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The future(s) of open science

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Abstract

Almost everyone is enthusiastic that 'open science' is the wave of the future. Yet when one looks seriously at the flaws in modern science that the movement proposes to remedy, the prospect for improvement in at least four areas are unimpressive. This suggests that the agenda is effectively to re-engineer science along the lines of platform capitalism, under the misleading banner of opening up science to the masses.

Keywords

neoliberal science, open science, platform capitalism, radical collaboration, science and democracy

We live in an era of trepidation over the future of science. It is all the more noteworthy, then, that science policy circles have embraced an open infatuation with 'open science'. The whole thing kicked off in the later 2000s, with rumors concerning something called 'Science 2.0'. In January 2012, the *New York Times* (Lin, 2012) then had the good sense to promote the rebranding of this imaginary as 'open science'. The British Royal Society intervened close on its heels in 2012, with a public relations document entitled *Science as an Open Enterprise* (Royal Society, 2012). Subsequently, this was rapidly followed by popularizing books (Nielsen, 2012; Weinberger, 2012) and a plethora of government white papers, policy documents and articles (e.g. OECD, 2015; CNRS, 2016; Strasser and Edwards, 2015; Vuorikari and Punie, 2015; Weinberger, 2012). All sorts of institutes and think tanks (the Ronin Institute, Center for Open Science, openscienceASAP, UK Open Data Institute, PCORI, Laura and John Arnold Foundation) sprouted across the landscape, dedicated to propounding the virtues of open science for all and sundry. The NIH even teamed up with the Wellcome Trust and the Howard Hughes Medical Institute

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to offer a much ballyhooed ‘Open Science Prize’ consisting of six awards to various teams of the not-very-princely sum of $80K with which to launch (?) their prototypes.[1] The concept was trundled out to the public in the format of a 2017 PBS television Series ‘The Crowd and the Cloud’, funded by the NSF.[2] Congressional mandates stipulating ‘openness’ were hidden in the US ‘Crowdsourcing and Citizen Science Act’, itself folded into the 2016 ‘American Competitiveness and Innovation Act’.[3]

Back in Europe in 2013, the G8 Science Ministers formally endorsed a policy of encouraging open science.[4] In May 2016 the EU Competitiveness Council issued a mission statement that all scientific articles should be ‘freely accessible’ by 2020 (Enserink, 2016).[5] ‘The time for talking about Open Access is now past. With these agreements, we are going to achieve it in practice’, the Dutch state secretary for education, culture, and science, Sander Dekker, added in a statement. Lord knows, the last thing an EU bureaucrat has patience with is talking about something not at all well understood. This, in turn, led to a programmatic ‘Vision for Europe’ in 2016 of ‘Open Innovation, Open Science’.[6]

The taken-for-granted premise that modern science is in crying need of top-to-bottom restructuring and reform turns out to be one of the more telling aspects of this unseemly scrum, a melee to be in the vanguard of prying science ‘open’. But the language is deceptive: In what sense was science actually ever ‘closed’, and who precisely is so intent upon cracking it open now? Where did all the funding come from to turn this vague and ill-specified opinion into a movement?

To even pose these questions in a sober and deliberate manner, while making direct reference to the actual history of science, constitutes a challenge to the prophets of openness, because it conflicts with their widespread tendency to treat the last three or more centuries of science as operating in essentially the same monolithic modality. The so-called ‘scientific method’, once it appeared, persisted relatively unchanged, or so goes the undergraduate version of Western Civ. To evade the admission that scientific research and dissemination might actually have been structured differently across diverse epochs and geographical eras, the prophets of openness instead rapidly pivot to a completely unsupported theory of technological determinism to motivate their quest. Change is inevitable, they preach, due to some obscure imperatives concerning the computer and the internet and social media. Once scientists acquiesce to the implacable imperatives of the information revolution, it is said, they will discover that science itself should necessarily become more ‘open’, and the whole society will naturally benefit.

The layers of confusion surrounding open science rival a millefeuille, and can be just as sticky. The quickest way to cut through the confection is to acknowledge that science has been constituted by a sequence of historical regimes of epistemic and logistical organization, long before the current craze for ‘openness’; this proposition could be perhaps patterned after the arguments made in what has been called the literature on ‘historical epistemology’ (e.g. Daston, 1994; Hacking, 1992). Much of this literature tends to make its case in the format of what used to be called ‘stage theories’: descriptions of historical sequences of relatively internally coherent modes, hegemonies or regimes, structured according to certain key self-images and practices, and punctuated by periods of instability and transition. Indeed, I shall argue that the open science movement is an artifact of the current neoliberal regime of science, one that reconfigures both the institutions and the nature of knowledge so as to better conform to market imperatives.[7]

But before that, it is necessary to take note of the slippery connotations and motives behind the open science movement. For some, it denotes mere *open access* to existing scientific publications; for others, it portends a *different format for future scientific publication*; for yet others, it signifies *the open provision of scientific data*; for others, it is primarily about something like *open peer review*; and for still others, the clamor for openness purports to welcome the participation of non-scientists into the research process, under the rubric of *citizen science*. Of course, these are individually wildly disparate phenomena; but it is noteworthy that many of the proponents and cheerleaders glide rather effortlessly between these diverse conceptions, and that in itself provides a clue to the deep structure of the emergent world of open science. Each 'reform' might accidentally have been deemed the imperative of the 'same' technological development or, conversely, they might each exemplify a more profound shift in epistemology. Thus, rather than track each of the above sub-components individually, I will approach the problem of understanding open science from the broader perspective of asking: What sort of thing is it that open science proposes to fix about older science?

Mody (2011) writes that if an 'epochal break has any features worth studying, they should be visible, in some way, down at the microlevel of practice' (p. 64). I agree with this precept. The way to make the case for a structural break in the nature of modern science is to link some broad abstract cultural ideas about knowledge to pronounced transformations of scientific practice at the microlevel. The primary manifestations of the new regime are the marriage of an *ethos* of what has been called 'radically collaborative science' with the emergent structures of 'platform capitalism', all blessed under the neoliberal catechism of the market as super information processor.[8] The ultimate objective of this paper is to describe how this marriage works; but it turns out to be more informative to begin by surveying the infirmities of recent science that the open science advocates claim they can fix.

The indictment of the old regime

The best way to begin to limn the profound rupture of ideas concerning science is to survey the complaints that open science revolutionaries make about the old regime. The dyad of open/closed does not in and of itself adequately capture whatever it was about the old regime that earns the obloquy of modern reformers: After all, science during the Cold War was considered one of the most noble and successful vocations of mankind. Nevertheless, there is a strange mélange of complaints concerning contemporary science. Some of the complaints turn out to be quite long-standing, concerning long-acknowledged flaws in the research process persisting over more than a century. Some of the complaints concern aspects of science that were never thought to be amenable to reform from within, at least prior to the recent fascination with openness. Some of the problems derive from recent instances of wayward practices in contemporary science. And some of the problems seem almost repressed from current discourse. The fact that open science is proposed equally as a panacea for each and every one of these problems is what prompts the suspicion of snake oil; that will bring us around to the prospect posed by the title of this paper. I will entreat the reader to entertain the possibility that actual open science initiatives as they currently exist on the ground may not adequately address any of these problems.

In this section, I make a list of all the ills of recent science invoked by the open science panacea, to gather together in one place the various defects and aberrations cited by the proponents of open science. It would take separate articles to do justice to each, but that is not my aim here. Rather, my primary aim is to better understand the nature of the imagined remedy. I begin with the most macroscopic indictments, and then work my way down the scale to the most local and individual manifestations of defective science.

Distrust of science is rampant in the general population

The profound discomfort with the level of resistance to and distrust of scientists in the larger culture (perhaps strongest in, but not confined to, America) has been percolating for quite some time, having been brought to the surface by various outbreaks of 'denialism', be it in the area of tobacco science, global warming, vaccination resistance, GMO labelling, drug efficacy, human cloning, and a host of other disputes. For a while, it was presumed by scientists that all the public needed was a good PR campaign to set it to rights, which presumptions led to the 'Public Understanding of Science' movement. However, three or more decades on, faith has flagged that a mere bout of good press, augmented by product placement in pop entertainment, would turn the tide towards respect for science. Some of the dismay derives from serious survey work, which reveals that the skepticism towards science has hardened into hostility amongst certain populations.

For instance, recent data from the US seem to show clear partisan divergences in opinions about climate change, with 68 percent of Democrats compared to 20 percent of Republicans agreeing that it is a very serious problem (Stokes et al., 2015). Partisan divides over support for funding alternative energy research have been increasing since 2008. Examples of stubborn contempt with respect to scientists are as fresh as today's netsurf, and as easy to encounter on the news: In August 2016, Sen. Ron Johnson (R-WI) publicly compared those mounting efforts to address climate change to Joseph Stalin and Hugo Chavez, while claiming that it has been 'proven scientifically' that the climate is not in fact warming. Similar trends can be observed in medical science. In a recent survey of more than 1,500 parents, one quarter held the belief that vaccines can cause autism in healthy children, and more than one in 10 had refused at least one recommended vaccine (Daley and Glanz, 2011). A Pew survey reports that about two-thirds (67%) of adults say scientists do not clearly understand the health effects of GM crops; only 28% say scientists have a clear understanding of the consequences (Funk and Rainie, 2015).

Whatever one thinks of the quality of these surveys and snippets from the news, germane in the present context is that a number of enthusiasts for open science have suggested that the remedy for this breakdown of comity is to enroll the public in the project of an open science:

> The opportunities for transparency, authenticity and timeliness of the record created by open science could both reveal the scientific process in real time and allow claims to be viewed within the context of their underlying data. Open science thus has the potential to contribute to the substantiation of the relationships which are central both to people's trust in science and to science's trust in people. (Grand et al., 2012)

While vague when it comes to specifications of how trust will be fostered in open science, even more cautions authors see nothing but upside for the new modality of research, claiming, for example that '[t]his drive for greater openness, albeit limited to certain aspects of the scientific enterprise, is an important contemporary dynamic of science, ripe with opportunity for scholars and advocates of public engagement' (Stilgoe et al., 2014: 10). Or, as another scientist put it: 'Blogging is also a way to demythologize science. Unlike laws and sausages, the public should see science during its manufacture' (J.S. Wilkins, quoted in Ritson, 2016: 3).

The major problem with this prescription is that it does not adequately examine the nature and distribution of the map of modern hostility; if it did so, its proponents might begin to appreciate that proximity to the process of manufacture might rather simply breed further contempt. Are science and sausages really so antithetical? Some of the most important work done on this question regarding the attitudes of the public towards science has been done by Gauchat (2015). His earlier work (Gauchat, 2012) demonstrated that in the US from 1974 to 2010 there was a statistically significant decline in self-identified conservatives' confidence in the scientific community. One of the counterintuitive results was that the more advanced the educational background, the stronger was this trend. Gauchat (2015) uses a different survey data set to break down the generic notion of 'attitude towards science' to two components: opinions whether science should be deemed relevant to public policy, and to what extent should basic science be supported by the state. In support of his earlier work, he discovers that only at the highest levels of education is there a strong divergence between conservatives hostile to these two options, and 'liberals' favoring them. As he writes, 'the culture divisions over science's authority have coalesced with political identities, rather than cross-cutting them' (Gauchat, 2015: 738–739). The other strong correlation he finds is between religious fundamentalism and hostility towards the use of science in public policy debates.

This work has direct and dire consequences for the widespread belief that greater 'openness' of the scientific process will inevitably lead to a more favorable general stance toward scientific authority by the public. On the contrary, higher levels of education, and thus familiarity, seems to harden outsiders in their prior political stances: Proximity breeds more entrenched skepticism. The religiously inclined still tend to believe that science is already basically irrelevant to big public controversies, and thus reject its claims to authority; whereas the educated neoliberals suspect that scientists need to feel the strong discipline of the marketplace before they should be trusted to produce reliable knowledge. This may produce the unintended consequence of a widespread regime of open science further exacerbating the existing disaffection of the public towards science, at least amongst those attracted to religious fundamentalism and neoliberal politics.

Science suffers a democracy deficit

This particular complaint about science has a long and hallowed lineage which dates back a century to the American pragmatist movement, and in particular, to the philosopher John Dewey. However, the tone and tenor of this complaint exhibits very little continuity over the decades, such that one has to tread gingerly to come to appreciate what it might signify today, in the context of open science. If 'democracy' has become an empty token in the interim, then perhaps crusades to revivify it need to be taken with a grain of salt.

Dewey was an early advocate of the notion that, if science was to be supported and accepted by the public, it would need to be stripped of its claim to monopoly on the development and use of valid knowledge, because, for most people, '[s]cience is a mystery in the hands of initiates who have become adepts in virtue of following ritualistic ceremonies from which the profane are excluded' (Dewey, 1927: 164; see also Mirowski, 2004b; Dewey, 1984). Thus science needed to be more like democracy. However, Dewey did not take the public simply as it came, but sought to improve upon its communal intelligence by rendering a new model of democracy that would putatively look more like science. Altogether, Dewey's prescription included idiosyncratic and sketchy definitions of 'science' and 'democracy' and even sympathetic readers have had great difficulty in finding anything specific concerning the nature of participatory democracy in Dewey (e.g. Westbrook, 1991: 317).

This rhetorical move of positing democracy as an ideal exemplar for science, and turning around to reverse the valence in near-tautological spin, became an overwhelmingly popular trope over the course of the 20th century, but with the qualification that the referents for both terms shifted dramatically during the Cold War, and then once again after roughly 1980. In effective repudiation of Dewey, after WWII the elevation of a separate, autarkic and supposedly smoothly self-governing scientific community was held to be the unattainable ideal of what a larger *demos* might aspire to be; crucially, the unwashed should not be encouraged to think they should or would have any rights of participation in or governance of science. Democracy, in tandem, became demoted to the colorless notion of majority rule by ceremonial ballot; the competence of the electorate became perverted into a notion of 'rational choice' imported from neoclassical economics. The science/industry partnership so spurned by Dewey had become a science/military cartel instead; and the pragmatic logic of inquiry Dewey saw became a foreign 'language of science' consisting of formal logic and axiomatization at the hands of the logical empiricists. The 'freedom' of scientists had been won at the cost of the 'freedom' of the public to have any say in science.

The situation since 1980 has undergone another great transformation, from a largely military and state-sponsored science, to a science primarily subordinate to market considerations, organized by corporate patrons and academic contractors. While Dewey would certainly be spinning in what remained of his grave, the images of science and democracy have become essentially unrecognizable relative to those of the early 20th century. As many have observed, the previous sharp distinction between pure and applied science has dissolved, as knowledge has come to be portrayed as both generated within and validated by a marketplace of ideas. Consequently, science has been recast as a primarily commercial endeavor distributed widely across many different corporate entities and organizations, and not confined to disciplinary or academic boundaries. Furthermore, democracy itself has also been demoted to a marketplace of interests and dollar votes, with 'citizenship' leached of any inherent rights or duties (e.g. Brown, 2015). In such a regime, the modern push to 'democratize' science has assumed the entirely different connotation of extending the marketplace of ideas to encompass the scripted participation of the non-credentialed public into various parts of the research process, but not, note well, to have any political input into the agenda or governance of science itself.

Thus we come to the new-found fascination amongst the open science advocates for so-called 'democratization' through so-called 'citizen science'. They assert that 'citizen science advocates are arguing implicitly and explicitly for a radical change to the structures of political power' (Cavalier and Kennedy, 2016: 117). What is especially noteworthy in these instances is the distinctly impoverished notion of democracy inherent in all of their pleas. Many of their assertions boil down to the format that the more outsiders are somehow folded into the scientific process in whatever capacity, the more that the public will come to appreciate and support science, and the better off democracy will flourish. Of course, for some, such as Michael Nielsen (2012), this simply posits that being lured to contribute sporadic unremunerated labor to some massive online assembly line to generate processed data leads those so beguiled to cease and desist in their distrust of scientists and rebellion against authority; surely a *non sequitur* if ever there was one. One can observe the sadly empty notion of 'democracy' that equates a greater quantity of people enrolled in minor (and unremunerated) support roles with a higher degree of democratic participation, when, in fact, they primarily serve as the passive reserve army of labor in the marketplace of ideas. All prerequisites of prior training or apprenticeship have been conveniently banished; whatever knowledge you might need, you simply purchase as a free-standing commodity.

Indeed, the very designation 'citizen science' (as opposed to amateur or extramural science) carries with it the unsubtle suggestion that participation in research renders science a *democracy*, and is therefore more politically palatable than the previous autocratic or dictatorial regime of science. People will thus get the knowledge they want and need through direct action, and will not have it shoved down their throat by some ivy-league elitist. Of course, it doesn't hurt that it lowers the pecuniary cost of any research which requires lots of repetitive labor, and makes use of the quirks of social media and connectivity to induce participants to approach science as a game which can be played for structured rewards (see Hamari et al., 2014; Walz and Deterding, 2015). For instance, many of the citizen science projects on the platform Zooniverse.org have built-in game-like structures, because, frankly, 'normies' get bored doing real regimented science. One project, Galaxy Zoo, has participants scan millions of images of galaxies for common galactic morphologies; but to keep their attention, people are sometimes encouraged to use various star configurations to spell out words, as in constellation games, or win points for certain cute galactic structures. A second project called Smartfin attaches to a surfboard with sensors that collect data on salinity, temperature, PH and other oceanic variables; the surfer then connects the fin to their smartphone back on land, which then transmits the data to the Scripps Institution. Another project, Snapshot Serengeti, has participants identify animals captured by automated cameras in the Serengeti National Park in Tanzania according to pre-arranged scripts; but to keep them amused it allowed people to attach lulz (lolantelopes rather than lolcats) and other Snapchat comments to some of their favorite photographs. Real science is hard; but everyone under 40 familiar with social media was brought up on computer games. citizen science is fun, fun, fun till daddy takes the sensors away.

None of this suggests there has not been a fair amount of determined organizing of various constituencies. The Citizen Science Association was initiated by the Cornell Laboratory of Ornithology in 2007, but has grown into a non-profit umbrella organization now housed at the Schoodic Institute in Maine, and funded by the Bechtel Foundation as well as governmental entities identified above. The European Citizen Science Association grew out of an initiative by Open Air Laboratories (itself funded by a grant from the national lotteries) for a pan-European umbrella of citizen science advocates, which resulted in a non-profit registered under German law in 2014 and housed at the Museum für Naturkunde in Berlin. Both units seem to be engaged in the slightly schizophrenic quest to 'professionalize' a movement nominally opposed to the professional pursuit of science: promulgating standards for data collection and collation, disseminating 'ontologies' for computer readable definitions of data preservation, promoting best practice standards for DIYBio, pre-certifying groups to qualify for government grants, publishing dedicated journals, and a host of activities familiar to any denizen of legitimate science. Nearly every text on citizen science insists that research should respond to the desires of its participants; yet the root presumption of the movement is that, deep down, what the target citizen on the street really wants to mime is many of the activities of real scientists, only, without having to undergo the painful inconvenience of an apprenticeship – that is, actually learning anything that is already common knowledge in the science in question. If this were all just a pantomime, a gallimaufry of play-acting for its own sake, then it might be harmless; but contrary to this, citizen science advocates claim to have higher goals. What has been missing so far is any discussion of just how bizarre and outlandish much of this activity has been, not to mention an attendant exploration of whose interests are actually being served. I return to this below.

Yet, in the modern setting, it seems that no one can manage to discuss democracy except as a derivative market phenomenon. This is most evident when it comes to the open access movement. The repeated assertion that 'we paid for it, so we deserve full and free access to the results of research' is one of the stranger stillbirths of the contemporary regime. What is fascinating about this vintage of openness is its inherent political asymmetry: Published findings funded by government grants are supposedly to be 'liberated' from locked file cabinets and the annals of selfish journals, but any research produced by private funding is nowhere expected to be held to the same standards. Who is it precisely that is capable of comprehension, and therefore really needs unfettered access to publicly funded research? Indeed, what is often misrepresented as 'openness' and 'transparency' is in fact *a posteriori* private expropriation. After all, is the average citizen really so desperate to read and selectively disseminate the latest research reports, or is it instead the corporate research manager? For 'the widest possible dissemination', read 'the most readily monetizable free resource'.

The slowdown in scientific productivity

The avatars of open science like to intimate that old-fashioned science is just not delivering the goods anymore. For many of them, oldfangled tenured academics are hopeless featherbedders and lollygags, frittering away the hours in their random undirected curiosity, sidetracked into needless obscurity, locked in solipsistic meditation. What is required is a bracing speedup of the assembly line, an imposition of discipline on research, conforming to a productionist ethos. In their fondest dreams, science could potentially accomplish so much more, at a much faster pace, in a nascent prosthesis of friction-free collaboration over the internet (see Lin, 2012; Nielsen, 2012). Of course, quantifying the productivity gap turns out to be pitched beyond the competence of any of its promoters, but that does not prevent them from evoking a frightening gap of extraordinary magnitudes.

In my experience, it is very difficult to convince others that there has been some national or even global slowdown in science (see Mirowski, 2011: ch. 6). There are just too many fields and too many metrics, such that controversy over any such proposition is bound to be interminable and irreconcilable. Fortuitously, The Economist (2013), in its narrow wisdom, has done us the favor of indicating a proxy area wherein one might begin to gauge the effect of an open science imperative for greater discipline and structured research collaboration, and then explore the extent to which the science had as a consequence become more or less 'productive' – that area being the combination of basic biomedicine and clinical trials in pursuit of new and better drugs. This is one indicator of 'productivity' identified by proponents of open science'; in employing it I do not mean to endorse the idea of productivity behind it.

The on-again off-again flirtation of Big Pharma with open science would itself require a book-length manuscript (see Maurer, 2007); barring that, for current purposes, I survey two more narrow theses bearing upon the larger question at hand: the issue of falling productivity in the pharmaceutical sector, and the possible relationship of this phenomenon with flirtations with open science in clinical drug discovery. The outcome will be a renewed skepticism that open science constitutes an open sesame for emancipation of scientific productivity.

The starting point for my excursion is to establish a threatening problem for the pharmaceutical sector, which is known colloquially as the 'drying up of the drug pipeline'. For the past two decades, there has been an abundant literature that bemoans the fact that, in the face of lush funding, the number of truly novel drug therapies has been falling over time, roughly since the 1980s. Every aspect of this problem, from what counts as truly 'novel', to what qualifies as a 'discovery', has been subject to fierce dispute in the literature. However, following standard practice, for now I shall stick to the definition of new therapies as what the FDA designates as 'new molecular entities' [NME], and take industry-reported expenditures as reasonable approximations of the funds committed to the research process – though there are good reasons to think that neither are adequate measurements of real innovation or the magnitude of expenditures devoted to actual scientific research. In Figure 1, the standard portrait of the 'drying up of the drug pipeline' is pretty apparent. Of late, some have suggested that the upturn in years 2014 and 2015 betoken an end to the drought, but there also should be factored into account profound changes in FDA approval practices in recent years.

Nevertheless, I will take it as given that there has been and may still be a 'drying up of the drug pipeline', at least as it has been stipulated through the FDA and acknowledged within the industry, and hence, constitutes direct evidence of a slowdown of scientific productivity in the circumscribed area of drug research. Since the amounts of money invested in pharmaceutical research has grown exponentially over the same

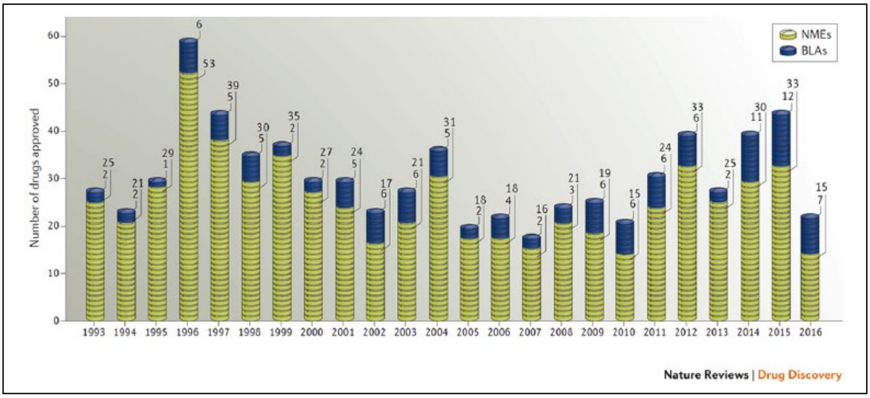

Figure 1. FDA approvals, new molecular entities and biologics, 1993–2016.
Source: Mullard (2017).

period, it has become commonplace to cite an overall fall in efficiency and efficacy of pharmaceutical research activities, to the point of dubbing it 'Eroom's Law', in invidious comparison to 'Moore's Law' for the number of transistors in dense integrated circuits. Eroom's Law reveals a linear decline in number of drugs approved per billion US$ from 1950 to the present (Scannell et al., 2012). While there are many attempts to enumerate the underlying causes of this trend, some have pointed to distinct deficiencies in the research process itself.

There abides a rather nagging suspicion in the pharmaceutical industry that half of all academic biomedical research will ultimately work out to be false, and in 2011 a group of researchers at Bayer decided to test it. Looking at 67 recent drug development projects based on preclinical cancer biology research, they found that in more than 75% of cases the published data did not conform to their in-house attempts to replicate (Prinz et al., 2011). These were not studies published in fly-by-night oncology journals, but blockbuster research featured in *Science, Nature, Cell*, and the like. The Bayer researchers were deluged with bad studies, and it was to this, in part, that they attributed the relentlessly declining yields of drug pipelines. Perhaps so many of these new drugs fail to have an effect because the basic research on which their development was based isn't up to snuff. We shall return to this issue in the next section.

This constitutes the background to a growing conviction within the pharmaceuticals industry that perhaps one deliverance from their gloomy prospects might lay in embracing what they call 'open science'. For instance, an Eli Lilly executive in 2012 asserted it was time to 'get on board' with open drug discovery (Krohn, 2012). Other journalistic interviews have produced quotes like the following:

> I think that, if I were a dictator of the world, I would probably give a try or at least analyze the [modified open science] model that we just talked about. (a CEO of a small pharma company)

> I think there is openness to it now that five years ago frankly would not have been there. (a CEO of another small pharma company; King, 2014)

But ‘openness’, like beauty, resides primarily in the eye of the beholder. The actual situation comes into focus when one examines the detail of the Science 2.0 initiatives that the industry has embraced in the interim. The first thing that strikes the outsider is that in no case does the actual nominal ‘open science project’ within Pharma resemble the sorts of ‘openness’ extolled by the cheerleaders of the new open science. Because the modern pharmaceutical industry is built upon the bedrock foundation of restrictive intellectual property and joint government/industry restrictions upon physician behavior, no such actual ‘openness’ was ever in the cards (see Maurer, 2007; Reichman and Simpson, 2016; Robertson et al., 2014; Wright and Boettinger, 2006). Indeed, the very existence of the Materials Transfer Agreement, a legal document essentially pioneered in biomedicine, constitutes the antithesis of anything that deserves the designation ‘open’ (see Mirowski, 2011: 152–170). Because the issue of intellectual property cannot be circumvented when it comes to open science, some advocates attempt a semantic shift: ‘Properly understood, “open source” is less a legal category than a behavior … simple analogies to computing will not provide much guidance’ (Maurer, 2007: 408, 420). Certainly, what is involved has been something other than a Creative Commons license; mostly, what exists are numerous hybrid formats that combine corporate control with a modicum of outsourcing or crowdsourcing.

One can observe a combination of corporate control and open access occurring as long ago as the NIH Small Molecular Repositories Library, founded in 2003-4 with a ten-year Congressional appropriation, over and above the standard NIH annual budget.[9] The stated purpose was to acquire and manage a compound library of approximately 300,000 compounds, purchased from commercial sources, to be made available to around a dozen academic centers for small molecule pharmaceuticals research. Pharma companies were not invited to submit any proprietary compounds of their own to the archive, nor any of the data from their assays. Instead, the NIH set up another designated database, called PubChem, which was intended to archive the results of the data surveys for bioassays; of course, that was available to any interested Pharma firm. Nevertheless, commercial vendors still control numerous defined small molecule libraries in drugs of interest not covered in SMRL, and make them available only to affiliated researchers. In effect, nothing about this system ever threatened the standard Pharma industry business model: If someone outside the usual research areas (but likely an NIH affiliated researcher) happened to find something of interest in the SMRL, they could rapidly be recruited by any firms concerned, and the research would effectively disappear. Since the whole scheme constituted a not-very-important indirect subsidy to the Pharma industry, the policy mavens decided after its initial mandate period that even the management of the library could be subcontracted out to a for-profit firm, Evotec.[10] To describe this setup as ‘public’ or ‘open science’ seems to be a travesty.

Labels do matter; and while such schemes can hardly be dubbed ‘pure’, the industry has opted for the awkward neologism ‘Protected Open Innovation’ for such public-private partnerships. As some industry insiders have noted,

> Completely open innovation, therefore, rarely if ever occurs in pharmaceutical R&D programs that have clear commercial potential. By contrast, allowing controlled access to pharma’s compound collections of small molecules ostensibly offers an attractive opportunity to monetize chemical assets … that otherwise would not be pursued owing to their high risk. (Reichman and Simpson, 2016: 782)

Table 1. Comparison of innovation models.

Innovation	IP strategy	IP	Payments	Royalty	Publication	Participants
Closed	Exclusive	Internal	NA	NA	NA	Homogeneous
Partnered	Assignment	Contractual	Contractual	Usually	No	Similar
Protected	Consignment	Option right	Flexible	Not usually	Limited	Heterogeneous
Open	None	None	Grants	NA	Unlimited	Homogeneous

The protected open innovation (POI) model enables a pharmaceutical company to provide its proprietary chemical library 'on consignment' to university scientists. The transaction terms for licensing of new IP and further collaborations remain flexible until potential new medicinal utility is discovered. NA, not applicable.

Indeed, the industry standard interpretation of their mongrel version of 'openness', taken from their own trade press, is conveniently summarized in Table 1 (from Reichman and Simpson, 2016). As this table shows, the bench scientist has almost no control and few rewards or remunerations from the research process. Pharma cuts its overhead costs, and the impecunious researcher is lured to donate free labor in a desperate attempt to gain the favor of a corporate sponsor. The results of this strategy generally have not been very fruitful, compared to the more straightforward option of simply snapping up free-standing privatized academic startups once their candidate molecules (derived from other research protocols) have shown promise in early stage clinical trials. Thus, the supposed promise of open science to rectify a falloff in scientific research productivity is doubly thwarted: first, the only 'openness' allowed in the research process is of a stunted and shriveled variety, barely distinguishable from recruitment of freely provided labor of an underemployed underclass; and second, perhaps due to this rather unpromising setup, the 'protected open' model has not resulted in any notable small molecule breakthroughs since this model was promulgated by the NIH more than ten years ago.

Consequently, open science has not in any straightforward way seemed to augment scientific productivity in the one specific instance where it has been embraced by industrial representatives.

The explosion of retractions and the falling rate of falsification

The earlier indictments concerned the relation of science to its publics, and problems in the quantity and speed of scientific output. In the remainder of this section, I focus on assertions that open science can actually improve the *quality* of the science being produced.

Any foray into the attribution of 'quality' of knowledge will tend to raise objections from almost every quarter. One man's masterwork is another woman's minor elaboration of prior thought. Everyone loves to hear tales of some favored paper that was rejected by *N* journals, only to be published by some perceptive editor at *N+1*, with the author going on to enjoy universal acclaim. Rather than strive for some grand but elusive conception of quality, many advocates of open science assert that they can repair some of the more egregious defects of contemporary science. In particular, they have lighted upon a rather troublesome development, the growth of retractions of scientific papers and the attendant publication biases that have been apparent for some time now.

Formal retractions of papers (as compared to 'errata' of corrections) were almost invisible in the scientific literature before the year 2000. However, a number of high profile fraud cases in the 1990s, combined with the public backlash against the legitimacy of science covered above, began to force some journal editors to openly repudiate particular papers which they had earlier deemed suitable for publication. This new practice of 'retraction' was implemented unevenly, especially when it came to disclosing exactly what had prompted the drastic option; moreover, since it had the potential to besmirch the overall reputation of the journal, it often was entered in a rather attenuated and unprepossessing format, often escaping general notice altogether. This situation cried out for clarification, which began to be provided by the now-famous blog *Retraction Watch*.[11] Launched in August 2010, the blog started a serious conversation over something that most scientists had previously treated as an embarrassment best left unspoken about. One of the first things that the blog documented was that the gross number of retractions was rising dramatically:

> they are rising at a rate that far outstrips the increase in new papers. As *Nature* reported in 2011, the number of retractions in 2010 was about 400, ten times the figure in 2001 (30). That compares to an increase of just 44% in the number of papers published per year over that time period. (Marcus and Oransky, 2014: 151; see also Oransky and Marcus, 2016)

Retraction Watch reports that it currently logs between 600-700 retractions per year; this suggests a substantial rate of growth in the first decade and a half of the new millennium. A second major revelation of the blog was that, once the motives for retractions were evoked from recalcitrant journal editors, they were quite diverse, ranging from honest errors to image manipulation to outright fraud. A barrier to better research into retractions remains that there is as yet still no easily searchable database of all retractions and their attendant motives, even for just those covered by *Retraction Watch.* Nevertheless, the offhand tendency of scientists to dismiss the phenomenon as of negligible significance has been refuted in a few instances. For instance, a 2012 paper in *PNAS* documented that misconduct – plagiarism, data fabrication, image manipulation, and the like – were to blame for two-thirds of the retractions that they were able to collate (Fang et al., 2012). There was also a tendency to blame the retractions on recherché low-status journals, but a quick inventory demonstrated that the higher the impact factor, the more retractions were issued, as demonstrated in Figure 2.

As awareness spread of these trends, the possibility of an outbreak of corrupt or untrustworthy science began to sink deeper into the consciousness of the wider scientific community. *Nature*, sensing that it was caught in the crosshairs in any potential search for scapegoats, proceeded to run a survey of the opinions of a cross-section of working scientists concerning the state of empiricism, and discovered 90% support for the proposition that something was rotten in modern protocols, and not just the journals themselves. The results of the survey are summarized in Figure 3.

Of course, any such interpretations were bound to prove controversial, since they attempt to infer the underlying health of the scientific community from what can only charitably be regarded as one of its least targeted output indictors. As a result, work proceeds on many fronts to better measure the prevalence of retractions. One investigator,

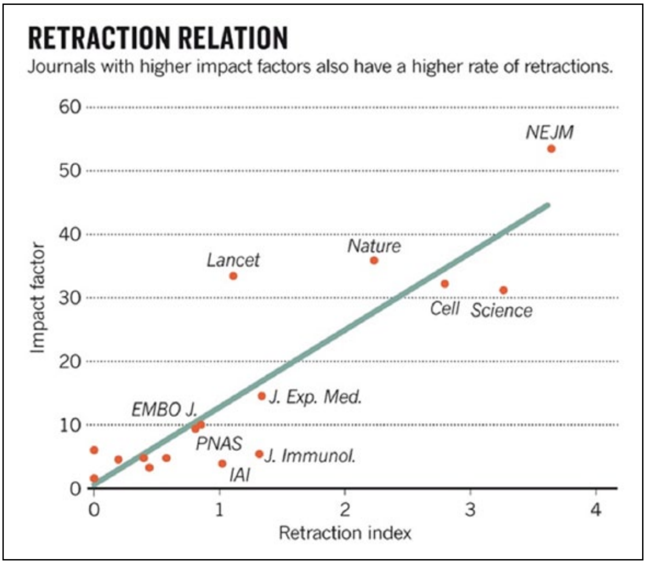

Figure 2. Retractions in high-impact journals.
Source: Fang et al. (2011).

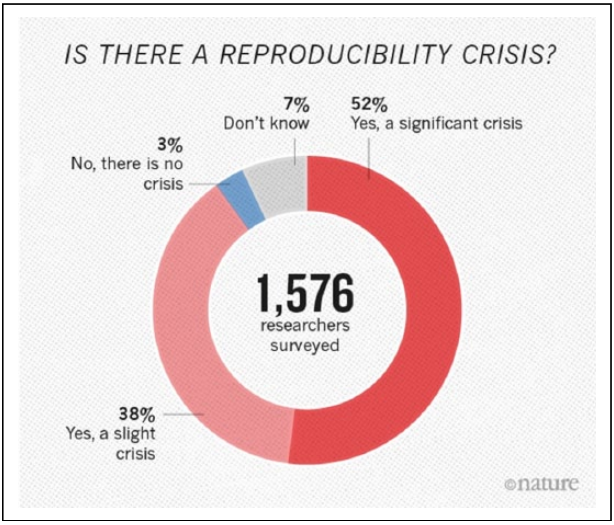

Figure 3. Impressions of a reproducibility crisis.
Source: Baker and Penny (2016: 452).

Daniele Fanelli, has collated a consistent time series of journal editorials that contained the word 'retraction' in their title, extracted from the Thomson Reuters Web of Science database, for the period 1901-2012 (Fanelli, 2013).[12] His results, graphed in Figure 4, show that errata are fairly flat since the 1970s; meanwhile, retractions climb from nothing in 1990 to a small but steadily increasing proportion in the new millennium.

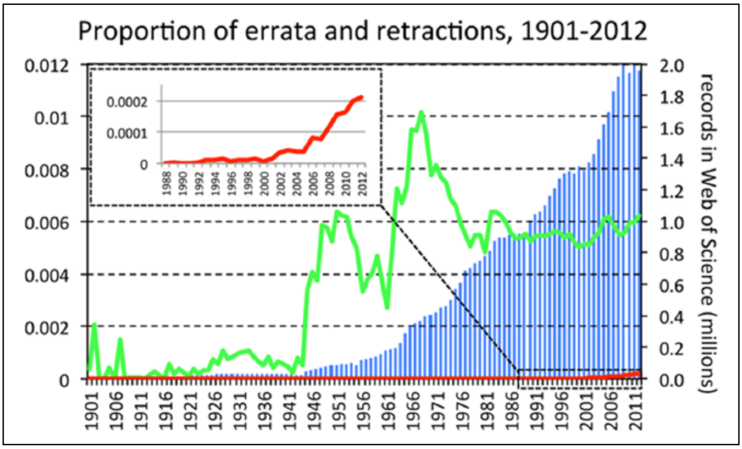

Figure 4. Published entries dubbed 'errata' (in green) and 'retractions' (in red).
Source: Fanelli (2013).

Fanelli suggests that the rise in retractions is not simply due to an uptick in research misconduct, but rather a growing capacity on the part of journal editors to detect and retrospectively 'delete' flawed and otherwise compromised papers. Clearly, there was no propensity for journal editors to retract papers in the first half of the 20th century, perhaps suggesting a different stance of editors towards their authors in this period. Equally clearly, contemporary journal editors have increasingly felt impelled to do something to expunge tainted papers from their archives. Nevertheless, Fanelli's simple keyword search is too blunt an instrument to provide dependable diagnosis of what has become one of the more troublesome *contretemps* of the contemporary scientific community. The rising incidence of retractions may signal something about the modern regime of science organization; the controversy comes in deciding just what that might be.

Science policy elites are inclined to frame the replication crisis as first and foremost an economic catastrophe: 'Similarly, an economic analysis published in June 2015 estimates that $28 billion per year is wasted on biomedical research that is unreproducible. Science isn't self-correcting; it's self-destructing' (Sarewitz, 2016: 18). Although one might suspect this cost might be laid at the door of the scientists themselves – and this is the position favored by editors at the major science journals (e.g. Kornfeld and Titus, 2016) – others favor the tendency of the open science enthusiasts to attack existing journals instead:

> there is little accountability for journals and reviewers. If a journal repeatedly publishes papers that draw untenable conclusions, eventually the authors of the papers may be blamed, but editors and reviewers who are arguably responsible for gross negligence are not held responsible. There are insufficient checks and balances in the publishing system; when high-ranked journals repeatedly publish papers that are later considered unreliable or even retracted, the journals seem to face no consequences—their premier status remains untouched. (Sudhof, 2016)

The rising rate of retractions has lent extra salience to a number of correlative criticisms of the structure of old-fashioned scientific publishing. First, the mere existence of retractions and rebuttals does not seem to extirpate the bad science in question. In one empirical study, rebuttals of seven high-profile articles were largely ignored, with the originals cited seventeen times more frequently than the rebuttals, and suffering no diminution of citations after the rebuttals (Banobi et al., 2011; see also Mirowski, 2004a: ch. 10). By relegating retractions to unobtrusive and uninformative pages in their journals, editors encourage a tendency to overlook any attempt to expunge faulty work from the literature. This raises the question of whether the scientists or the publishing outlet should be made to suffer for polluting the scientific archive, or, instead, whether the whole embarrassing incident should be covered up to a large extent.

Another blemish of existing journals is their bias against publication of negative results, sometimes referred to as the ‘file drawer problem’ or ‘p-hacking’. Quite simply, journals are more inclined to publish new additions to knowledge than demonstrations of the vastly larger backlog of refuted claims. The situation is exacerbated when statistical inference is involved, given the tendency of the analyst to search for significant positive results, and to suppress the much more common insignificant or negative results (Ioannidis, 2005, 2014; Lehrer, 2010; Mirowski, 2004a: ch. 10). Publication bias has been explicitly discussed and denounced since the late 1950s; but journals have nonetheless seemed impervious to any concerted effort to offset it in the interim. This has had direct consequences for the replication crisis, since it seems obvious there has been little interest in publication of successful replications, and only marginally more enthusiasm for publishing failed replications. In a *New Yorker* article claiming that ‘The Truth Wears Off’, the author reports the views of psychologist Jonathan Schooler:

> We’re wasting too much time chasing after bad studies and underpowered experiments, he says. The current ‘obsession’ with replicability distracts from the real problem, which is faulty design. He notes that nobody even tries to replicate most science papers—there are simply too many. (Lehrer, 2010: 56)

Moreover, it appears the situation is not getting any better. Fanelli collected 4,600 published articles from the ISI Essential Science Indicators database over the years 1990-2007 that claimed to have ‘tested’ some hypothesis. Not only did supposed ‘positive’ findings outnumber negative findings 70% to 30% in the aggregate, but the overall frequency of positive reports rose by 22% in the period covered (Fanelli, 2012). He glosses this result by suggesting that ‘research is becoming less pioneering and/or … the objectivity with which results are produced and published is decreasing’.

Problems of replication failure, growing retractions and wonky statistics have motivated the proponents of open science to suggest that it is the very institution of the scientific journal that is irredeemably rotten, and that a completely different approach is warranted. Here the reformist stance has almost imperceptibly shaded over into an economic reformation. Thus it has come to pass that one consequence of the reverberating debates over the depth of the replicability crisis is to shift the terms of proposed remedies to different *business models* covering not only publication, but the peer review process as well. The entrepreneurial visions of a different configuration of science often evoke the magic of the marketplace to displace centuries-old practices of science:

> You don't have to reinvent the system, just nudge it a bit …. If you do it in an efficient way, people will do it …. Open science funders get a higher return on investment. (Brian Nosek, quoted in Effective Altruism Global, 2016)

Michael Nielsen, perhaps the most important publicist for open science, similarly sings the praises of a commercial approach to reform: 'One of humanity's most powerful tools for amplifying collective intelligence is the market system' (Nielsen, 2012: 37).[13] Since many scientists are attracted to the open science movement because they believe it to be a renunciation of older commercial models, it is of paramount importance to understand precisely what the advocates of open science imagine will replace the current system of science organization.[14]

In the current climate, the preferred panacea for the replication crisis, and indeed almost everything else that ails science, is more 'transparency' imposed through the regimentation of a social-media style internet platform. Sometimes its advocates hint that such platforms will displace journals gradually, while others imagine a world without any old-fashioned journals at all. For instance, Mike Eisen, one of the pioneers of e-Biomed and PLOS has explicitly proposed that we should eventually just do away with journals and convert to a complete open preprint plus post-publication peer review system (Eisen and Vosshall, 2016). Others imagine a different sort of scientific paper altogether, a sort of kit in a box, containing text, data, programs and reference, along the lines of a Jupyter notebook (Somers, 2018). Others have nurtured yet larger ambitions. Some early entrepreneurs openly advocated a 'Facebook for Science', which begins to reveal how the scramble to produce platforms is informed by earlier developments in social media (Hearn, 2016; Lin, 2012).[15] Others extoll a 'Match.com meets Amazon for citizen science' (Cavalier and Kennedy, 2016: 122). They start with the premise of greater transparency, and rework it into a new model of radically collaborative research, essentially dissolving the persona of the author altogether (Huebner et al., 2017). The modern open science movement trends towards an entirely public re-engineering of science, ranging from the earliest inchoate preparatory stages of a research project to the final dissemination and evaluation of the results. As summarized in Table 2, this imagines every aspect of the project occurring online, from the earliest preliminary reading regimen as a survey of the literature, to recourse to Open Data sets, produced either by the researcher themselves or else by some other scientist, to real-time commentary by others on the research protocols, to drafts of reports uploaded to preprint servers, to quasi-journal publications online, to extensive peer review continuing well after the final draft is posted online. Back in 2010, one might have envisioned this happening piecemeal, with, say, a stand-alone preprint server like arXiv performing one repository function, while a separate website like PubPeer might foster critical commentary linked to specific papers, combined into a free-for-all semi-peer-review. As one proponent put it, 'open science is trying to fix the historical monopolization of knowledge that was established by past practices' (Piper, 2017). Monopoly is the culprit, yet there seems to be no whiff of markets. But the question persists: why would anyone believe any such cobbled-together system would work without the reassurance of a political ideology to fortify their ambitions?

Platform capitalism meets open science; romance ensues

The most important aspect of this Brave New World is to understand why its champions would believe that such a sloppy unintegrated bottom-up system beset by waves of ignorant kibitzers would produce anything but white noise. The paladins of Science 2.0 love to quote the injunction ‘With enough eyeballs, all bugs are shallow’, but that presumes that all science is merely an instrumental task, similar to the building of software. Here one has to re-inject a modicum of context, as well as insist upon the dominant narrative of a political ontology to render this revolutionary project plausible, and a novel set of economic structures that make it real.

There may be abundant dissatisfaction with the state of science in the modern university, but as I have argued in detail in my *ScienceMart* (Mirowski, 2011), much of this current distress derives from the concerted political project to wean the university sector away from the state over the past three decades, and to render both instruction and research more responsive to market incentives, thus doing away with older Humboldtian rationales of *bildung* and the preservation of the cultural values of civilization. This, in turn, has been motivated by the political project of neoliberalism, which takes as its first commandment that The Market is the most superior information processor known to mankind.[16] For their acolytes, no human can or ever will match the Wisdom of the Market. The knowledge held by any individual is (in this construction) of a weak and deceptive sort; no human being can ever comprehend the amount of information embodied in a market price; therefore, experts (and scientists) should not be accorded much respect, since the Market ultimately reduces them to the same epistemic plane as rank amateurs. This is glossed in some quarters as the ‘wisdom of crowds’. Neoliberals propose a democratization of knowledge, but in a curious sense: Everyone should equally prostrate themselves before a Market, which will then supply them with truth in the fullness of time.

The ailments and crises of modern science described in this paper were largely brought about by neoliberal initiatives in the first place. First off, it was neoliberal think tanks that first stoked the fires of science distrust amongst the populace that have led to the current predicament, a fact brought to our attention by Oreskes and Conway (2011), among others. It was neoliberals who provided the justification for the strengthening of intellectual property; it was neoliberals who drove a wedge between state funding of research and state provision of findings of universities for the public good; it was neoliberal administrators who began to fragment the university into ‘cash cows’ and loss leader disciplines; it was neoliberal corporate officers who sought to wrest clinical trials away from academic health centers and towards contract research organizations to better control the disclosure or nondisclosure of the data generated. In some universities, students now have to sign nondisclosure agreements if they want initiation into the mysteries of faculty startups. It is no longer a matter of what you know; rather, success these days is your ability to position yourself with regard to the gatekeepers of what is known. Knowledge is everywhere hedged round with walls, legal prohibitions, and high market barriers breached only by those blessed with riches required to be enrolled into the elect circles of modern science. Further, belief in the Market as the ultimate arbiter of truth has served to loosen the fetters of more conscious vetting of knowledge through promulgation of negative results and the need to reprise research protocols. No wonder replication turns out to be so daunting. One can understand the impetuous desire to cast off these fetters and let the Market do the work for us.

Table 2. The landscape of 'openness'.

	Bibliography	Data	Working notes	Draft Paper	Article	Comment on others work
2010	Not public	Not public	Not public	Semi-public	Public	Only indirect
2030	Public	Public	Public	Public	Public	Public at every stage

Adapted from Burgelman et al. (2010).

The irony of the situation is that although this petrification of the scientific enterprise could largely be attributed to previous neoliberal 'reforms' in the first instance, the remedy proposed is to redouble neoliberal policies, now under the rubric of 'open science'. For most working scientists, the notion of 'neoliberalism' may seem a vague and fuzzy abstraction; what they confront in everyday life is instead something often called 'platform capitalism'. Increasingly, open science is promoted and organized by a number of web sites, apparently based on free services but constituted as for-profit corporations that aim to actualize one or more of the cells of activity indicated in Table 2. As Srnicek (2017; see also Pasquale, 2016) explains, this is a novel corporate structure that capitalizes on network effects and the large-scale collection of data, as well as nominally free labor, to eventually achieve a monopoly position in their area of endeavor.[17] It is a mode of production based upon the appropriation and dissemination of information, and not with physical production as such. We have already observed the ambition of some of these platforms to become the 'Facebook for Science'; one reason is because Facebook provides one of the proofs of concept of platform capitalism, as do Google, Uber, and AirBnB (c.f. Hall, 2016). While Facebook runs on pure narcissism, platforms for science capitalize on the desire on the part of professionals and amateurs alike to become enrolled in some form in scientific research.

Rather than simply foster 'participation', modern science these days is choc-a-block with proprietary websites that aim to utterly re-engineer the research process from the ground up. Internet startups are thick on the web, befitting the early stages of a push to engross and capture new electronic real estate. Academia.edu, Mendeley and ResearchGate seek to foster artificial research communities to attract far-flung kibitzers to discuss and criticize the early-stage search for topics in which to become engaged in research. CERN has built Zendor in order to standardize the sharing of early-state research products. Open Notebook and Open Collaborate (and Microsoft's failed myExperiment.org) are platforms to organize the early stages of research out in the open, even to the extent of conducting 'virtual experiments'; while sites like Kickstarter and Walacea offer alternative modes of seeking out research support. There are purported 'citizen science' sites such as SciStarter.com, which entice non-scientists to perform remote labor for aspects of data processing which can be Taylorized and automated – SETI@home and Foldit are oft-cited examples. There are even citizen science directory sites which allows the user to search for the distinct type of project they might like to sign onto.[18]

In parallel, there are a plethora of platforms for publication management and controlled revision of research by multiple 'authors', although most of them are proprietary and closely held, in contrast with something like the physics pre-publication site arXiv.org. Indeed, in clinical trials, most Contract Research Organizations are built around such proprietary platforms. A burgeoning field of startups foster post-publication platforms to evaluate and otherwise rank papers in various fields using what are dubbed Altmetrics, sometimes combined with collated unpaid reviews, as on the site Faculty of 1000. Firms like Science Exchange, Transcriptic and Emerald Cloud Lab attempt to automate actual (mainly biochemical or clinical) lab procedures online, to better to outsource and fragment the research process, and nominally, to render replication relatively effortless. While different platforms aim to apply the concepts of social media to some restricted subset of the research process – say, the blog-like character of unfocused searching around for topics, early-stage establishment of research protocols, the arrangement of funding, the virtualization of the laboratory, the intermediate stage of manuscript composition and revision, or post-publication evaluation – it does not take much imagination to anticipate that once the market shakes itself out, and one platform eventually comes to dominate its competitors within key segments of certain sciences, Google or some similar corporate entity or some state-supported public/private partnership will come along with its deep pockets, and integrate each segment into one grand proprietary Science 2.0 platform. Who would not then want to own the obligatory online passage point for the bulk of modern scientific research? The science entrepreneur Vitek Trask has already sketched the outlines of one completely integrated online research platform (Trask and Lawrence, 2016). The aptly-named ‘Ronin Institute’ has proposed another, arguing that ‘Open Access and Open Data will make so much more of a difference if we had the same kind of dynamism in the academic and nonprofit sector as we have in the for-profit start-up sector’ (Lancaster, 2016). As many of the entrepreneurial protagonists of the reorganization of science admit, Facebook is their lode star and inspiration.

Much of the vision behind Table 2 presupposes that scientific data is *inherently fungible*, once a few pesky obstacles are cleared away. Some outstanding work by Leonelli (2016; Leonelli et al., 2015) has demonstrated that this impression concerning the nature of Open Data is illusory. Partisans of open science love to celebrate the kumbaya of ‘data sharing’; Leonelli counters that there is no such thing. Data in the modern context would never venture outside the lab were it not for dedicated curators and their attached data consortia, such as the Open Biology Ontology Consortium (active since 2001). No database ever contains ‘everything’, and all curators choose what they consider to be the most reliable or representative data. Furthermore, the consortia are irredeemably *political*, in the sense that they legislate the protocols for curators, and promote common objectives and procedural best practices. This involves delicate negotiations between sub-fields, not to mention polyglot curators. Furthermore, if you understand the power-law characteristics of the web, curators must necessarily struggle to attract data donors, so they can rapidly grow to be the one or two dominant repositories in their bailiwick. This is the first commandment of platform capitalism. Consequently, curators may have to anticipate uses of the data (and therefore research programs) that may not yet exist, and adjust their procedures accordingly. If they stumble in any of these endeavors, then their repositories may ‘fail’, as foundations and other funders press their grantees to become self-supporting. Data is what the intermediaries make of it; or as Leonelli writes, these ‘data have no fixed information content’, and ‘data do not have truth-value in and of themselves'. The partisans of open science neglect to highlight the extent to which they define what the data actually signifies in Science 2.0, something that should give pause to anyone believing that data is effortlessly separable from its generators and curators.

Readers of Foucault will realize that the key to the process of spreading neoliberalism into everyday life involves recasting the individual into an entrepreneur of the self. Technologies such as Facebook already foster neoliberal notions of what it means to be human amongst teenagers who have never read a page of Friedrich Hayek or political theory in their lives (see Mirowski, 2013: ch. 3; also Gershon, 2017). Novel open science platforms inject neoliberal images of the marketplace of ideas into the scientific community, where participants may not have paid much attention to contemporary political economy. For instance, the programs are all besotted with the notion of complete identification of the *individual* as the locus of knowledge production, to the extent of imposing a unique online identifier for each participant, which links records across the platform and modular projects. The communal character of scientific research is summarily banished. The new model scientist should be building their 'human capital' by flitting from one research project to the next. That scientist is introduced to a quasi-market that constantly monitors their 'net worth' through a range of metrics, scores and indicators: h-index, impact factors, peer contacts, network affiliations, and the like. Regular email notifications keep nagging you to internalize these validations, and learn how to game them to your advantage. No direct managerial presence is required, because one automatically learns to internalize these seemingly objective market-like valuations, and to abjure (say) a tenacious belief in a set of ideas, or a particular research program. All it takes is a little nudge from your friendly online robot.

There is another curious aspect concerning the open science movement which is illuminated by a more general understanding of the neoliberal project. As I have explained elsewhere, neoliberalism is beset with a brace of inherent 'double truths' (Mirowski, 2013: 68–83): 'openness' is never really 'open'; 'spontaneous order' is brought about by strict political regimentation; a movement which extols rationality actively promotes ignorance. The first of these double truths has already been highlighted for the early versions of the open science movement by some perceptive work in science and technology studies (Ritson, 2016). The physics prepublication service arXiv is often praised as a proof of concept for open science; but that just ignores its actual history of conflict and unresolved problems. Founded in 1991, arXiv rapidly became the website of choice, to the extent of receiving 75,000 new texts each year, and providing roughly 1 million full-text downloads to about 400,000 distinct users every week (Ginsparg, 2011). The growth in arXiv has been linear, attracting papers in mathematics, astrophysics and computer science.

What has been omitted from this litany of success is the extent to which arXiv has not been altogether 'open'. The problems are only hinted at in Ginsparg's (2011) retrospective:

> Again, because of cost and labour overheads, arXiv would not be able to implement conventional peer review. Even the minimal filtering of incoming preprints to maintain basic quality control involves significant daily administrative activity. Incoming abstracts are given a cursory glance

> by volunteer external moderators for appropriateness to their subject areas; and various automated filters, including a text classifier, flag problem submissions… Moderators, tasked with determining what is of potential interest to their communities, are sometimes forced to ascertain 'what is science?' At this point arXiv unintentionally becomes an accrediting agency for researchers, much as the Science Citation Index became an accrediting agency for journals, by formulating criteria for their inclusion. (p. 147)

Although Ginsparg tries to dismiss this as a mere matter of logistical housekeeping, arXiv has been continually roiled by pressure to act as a validator of legitimate knowledge: that is, to reign in its nominal 'openness'. This problem broke out into the open during the so-called 'string theory wars' in 2005-2007 (Ritson, 2016). In short, arXiv introduced a 'trackback' function in 2005, which enabled authors of blog posts to insert a link for the post on the paper abstract page in arXiv. This is the beginning of integration of arXiv into a larger open science platform characteristic of platform capitalism, linking archive functions to evaluation of ideas. The physics community found itself up in arms to deny this capability to 'crackpots', revealing a fear of integration of blogs into the permanent body of scholarly communication. In effect, there was no acceptable standard to distinguish those who had the right to comment from those who needed to be excluded. The problem was only exacerbated by differing research communities allowing different attitudes to the forms and protocols of debate. There have been repeated attempts to severely restrict the trackback function to prevent the turning of arXiv into a central component of a larger open science platform. The neoliberal response would be: It is not the place of the disciplinary community to decide where openness 'ends'.

Another major inspiration for the open science movement has been online gaming. One need only spend a little time with FoldIt or Mendeley or ResearchGate to realize how the generation that grew up with online gaming might be attracted to these sites. There is now an extensive literature covering the phenomenon of 'gamification' in platform capitalism: that is, the application of design principles learned in the production of online games to tasks not often considered to be games (Hamari et al., 2014; Hammarfelt et al., 2016; Hunicke et al., 2004). Some components of gamification are building in aspects of narrative, personal challenge, fellowship, discovery, expression and submission; many of these motivations are already considered to be aspects of the scientific research process. The central parallel is the reprocessing of research activities into 'reputation', which then becomes a surrogate metric through which one cooperates or competes with other 'players'. Built-in triggers stimulate a desire to improve, and shape your own persona to better conform to the game. Life is treated as precarious in much online gaming, and so the scientific career is rendered precarious for those unwilling to attend to the scores and signals. The mantra of 'openness' thus becomes a synonym for gameplay, and flexibility in responding to market-like signals from the platform. Your own opinions only become actualized when they are channeled into the structured activities permitted by the platform; eventually, truth itself is conflated with quantified scoring.

This brings us full circle, to the 'version' of openness that probably first attracted the attention of those smitten with the movement, namely, the rebellion against the lucrative ownership of existing legacy scientific journals by big corporations such as Elsevier, Springer, Wiley, and Taylor and Francis (Odlyzko, 2015). The rebellion seemed to gain some traction with the 2012 attempted boycott of Elsevier journals under the flag of the 'Cost of Knowledge' movement, as well as the initiative to set up dedicated web-based replacements. However, five years on, we can see how both rebellions fared. First, the Cost of Knowledge boycott essentially collapsed, with large proportions of those who pledged their troth returning to publishing with Elsevier (see Heyman et al., 2016). Secondly, all manner of entrepreneurs seized upon the opportunity to start up their own web-based journals, often for-profit, with current cyberspace flooded with a swamp of dubious Potemkin publication ventures. Much like the Occupy movement, the open access movement has become bogged down in the political practicalities of being out-maneuvered by their opponents.

Many observers have come around to the position that so-called open access has morphed into its neoliberal antithesis:

> We argue, in part, that open access has served less as an alternative to commercialized academic research than as a moral cover for increasingly neoliberal policies …. Far from a moral force for counteracting the avarice of corporate publishers, open access initiatives have exposed new strategies for raising revenue, such as collecting author-paid Article Publishing Charges (APCs) that range from $500 to $5,000 USD [Elsevier *OA*]. The ability of corporate publishers to easily assimilate open access into their profit model merits more attention, especially as open access moves to occupy a dominant position among scholarly communications in digital media. That move manifested in 2013 when the Research Councils UK (RCUK) mandated an implementation policy to make all government-supported research in the United Kingdom freely available online. (Anderson and Squires, 2017)

The future is already here

The notions that any of these open science initiatives exist to render scientific knowledge more accessible to the general public and research more responsive to the wishes of the scientist turns out to be diversionary tactics and irrelevant conceits. Open science is to conventional science as 'online education' is to university education: Neither has as its primary goal serious enlightenment of the citizenry. In reprise of our earlier sections, that is not the problem that open science is directly intended to address. Indeed, it would even be misguided to infer that Science 2.0 is being driven by some technological imperative to 'improve' science in any coherent sense; rather, it seeks to maximize data revelation as a means to its eventual monetization. What is fascinating is that, in the process of attempting to square this circle, many of the prophets of open science unselfconsciously cite Friedrich Hayek and Karl Popper, two early members of the Mont Pelèrin Society most concerned to rethink the politics of knowledge (e.g. Mirowski, 2018; Nielsen, 2012: 37–38). The objective of each and every internet innovation in this area, summarized below in Table 3, is rather to further impose neoliberal market-like organization upon some previously private idiosyncratic practices of an individual scientist. Forget Hayek and the fairytale of 'spontaneous organization'; this New Order is the province of business plans, strategic interventions, creative destruction and the apotheosis of knowledge as commodity. There is a logic to platform capitalism: Radical collaboration deskills the vanishing author, dissolving any coherent notion of 'authorship' (Huebner et al., 2017), and tends inevitably toward monopoly, in the name of profit.

Table 3. The landscape of science platforms.

By whom	Getting interested	Preparatory	Research protocols	Writeup	Publication	Post-publication
Normal scientist	Academia.edu; Blogs, ResearchGate; LinkedIn	Open notebook; Mendeley; Colwiz	Emerald Cloud; Science Exchange	arXiv; Zenodo	Frontiers.org; eJournals	Academia.edu; PeerJ; PubPeer
Funders	OSSP	Kickstarter; Walacea	NIH Open source; Hivebench	Zenodo; Pub management	Altmetrics; F1000 Gates platform	Open access commentary
Competing scientists	ResearchGate; Twitter	Polymath; Mendeley; EU OS Cloud	Open data; Pure; EU OS Cloud	Zenodo; PubPub	Publons; Peerage of science	Fac of 1000
Spectator scientists	Twitter; Blogs	Open collaborate; ScienceMatters	Virtuallabs; Vlab.co.in		Thinklab; Open comment	Blogs; Clarivate
Outsider citizens	Wilson Ctr CS	SETI@hom; Foldit	DIY bio; zooniverse	Publication managers		
Kibitzers	Twitter		Open source software			Blogs

What exactly is neoliberal about the incipient electronic manifestation of Science 2.0? Let me survey the possibilities. First off, the proliferation of open research platforms is primarily subordinate to the project of breaking up the research process into relatively separable component segments, in pursuit of their rationalization – which means first and foremost, *cost-cutting*. This happens through the intermediary of deskilling some of the tasks performed (through citizen science or tools like Mechanical Turk) and automating others (publishing AltMetrics, rendering Big Data accessible to Web crawlers, creating virtual labs). Open Notebook permits outsiders to freely kibitz in your project preparations. Capturing freely donated labor which can later be turned into proprietary knowledge products is the analog to capturing freely provided personal data in social media. Hivebench proposes to take data management out of the hands of the scientist. Meanwhile, ScienceMatters seeks to entice scientists to freely donate their datasets, however small, to an opaque data manager. ‘Publication’ itself becomes fragmented over many different sites promoting radical collaboration. Many schemes exist to quantify or transform the very process of peer review, from Publons (which keeps track of your peer review activity and awards little gold stars, in the shape of ‘merits’) to Peerage of Science, which actually claims to evaluate the quality of peer reviewing, with cash prizes (see Ravindran, 2016). After the fact, Faculty of 1000 recruits ‘thought leaders’ to provide post hoc evaluations of already published papers (although there is no attempt to prevent ghost authorship of reports). Each of these platforms occupies a single cell in our table of the fragmentation of open science.

The extreme disembodiment of knowledge has been enshrined at MIT in a platform dubbed PubPub. It imagines that anything – a bit of data, some text, an image, an equation – can be entered into a mega-platform, each identified by an appended DOI. Call each of these entities a ‘blob’. Then anyone (the Media Lab suggests ‘data-driven citizen science’) can sign on to the system, connecting blobs to other blobs in unbounded permutations. This is called a ‘collaboration’; although that is perhaps misleading, because the ‘author’ has entirely disappeared and there is no finality to ‘publication’. All you have is one big blob, like some 1950s sci-fi nightmare.

Thus Science 2.0 constitutes the progressive removal of autonomy from the research scientist. Indeed, ‘ghost authorship’ is the natural outcome of open science. Neoliberal science disparages scientists who remain in the rut of their own chosen disciplinary specialty or intellectual inspiration; what is required these days are flexible workers who can drop a research project at a moment’s notice and turn on an interdisciplinary dime, in response to signals from the Market. The short-term nature of science funding, as embodied in Kickstarter or recent innovations by the NIH, simply expresses this imperative. Second, the selling point of many of these platforms is not just providing direct services to the scientist involved; at every stage of research, they provide external third parties with the capacities for evaluation, validation, branding and monitoring of research program. This is the very essence of the new model of platform capitalism. Their nominal ‘openness’ constitutes the ideal setup for near real-time surveillance of the research process, a Panopticon of Science, something that can be turned around and sold in the very same sense that Facebook provides real-time surveillance of consumer behavior. Third, the paladins of Science 2.0 have moved far beyond quotidian concerns of appropriation of individual bits of intellectual property, like patents. What they have learned (as have

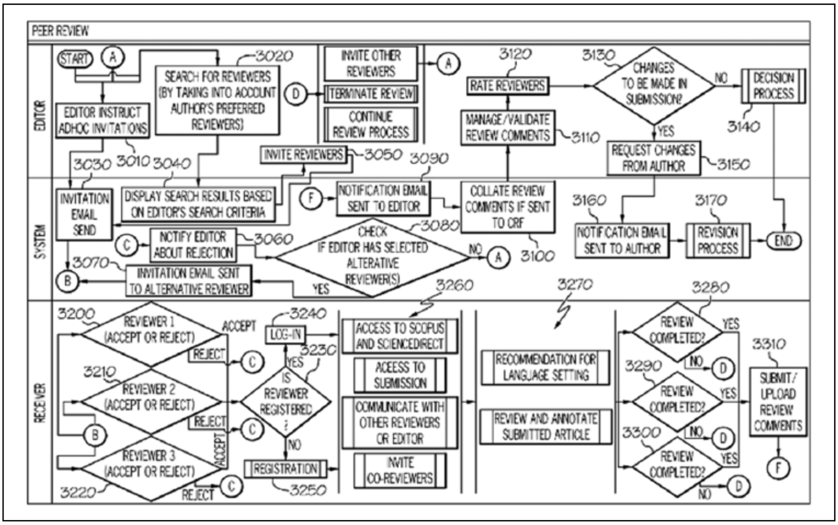

Figure 5. US Patent #9430468.

Microsoft, Google, Uber and others) is that the company that controls the platform is the company that eventually comes to dominate the industry. Microsoft has learned to live with Open Source; Amazon leases out cloud computing, Google ‘gives away’ Google Scholar (Newfield, 2013). The future king of Science 2.0 will not be a mere patent troll, living as a parasite off companies who actually work the patents; it will not be perturbed by a few mandatory Open Data archives here and there, or some nominal government requirement of open publication. Instead, it will be the obligatory passage point for any commercial entity that wants to know where the research front of any particular science is right now, and that must be paid to influence and control that front.

This race to be the King of Platforms that controls the future of open science is already happening. As Table 3 demonstrates, the future is already upon us.

This dream of an Uberization of science is much further along than most people realize. While some academics spin their visions of sugarplum in the air, various big players are positioning themselves to package together all the functions in Table 3 into one big proprietary platform. On August 30, 2016, the US Patent Office issued US Patent #9430468 entitled, ‘Online peer review and method’. The owner of the patent is none other than the for-profit mega-publisher Elsevier. The essential gist of the patent is to describe the process of a peer review being organized and effectuated on a computer program, as in Figure 5.

Of course, it would be the height of hubris to expect to appropriate the entire concept of peer review as intellectual property, but perhaps that was not really the aim of Elsevier. The Patent Office rejected this patent at least three times, but under the unlimited do-over rule in US law, Elsevier kept narrowing the claims until the stipulation passed muster. It does include an automated ‘waterfall process’ in which the rejected paper is immediately turned around to be submitted to another journal in a recommended sequence. It is also compatible with a variety of different formats of 'reviewer' inputs. One might regard this not so much as a stand-alone automated peer review device as a manuscript submission manager to be marketed to certain institutions, such as for-profit publications managers (Hinchliffe, 2017; see also Sismondo, 2009).

In the brave new world of open science, platform inputs might take many forms. Some researchers are already exploring automated peer review: using a natural language generator to produce plausible research reports, and using some more unconventional evaluation inputs (Bartoli et al., 2016). One of the inputs has been constructed with an eye toward the crisis of replicability: taking standardized datasets and research protocols and conducting automated replication with robot labs. Far from being science fiction, there are already two for-profit firms, Transcriptic and Emerald Cloud Lab, positioning themselves to provide this service in a more automated and streamlined open science platform (Wykstra, 2016).

But the real shape of Science 2.0 is only being tracked in the business press. Once one is equipped with a roster of component modules of open science, then one learns to look for the grand wave of consolidation going on in platform capitalism. First, in 2016, the owner of Web of Science spun off that unit to purchase by a private equity firm, where it was renamed 'Clarivate Analytics'. Then, in 2017, Clarivate bought Publons, with the justification that it would now be able to sell science funders and publishers 'new ways of locating peer reviewers, finding, screening and contacting them' (Van Noorden, 2017). In the meantime, Elsevier first purchased Mendeley (a Facebook-style sharing platform) in 2016, then followed that by swallowing the Social Science Research Network, a preprint service with strong representation in the social sciences (Pike, 2016). In 2017 it purchased Berkeley Economic Press, as well as Hivebench and Pure; Elsevier now claims to be the second largest publisher of 'open access' articles in the world. In 2017, the corporation F1000, which owns and operates the platform associated with Faculty of 1000, partnered with both the Gates Foundation and Wellcome Open Research to consolidate open peer review and publication of medical research under a single platform structure, the better to integrate upstream funders with publication outlets (Enserink, 2017). Here we observe nominally philanthropic foundations collaborating with for-profit firms to build the One Platform to Rule Them All.

It is clearly a race to fill a horizontal or diagonal row in the Bingo card of Figure 3. The future of platform capitalism in science depends upon it.

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Notes

1. See www.openscienceprize.org. The six teams further engage in further competition for a single prize of $230K, which hardly matches more conventional big science grant amounts. The final winner was announced in March 2017.
2. See http://www.pbs.org/show/crowd-cloud/
3. See http://www.teresascassa.ca/index.php?option=com_k2&view=item&id=235:us-law-clears-way-for-use-of-citizen-science-by-government&Itemid=81

4. See http://www.g8.utoronto.ca/science/130613-science.html. This includes the ominous statement, 'To ensure successful adoption by scientific communities, open scientific research data principles will need to be underpinned by an appropriate policy environment, including recognition of researchers fulfilling these principles, and appropriate digital infrastructure'.
5. A Dutch infomercial promoting open science is available at: https://www.youtube.com/watch?v=fxHmi5omhj4
6. See https://ec.europa.eu/digital-single-market/en/news/open-innovation-open-science-open-world-vision-europe
7. The description of regime changes was first broached in my *ScienceMart* (Mirowski, 2011). See also Forman (2007, 2012).
8. For discussions of 'radically collaborative science', see (Huebner et al., 2017; Winsberg et al., 2014); for 'platform capitalism' see (Pasquale, 2016; Srnicek, 2017); for the definitions of platforms in media studies, see (Gillespie, 2010; Helmond, 2015); and for neoliberalism in science, see (Lave, 2012; Lave et al., 2010; Mirowski, 2011).
9. See Austin et al. (2004) for the announcement.
10. See http://evotec.sissy.bgcc.at/archive/en/Press-releases/2012/NIH-awards-major-contract-to-Evotec-to-Manage-and-Operate-a-Small-Molecule-Repository/2306/1
11. http://retractionwatch.com/. See Marcus and Oransky (2014) and, in this journal, Didier and Guaspare-Cartron (2018).
12. On the drawbacks of using Thomson Reuters statistics, see Mirowski (2011: 267–270).
13. More recently, Nielsen admitted that some recent open science projects have failed, because many projects have resorted to 'unconventional means for conventional ends'; the solution is the neoliberal precept to 'change the incentives'. See https://www.ted.com/talks/michael_nielsen_open_science_now/discussion
14. For some sources, see Hammarfelt et al., 2016; Lehrer, 2010; Lin, 2012; Nielsen, 2012; Oransky and Marcus, 2016; Trask and Lawrence, 2016; Weinberger, 2012.
15. Long after I had begun this research project, I was shocked to discover one of these projects as my own university: https://www.youtube.com/watch?v=enohoM6cBww
16. There is a massive literature debating the doctrines and history of neoliberalism; something we simply must pass by in this context. For a detailed discussion of neoliberal politics and economics, see Mirowski (2013). For neoliberal science, see Kansa (2014), Pinto (2015), Tyfield (2013), Lave et al. (2010) and relevant chapters in Tyfield et al. (2017).
17. Srnicek (2017) helpfully breaks down platforms into different formats for extracting revenue. There is a large literature in media studies which deals in detail with the structure of internet platforms: see Helmond (2015) and Plantin et al. (2018).
18. For some general examples, see https://ccsinventory.wilsoncenter.org/ and https://scistarter.com/

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