, as a PhD student/ECR, you are often almost guilted into this state, as leaving for a job outside of academia is perceived as 'failure' by those within? As well as this, many bright young students come into this system, full of so much potential and energy, and then become disillusioned by it and leave as a result. Which basically creates a bias in which it is those who are conformist, the privileged, or have more support (or just a stronger desire) who end up staying. In the paragraph on families, I would make it clear that this present state is "actively discriminating" against those who cannot conform to that lifestyle. True, and impactful. The content of this box though is very well written and conveys many of the large issues in academia very well.

Paragraph 5. What is the fundamental cultural change?

The introduction is well-written, provides sufficient context and background for the piece, and finishes with a nice summary of the work within.

### **Fixing the pipeline**

First paragraph. Should make it clear here, I think, that by framing it as a pipeline it constrains the potential scope for solutions.

Adjusting the flow. I think it is imperative to make the point here that adjustments at this end do not impact all demographics equally. For example, by raising costs to reduce student numbers, this discriminates against different groups based on their financial status. Here, could one or two specific examples of changes to the supply side be provided, and what their impact was.

Adapting to the pipeline. Here, I think a comment is needed about the divergence between what it means to be a good academic in order to conform to the system and advance one's career, and the fundamentals of research. For example, this has repercussions on how research is performed and communicated.

Finding another pipeline. In the final sentence, do you think this goes wider than just science though, and is an outcome of an increasingly neoliberal academy?

Thinking outside the pipeline. So, once you're 'in the pipeline', is it very difficult to see outside the pipeline, do you think? And do you think reform is so slow because we are waiting for it to come from the top down? "I made it here, so why can't you. Nothing needs to change."

### **The science ecosystem**

Personal preference, but I would love it if somewhere here the UN Sustainable Development Goals could be mentioned (<https://sustainabledevelopment.un.org/>).

Do you feel that, within the rapidly developing Open Science 'movement', researchers are being taught the core skills and competencies they need to maintain their careers? See the EU report on this from 2017:

<https://publications.europa.eu/en/publication-detail/-/publication/3b4e1847-c9ca-11e7-8e69-01aa75ed714>

Fundamental development of the scientist. For me, journey implies pathway, which is kind of similar to a pipeline. I think the key here is that development is part of an immensely complex network, where every interaction, every thought, every event has some sort of untraceable impact. You could say, to use your own analogy, that each individual has their own ecological niche within a hierarchical network, and that niche is defined by an incredibly multi-dimensional series of developmental traits. I like this analogy. Does an increased diversity of developmental traits decrease the chance of extinction?

Multiplicity of niches. A key here is the recognition that an individual is the product of their ecosystem. Therefore, it takes into account developmental history (point 1), as well as external factors over which they have no control. As well as genetic heritability, which I think in academia is manifested as privilege. Is there any data out there on the proportion of researchers who have secondary jobs or income-generating activities? Thinking things like teaching, writing, public talks etc.

Open ecosystem flows. As someone who is independently pursuing research beyond academia, I think that this section is critical. Academia is vastly prohibitive to numerous dimensions of social mobility, and allowing greater physical flow is also important for researchers to take advantage of the power of networked worlds. Research does not need always need a desk.

Box 3: As well as what is already mentioned, how about support fairer research evaluation initiatives like DORA (<https://sfedora.org/>), as well as organisations like Future of Research (<http://futureofresearch.org/>). There could be whole papers written about this, so appreciate if the authors don't want to list all possibilities here!

Diversity of scales and budget. I would mention here the impact that this can have on research. Salami slicing for publications, claims of data ownership and generally selfish attitudes, data doctoring and manipulation, fraud, other questionable research practices – all driven by hyper-competition and the modes of research evaluation. Box 4 might be better for this though.

Box 4. "“High profile” journals also tend to favor work done at larger, and therefore more expensive, scales.” – citation needed.

Peer to peer networks. It's a shame the way the present power dynamic works. Even if such a research apprentice should be fortunate enough to sit on a high-level council, they might not be granted the rank of master. This can have disastrous consequences for the Galaxy.

Box 5. I like this idea of sort of decentralised power structures within academia. Are there any examples you can think of where Wiki- or FLOSS-like communities exist within research specifically? A recent study

by Hartgerink and van Zelst<sup>1</sup> on peer to peer networks might be interesting to mention here too. What impact do these approaches have on inclusivity, as well as prestige or reputation for belonging to such a community?

Fluid communication networks and shared access to resources. So, this is about exposing just the outputs of research, then? What about wider engagement in science, especially from citizens? And more transparency into the processes, to help enable verification, trust, and collaboration in research? Note that this aspect also includes factors such as open evaluation, and therefore incentive structures within academia.

Box 6. Should probably mention something about the principles of the scholarly commons ( <https://zenodo.org/record/569952#.Wy0XHijRBPY>, and other links). I would perhaps mention some of the causes for this open science movement, such as negative feelings towards the publishing industry, non-scientific evaluation criteria, reproducibility issues, a demand for greater transparency and public accountability etc. If you really wanted, you could discuss some of the wider impacts of Open Access too<sup>2</sup>. Might also be worth mentioning that commercial publishers are rapidly moving into this area too, such as the recent launch of the EU Open Access Monitor, which was sub-contracted to Elsevier, one of the scholarly publishers with the worst reputation (which I'm sure I don't have to tell you; <https://ec.europa.eu/info/research-and-innovation/strategy/goals-research-and-innovation-policy/open-sci> ).

Broader distribution of resources. How many researchers does Ronin currently support? And how do we work out which questions are more valued by society?

Institutional change. How about institutes recognizing different forms of scholarship, beyond just research papers? So, training, software, code, tech support, educational resources, among other things. I think that it's important to mention the link between institutional change and incentives.

### Writing a new cultural narrative

This sums up the content of the work nicely, and makes it clear what the intention of it was. I wonder, just to strengthen it, could you perhaps provide just several simple, concrete steps that the different stakeholder groups can take towards reaching such a new culture? Otherwise, I find this section very inspirational!

Congratulations to the authors on a great piece of work. I think that this could be very impactful and spark substantial new discussion and action in this area.

### References

1. Hartgerink C, van Zelst M: "As-You-Go" Instead of "After-the-Fact": A Network Approach to Scholarly Communication and Evaluation. *Publications*. 2018; **6** (2). [Publisher Full Text](#)
2. Tennant JP, Waldner F, Jacques DC, Masuzzo P, Collister LB, Hartgerink CH: The academic, economic and societal impacts of Open Access: an evidence-based review. *F1000Res*. 2016; **5**: 632 [PubMed Abstract](#) | [Publisher Full Text](#)

### Is the topic of the opinion article discussed accurately in the context of the current literature?

Yes

### Are all factual statements correct and adequately supported by citations?

Yes

**Are arguments sufficiently supported by evidence from the published literature?**

Yes

**Are the conclusions drawn balanced and justified on the basis of the presented arguments?**

Yes

**Competing Interests:** COI for full transparency: I was a recipient of a travel award from IGDORE, one of the organisations mentioned in Box 2, earlier in 2018. I am also an 'independent researcher' of sorts at the present.

**I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

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