14th Berlin Debate on Science and Science Policy

Who Owns Science? Reshaping the Scientific Value Chain in the 21st Century

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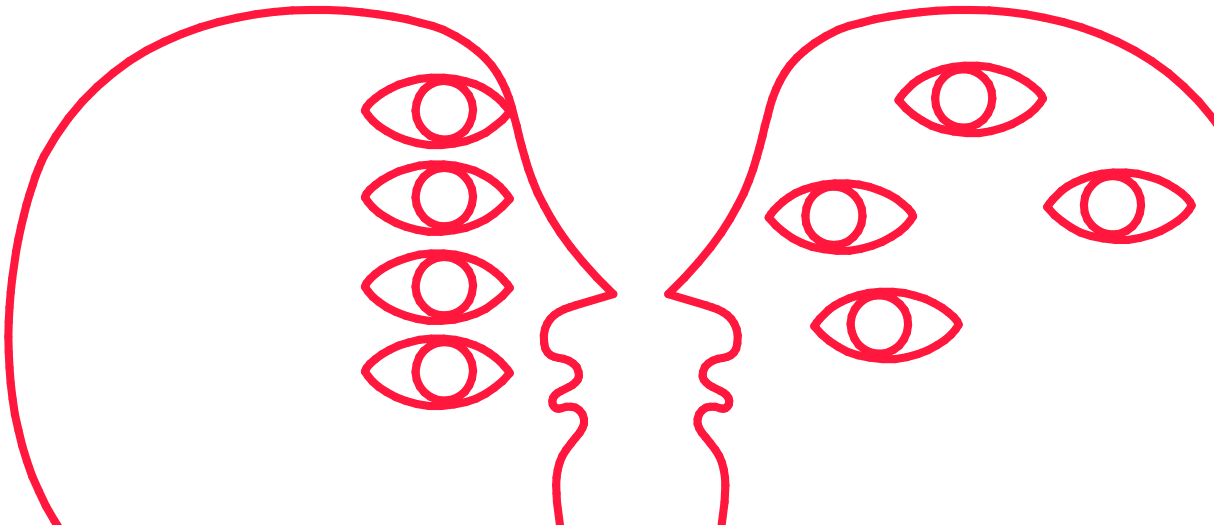
REPORT



Foreword

The Robert Bosch Stiftung started the Berlin Debates on Science and Science Policy in 2001. Our ambition with this format has always been threefold: to address a key issue in global science and science policy, to find the perfect mix of distinguished guests for each particular subject, and to create a safe intellectual space where opposing arguments can be exchanged openly and even the most audacious solutions proposed.

For this 14th edition, held in Berlin on November 7, 2019, we chose Open Science as our topic, but decided to frame it in a slightly unusual way, to highlight what we think is at stake. Instead of discussing different color-coded routes to Open Access or the necessity of Article Processing Charges (APCs), we focused on a set of more fundamental questions, thus trying to make a dent in the complex universe of Open Science.

- Who should “own” science - its results as well as the research data?
- Who should have the power to decide about the quality of research/of a paper and its authors?
- How should this quality be secured and how can it be measured?
- How would a scientific value chain look which allows for a globally inclusive collaboration between researchers, industry and society and which yields results that best benefit humanity?

Funding science and addressing shortcomings in the science system is part of the DNA of the Robert Bosch Stiftung, which was established in 1964 and is one of the leading private foundations in Europe. We believe in the pivotal role of science in solving the world´s great challenges. We cherish and promote the freedom of science – but we are also committed to make scientists understand that no man, no woman and especially no scientist is an island. Excellent research depends on strong ties with society – and on all sorts of infrastructure. The way we are storing, sharing and publishing scientific results is an essential part of this infrastructure. And it seems that there is ample room for improvement – if not revolution – here.

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1. Summary and recommendations

The advent of “open science”, and widespread efforts to extend it, raise a host of technical and social issues. The fine details of publication practices, evolving alongside changing technologies, preoccupy many. These passionate discussions about “open access”, however, can obscure many other aspects of open science, and divert attention from the fundamentals: why is it the way to go, and what benefits should it bring? This year’s Berlin debate was an opportunity to reconsider some of these more basic questions.

But while no science may ever be completely closed, wholly open science is also a mythical beast. Other values of the science system, such as being first, securing credit, or protecting intellectual property may conflict with aspirations to be transparent and accessible to all. Openness, it seems, is always a matter of degree. The precise degree is negotiated at many points in the research process. What to include in a paper? Who might publish it? Who has access to the publication, and on what terms? Who can make use of the data or materials the paper reports on? Who benefits from exploitation, whether the benefits are direct or indirect, financial or social? As the title of the debate indicates, we need to set conditions of ownership, and understand what counts as value, in contexts in which these terms are not always easy to define.

There are no unequivocally right answers to these questions, and the status quo differs by country, discipline and research sector - most obviously whether academic, industrial or military. Historical answers are embedded in complex institutions, with publishing infrastructures at their core. Reward systems, financial and reputational, are built on top of those, and make them harder to change.

Nevertheless, this discussion took place at a time when there is an overall movement - everyone agreed - toward greater openness and access: of insights generated and data used, but also of processes behind their production as well as their interpretation. The idea that we are nearing a “tipping point” drew wide assent. What our various contributors want the world to look like after that point, and how to help it tip in the right direction, were the main business of the day.

The discussion ranged widely, but the direction of travel seemed clear - and indicated a series of recommendations, which are itemized below.

Recommendations for the future development of open science

- ❖ Think of science in terms of an ecosystem rather than as a value chain; cultivate systems thinking, especially when relating to governance.

- Open access is key, but only one of many features that need addressing when planning the development of open science. The diversity of research practice is also important to appreciate when advancing open science.

- Treat scholarly publications and other research outputs as part of the commons, not marketable goods.

- Agree on principles for establishing and maintaining open access, rather than the details of how it is to be realized; this allows for experimentation and learning.

- Ensure transparency about costs of publication, and who is paying for which elements of the process.

- Rebalance the costs incurred by established scientific publishers and growing scientific powers in the developing world.

- Consider the future of all “research objects” (from research protocols to data repositories) - not just journal articles.

On protecting research quality

- Stop just agreeing that impact factors are misused, and do something about it. Recognize that reducing reliance on impact factors involves more than policy declarations: it depends on a culture shift and requires institutional follow-through.

- Promote solutions such as preprint repositories and open peer review; this would also mean encouraging more funders to allow applicants to cite preprints in grant applications.

- Extend the use of registered reports, in advance of peer review.

- Bear in mind that open review is not always straightforward - mediation may still be needed when anonymous review is not available.

- Experiment with automated tools to identify high and low scientific rigor (e.g. statistical standards).

- Consider research impact as an important quality, yet be aware that it typically occurs after a considerable timespan (10-15 years).

- Bear in mind researchers’ individual and collective responsibility for maintaining a culture of quality and that they need to be supported and incentivized accordingly.

- ❖ Keep the quality of the publication outlet in mind when making publication choices. For example, don't submit to a journal you do not read.

On publishing infrastructure

- ❖ Be aware that the advent of integrated platforms allows data extraction that shapes thinking about institutional performance measurement and management - at a price. Ownership of such platforms bears close scrutiny.

- ❖ Build more diverse publication systems/repositories. They should be able to meet local needs (research agendas, linguistic requirements), while ensuring international standards. This could be achieved by research institutions investing parts of the subscription payments publishers now take.

- ❖ Emphasize and care for equity and inclusion at the outset of new initiatives - to minimize unintended consequences of any system changes.

- ❖ Ensure common, public standards for any new publishing infrastructure to make them interoperable.

- ❖ Ensure all future "research objects" are machine readable, with a view to the advances in AI and the potential this might open to foster new forms of engagements.

2. Opening discussion: looking for common ground

“We are in a process of restructuring and rethinking science in quite fundamental ways”, suggested debate chair Ulrike Felt, Professor of Science and Technology Studies at the University of Vienna. That involves the science system in the largest sense, including scientists, policy-makers, funding agencies, and the whole publication industry and its infrastructure. Asking questions of ownership, said Felt, will push us to address issues of control over and access to scientific information and products that result from research. And it calls for reflecting on the socio-political and ethical dimensions of ownership.

The notion of “scientific value chain”, in turn, invites us to collectively discuss where, when and by whom value is being defined, who is engaged in creating it and who can and will profit from it, Felt explained. From a global perspective, we will have to acknowledge that approaches to open science/access/scholarship may vary considerably across sites, affected by economics, infrastructures, histories and diverse forms of politics both within science and beyond. The recognition that such a change is under way invites reflection on how to continually monitor and adjust changes in progress to avoid unintended consequences.

Glenn Hampson, executive director of the Science Communication Institute in the USA, outlined how he and the global Open Scholarship Initiative (OSI), which he also directs, see this transformation as it relates to scientific publishing. In his opening statement, he set the scene by emphasizing that actors who may dispute details of open access nevertheless have much common ground. He suggested that both science and society could benefit from open science, that success calls for broad collaboration, and will lead to a range of outcomes. Indeed, “open” wasn’t a clear goal. “At present, it is just an ill-defined means to an ill-defined end”. The openness of knowledge can be assessed along five different scales, summarized by the OSI as “DARTS”: Discoverable; Accessible; Reusable; Transparent; Sustainable.

- DISCOVERABLE: Can this information be found online? Is it indexed by search engines and databases, and hosted on servers open to the public? Does it contain adequate identifiers (such as DOIs)?
- ACCESSIBLE: Once discovered, can this information be read by anyone free of charge? Is it available in a timely, complete, and easy-to-access manner (for instance, is it downloadable or machine-readable, with a dataset included)?
- REUSABLE: Can this information be modified? Disseminated? What conditions (both legal and technical) prevent it from being repurposed or shared at will?
- TRANSPARENT: What do we know about the provenance of this information? Is it peer reviewed? Do we know the funding source (are conflicts of interest identified)? What do we know about the study design and analysis?

- SUSTAINABLE: Is the open solution for this information artifact sustainable? This may be hard to know---the sustainability of larger, more established solutions may evoke more confidence than new, small, or one-off solutions.

The payoff of moving to the open end of each scale could be an “open Renaissance”, promising big gains. “Once open becomes the default global standard, then we get to the point where it feeds back into the science system and science will grow exponentially”, he declared. A fully connected and standardized system for publications, linked to data repositories, would underpin a research system that grows in power. In the best scenario, as “connecting the dots“ gets easier, “new fields and directions emerge, funding efficiency improves and discovery accelerates”. There might even be improvements in science literacy, public engagement with science and scientific inputs into public policy. In this way, he suggested, science becomes a global public good. That is a high aspiration, because it means scientific results and the underlying data should be “physically, not just intellectually, freely accessible and beneficial to everyone.” This is only partly a matter of taking down paywalls. “It has more to do with improving access to science such that we can more freely exchange ideas, and science knowledge can more freely have influence.”

As reformers pursue these benefits, there are also common concerns. They include ensuring publication and access are affordable, avoiding the creation of new inequalities when needing to pay for publications, addressing the needs of the global South and the humanities, and guarding against unintended consequences of reform, especially any jeopardy to the reliability of published data.

‘Open’ is a means, not an end

This emphasis on the highest-level goals was in part a recovery of the thinking developed during early discussions of open access. Heather Joseph, director of the Scholarly Publishing and Academic Resource Coalition (SPARC) in Washington, recalled that ‘open’ was not a goal in its own right, but a means to an end. She quoted a key passage from the Budapest Declaration, originally published in 2002, which argued that:

“Removing access barriers… will accelerate research, enrich education, share the learning of the rich with the poor and the poor with the rich, make this literature as useful as it can be, and lay the foundation for uniting humanity in a common intellectual conversation and quest for knowledge.”

The rich-poor relation was crucial here. “We have to think about building the structures into the new open science system that will create the greatest equity for both access and participation in the conduct of science, the sharing of science, and the practice of science.” In short, the entire value chain – although along with others she felt value chain was not the best term to use.

Helga Nowotny, chair of the ERA Council Forum Austria, preferred the term ecosystem. That mirrors the change in terminology that has commended itself to many in discussion of innovation, in recognition that it does not happen in an orderly, linear fashion, but involves change in several dimensions simultaneously.

If scientific publication and dissemination is an ecosystem, one job then is to identify where in this ecosystem ownership changes. “And does the transition create more value, or reduce it? Knowledge that is not taken up may not be realizing value for anyone. And need to know: value to whom? Who is the community that makes use of it?”, Nowotny asked. A very good question, said Stephen Curry, professor of structural biology at Imperial College London, but also very difficult to answer. It poses the same problems as trying to figure out how research has impact.

Jean-Paul Bourguignon, president of the European Research Council, also contrasted the apparent simplicity of the idea of a value chain involving science with the reality of the history of scientific fields, and the transformative power of key concepts. He cited artificial intelligence as a field where concepts have shifted radically more than once. The history of AI is marked by radical breaks, and reinventions of the foundations of much of the work, making continuities harder to trace.

It was also apparent that the ecosystem, if that’s the right framing, is not simply going to change to a new stable state. It will continue to evolve. Matthew Todd, professor of drug discovery at University College London, stressed the need to consider changes in technology. One important consideration was whether new knowledge is created in machine readable form. “I think this is very important, even though it sounds a bit like science fiction, because there’s not going to be long now before we have decent AI and machine learning that can use what we create to do things we can’t.” By this he referred to the capacity of AI to extract new insights based on the huge amount of available knowledge.

Magdalena Skipper, editor-in-chief of *Nature*, pointed out that the system needs to accommodate more than the words in journal papers. The discussion tends to focus on open access, overcoming paywalls, and patterns of authorship, but all of these mainly concern scientific text. There is much more to the research process than text generation, from research protocols to data repositories. “If we really want to accelerate research, then we have to focus on opening all research objects because that's really how knowledge is going to grow. And the same applies to machine readability. We need to think about opening up and systematizing all research objects so they can be interrogated in an analogous way.”

3. Open access and open science around the world

Glenn Hampson noted that open access in some form now covers more than half of all new publications. For older papers, around 28 per cent of the archive now qualifies as open, rising at four per cent each year. There are of course wide variations between disciplines. And there are initiatives that have boosted open access in some regions, notably Latin America and Africa. These were explored in Session 1 of the debate.

SciELO (Scientific Electronic Library Online), for example, began in Brazil more than 20 years ago as an open access, web-based library. As Abel Packer, SciELO's co-founder described, it now covers 1200 peer-reviewed journals from 17 countries, publishing 50,000 articles a year (see https://scielo.org). As he put it, "the key contribution of the SciELO is the recognition of the relevance of its journals to the advancement of research from a global perspective as they communicate basic and mainly applied research related to national issues." The network has been both a vehicle for development of national policies for scientific publication and for making information available globally. The aim is development of peer-reviewed journals that follow international standards, but are not impeded by journal impact factors, for example. The library is accessible to researchers but also to policy-makers, educators, and even schoolchildren.

Another Latin American initiative grew from a similar conviction that "the prevailing science communication system has failed in terms of making science a global, participatory and equitable conversation", as Arianna Becerril-Garcia, executive director of Redalyc (https://www.redalyc.org) explained. This publicly-funded open access network began in Mexico 16 years ago, offering a service to journals published by academic institutions. It has recently been supplemented by AmeliCA (http://amelica.org/en/), in response to an increase in demand following improvements to the original platform. It is another facet of an open access system that adheres to the principle of science as a public good, and by-passes commercial publishers. AmeliCA is now training editorial teams as far afield as India.

A view from Africa

Susan Veldsman of the Academy of Science in South Africa described the African Open Science Platform (http://africanopenscience.org.za), launched three years ago with backing from the South African National Research Foundation. Despite its name, this venture is not (yet) establishing infrastructure, but more concerned with taking stock of the current situation across the continent and offering a forum to discuss open access in Africa. That led to creating frameworks for training, building capacity for data collection and open science policies more generally. Challenges include the current levels of investment in many countries, and that not many researchers in Africa are able to contribute data. Further inquiry discovered a range of reasons for this, ranging from "nobody told me to" to those who said they had used their own time and money to gather data so were disinclined to pass it on.

This pointed to a larger background issue of building trust to expand collaboration, as well as instituting standards in what turns out to be a large number (66 so far) of data repositories. Meanwhile, national policies are beginning to emerge, with White Papers on open research and data policy recently forthcoming in both Africa and Botswana.

Meanwhile, in Europe

In Europe, matters are far enough advanced to permit efforts to propose continent-wide, or possibly global, policy guidelines. Mark Schiltz, president of Science Europe observed ruefully that “Plan S”, proposed by a broad coalition of research funders in 2018 (see https://www.coalition-s.org) has been decried by some as too radical, and by others as not going far enough.

In his view, laying down principles is more constructive at this stage than detailing how they should be implemented. This should allow organizations which favor different models of open access to sign up. Plan S has ten principles, but he highlighted some key points. All new work should be paywall free, and there should be no embargo periods. Ownership of publications remains with researchers, and licensing is open. And it must be clear who pays for what: “We admit that publication generates costs. We admit that the publishers can charge fair value for these costs, but we want to have complete transparency about what we are actually being asked to pay for.”

The obstacles to wider adoption of these principles, in his view, were not commercial publishers. “The legacy publishers will have to change their business model in one way or another, or simply die.” However, there are other blockers in the science system, with its impact factors, rankings, metrics and performance indicators. The individual researcher faces a version of the prisoners’ dilemma: Can they afford to ignore these things if others are not going to do likewise? The same applies to institutions. “When we have found a way out of this, I think the question about open access will have been solved or will solve itself.”

Reflecting different needs

Discussion among all participants exposed more reasons for enthusiasm about these developments, as well as reluctance to embrace them as presented. Stephanie Dawson of ScienceOpen in Berlin was keen on the “good, well-structured databases” exemplified by SciELO because they offer opportunities for companies to develop new products. “If you put it out there and it's good data, startups will come”.

For others, concerns about costs and their distribution remained a major issue. Xiaolin Zhang, chair of the Strategic Planning Committee of the National Science and Technology Library in Beijing, stressed that China is committing to open access. But he would not recommend signing up to Plan S, for example, at present, unless there

is a “rebalancing” of subscription costs. “Chinese research volume is high, we are a major contributor”, he said, but it does not lead to a fair share of journal revenues. Other countries building up their scientific efforts might have similar reservations, Susan Veldsman agreed.

Kathleen Shearer, director of the Confederation of Open Access Repositories (https://www.coar-repositories.org) in Montreal, saw this as one aspect of a key tension. Local environments matter, and institutions need to support local needs and priorities and deal with different languages. At the same time, a global network of repositories needs interoperable standards to support research internationally. “I think that's one of the biggest challenges and there's a sort of inherent bias against the infrastructures in developing countries that I think needs to be corrected”.

Perhaps the best way to think about the system we need in the future, she suggested, was to recognize that we have had too much trust in the market to define how things should work. Instead, it is time to start thinking about scholarly publications and other research outputs as part of the commons. The commons still need to be managed, but call for different governance to support and maintain knowledge in a way that works for everyone.

4. But is it any good? Securing and measuring quality

Unlimited access to knowledge would be useless without ways to gauge its quality, which was the focus of Session II. As Ousmane Badiane of the International Food Policy Research Institute in Washington emphasized, society does not gain from research whose quality has not been vetted. Bourguignon emphasized the vast outpouring of journal papers. The “cataclysm” of publications makes filtering essential, and it needs to be done within scientific communities.

So what changes are needed to the systems of review and quality control? In his short input statement, Stephen Curry suggested that the present arrangements are good “up to a point”. But he believed that research evaluation has become over-metricized, and “we all know we have an over-developed reliance on journal prestige”, epitomized by the impact factor. The functions of publication have become unbalanced, emphasizing accumulation of reputational capital over knowledge sharing.

Open science, he argued, offers a way out of this situation, demanding a more expansive view of the qualities of research that matter, and how they should be assessed. Voicing the idealism that fires many advocates of open science, he suggested that it represents an opportunity to reconnect science with fundamental values. “Open science represents hope: a chance to re-negotiate science’s social contract in ways that are more inclusive, more open to public dialogue on the proper balance between academic freedom and responsibility, and more rooted in moral purpose.” It will better serve many stakeholders with a genuine interest in research - “patient advocacy groups, environmental campaigners, citizen scientists - indeed any citizen concerned about the modern world.”

In his view, quality control doesn’t pose insoluble problems for open science. Preprints permit wider scrutiny of papers. Open peer review complements that, and its wider adoption would kill off predatory open access journals. (As would adhering to simple advice like don’t publish in journals you don’t read yourself.)

Explosion of misinformation

But the question remained: how open is too open? In her statement, Stephanie Dawson observed that internet users are drowning in junk science. For example, over half the 20 most shared cancer articles on Facebook in 2016 were based on scientifically discredited information. And peer review is showing signs of strain. “Securing and measuring quality is absolutely vital not only in furthering our scientific goals, but to protect the public and the very fabric of some of our most important institutions. But the explosion of misinformation suggests that our current gateway system based on expert peer review may need new tools and strategies”.

Her own platform uses open peer review, although she had come to appreciate there were also virtues in anonymity. Experience with open review has generally been good, but it has been slower and harder to develop than envisaged. Researchers

were not all delighted by the invitation to publish work “and then have it out there on the internet for free for all review by anybody.” Some reviewers reserved their real opinions for backchannel conversations with editors. Open review reveals a need for some mediation in the process. In short, “there's a huge amount of hesitation to treat this scientific process as if it were an Airbnb apartment.”

Open, anonymous, or not, at the moment peer review is there because we depend on a hierarchy of excellence based on human judgment. But the volume of work is making this harder to maintain. A degree of automation may be one way to go. “I’m interested in experiments in peer evaluation that can flag poor or fraudulent content in a consistent and machine-readable way across all publishers.”, said Dawson. “I think we need automated tools to identify high and low scientific rigor and support scientists in improving not only their paper, but their science”. There are a few experiments along these lines already - examples include StatCheck, developed by Michèle Nuijten for psychology, and the startup Ripeta who propose to automate manuscript checks for the reporting of essential information for reproducible research. But much more effort is needed. “My thesis is if we as a society could spend just a fraction of the energy that we spend developing algorithms to prevent credit card fraud [on assuring quality of research publications], I think we could go a long way to cleaning up the scientific record.”

Researchers’ and funders’ responsibilities

Automation aside, much of the following discussion turned on how to handle familiar features of the system. Curry emphasized that quality depends first and foremost on the researcher. “I’m very much a believer in peer review, but I don't think we should oversell it.”

Once a paper is out there, evaluative short cuts remain. Packer felt that the impact factor remains a major barrier to open science. Skipper, on the other hand, suggested the problem was not impact factors in themselves, but how they are used.

On that point, there is particular frustration in the African context at dealing with researchers chasing publication in high impact journals, at the cost of focusing on less relevant work. That raises the kind of problem epitomized by an anecdote from Leslie Chan of the University of Toronto. He recalled a colleague who studied an indigenous African vegetable “for some 20-odd years”. A paper submitted to a Western journal was speedily turned down because the reviewers regarded the plant not as a vegetable, but a weed. “So they rejected not because of the quality of the paper, but on their limited view of what people actually eat.”

The culture of easy metrics is also slow to change. Sir Philip Campbell, editor-in-chief of Springer Nature, stressed that discussion of impact factors’ malign influence has been ongoing for many years, and everyone seems to agree that they should not feature in evaluating individual researchers. But, “when will this actually happen?”, he

wanted to know. Nowotny suggested we are still “hypnotized” by a very narrow definition of quality for promotion.

Schiltz related that a policy shift in a funding agency to disregard impact factors had to be followed up vigorously. “I instructed the program managers that whenever indices or impact factors were mentioned, they should stand up and recall to the committee that they should assess the work not based on these indicators. There is an education process here.” Similar changes may be afoot soon in the USA, where Heather Joseph reported that a National Academy of Sciences Roundtable is keeping track of trails of different promotion procedures in institutions.

If use of impact factors is ruled out, what broader criteria can be deployed? Impact beyond the scientific community - extending to socially useful outcomes - is an obvious wish. But it takes diverse forms and entails a variety of different measures. In addition, Campbell stressed, the evidence is that it takes a long time, perhaps 10 or 15 years, to register. Simpler measures include accepting preprints in grant or promotion applications, limiting submissions to a selection of the top five publications, and instituting recognition for data generation. Skipper highlighted the introduction in some contexts of registered reports, “a format which is relatively newly emerged, which precisely shifts the emphasis from the final result on to how something has been done. So the peer review is further upstream.”

5. Publication infrastructure – shared and inclusive, or monopolized and exclusionary?

Any discussion like this which touches the foundations of the research system will consider the choice between root and branch reform and incremental change. So it was in Session III, which considered the infrastructure of scientific publishing. Ulrike Felt cautioned that one speaker's slides depicted a bulldozer demolishing a house, symbolizing the need for a rebuilt system, "but the house of science is inhabited by generations of people - we have to renovate while they live in it."

Nevertheless, there were suggestions that extensive rebuilding of publishing infrastructure is necessary. In his input statement, Leslie Chan outlined the critique of the existing publication system. Infrastructure, in his terms, is "our mechanism for creating rules, and for locking people into doing things that often are beyond their own personal control, but not necessarily beyond our collective control." That applies to the global system of knowledge production, where the rules are set by a small set of powerful players. One might, as Liselotte Højgaard suggested, get together with some of the large private foundations and buy a publishing house. But it would mean buying into a system that is problematic.

Publishing as data extraction

An integrated platform such as the one Elsevier, for example, is now offering, combines publication with data analytics. It is "a platform of extraction", said Chan, that covers the whole process of research and evaluation, and then derives further value by selling data back to researchers and especially, their institutions. Impact factors and similar indices persist in use because they are built into this infrastructure. Publishers build new business on the back of journals and publication indices. "They are now coming directly to our VP of research to say, well, you actually don't know enough about your own institutional performance. Let us tell you how you are performing. Let us tell you how you can raise the ranking internationally to become an even more well-known global university. Let us tell you who to hire next because they have a publication record that will contribute to your ranking."

The general point, Chan explained, is that infrastructures are never neutral, they embody forms of governance. Publishing companies now drive decisions in publicly-funded institutions through sale of new products, and sale of those products is self-reinforcing. That poses not an economic issue, or even one of access, but comes down to power and structural inequalities. Such concerns will be reinforced by any growth in reliance on artificial intelligence - technology is not neutral, either. We may move toward "algorithmic governance of public institutions by private interests.", Chan warned.

To avoid all this, he proposed investment in new, open infrastructure, which should be decentralized and community governed, "to enable epistemic diversity and biblio-diversity".

Against this, some saw benefits in the development of consolidated infrastructure. Perhaps there were also benefits in Elsevier's ability to extract more, and do more? In that case, it was said, there should at least be more sharing of the benefits with the community. Companies had a tendency to keep taking and never give back. If so, said Zhang, publishers should remember that their key resource comes from researchers, and they can take it back.

In the absence of demolition, the house might gain some new outbuildings constructed to a different design. Shearer argued that a decentralized system is needed to support the needs of a diverse, globally distributed research community. She suggested diverting 20 per cent of the subscription payments publishers now take to build more diverse systems. Ensuring they attract users would call for careful attention to branding. Joerg Heber, editor-in-chief of PLOS One, emphasized that there should be common, public standards for any new infrastructure. Campbell pointed out that any ventures designed to supplant existing publishers need to take account of the numerous functions publishers take care of - "So any system that you want to replace the current power structure, presumably, collectively needs to do those things."

Badiane felt that any new infrastructure would incur many of the same costs, so allocating them would still throw up familiar problems of access and equity. Chan held to his critique, but said what he was really arguing for was not necessarily to replace what exists, but to introduce new options within a broader system.

And Todd struck an optimistic note by noting a conversation with an expert in trust law who assured him that there are already viable legal frameworks for managing public goods that could be applied to the kinds of open, common infrastructure being proposed. "You don't need to reinvent the wheel, as there is old law already in place - which could be useful for the coming years."

6. The next level: from open science to market

The final session turned to a specific segment of the "value chain", the take up of scientific results in industry. Open science is progressing against a backdrop of decreasing research productivity, it was said. Costs rise, while output per researcher decreases. But can open science help restore productivity, or increase it in areas that the current reward system neglects?

Richard Gold of the Law Faculty at McGill University in Montreal, joining the meeting via video, outlined two exemplary initiatives in this connection. Montreal Neurological Institute-Hospital (the Neuro) launched a "radically open" science platform in 2016, covering both hospital and research labs. This has led to an upsurge of interest from pharmaceutical companies and AI companies interested in partnering with them because their data is open.

The Toronto-headquartered Structural Genomics Consortium (SGC) and their international collaborators have worked with industry since its foundation. It began work on identifying 3-D protein structures but has now moved on to developing chemical probes to study obscure portions of the genome. Like the neurology effort, it is open, and has built up trust among industrial partners, who now donate probes to the consortium.

Open notebooks and the end of patents

Both ventures adhere to similar principles: open access publication is a given, and so is open data - no later than first publication - often aided by tools such as electronic lab books that are uploaded day to day in real time. Young researchers in particular have taken to this method and some have built partnerships with industry through this sharing.

The projects also offer open materials. The only restriction on sharing is patient confidentiality, and when a limited supply enforces choice between projects. Finally, although the private sector is heavily involved, there are no patents, Gold explained. “Within the scope of the partnership, whether you're a private entity, a pharmaceutical company, an AI company, or a researcher in a university, there is no intellectual property that anybody can gain that would prevent anybody building upon that knowledge and all information and all data has to be shared on the same basis.”

The model has proven successes, such as a cancer drug derived from a gene probe after it was freely shared with other researchers. The Ontario cancer institute was able to develop the (proprietary) drug before anyone else because of the tacit knowledge shared with those closest to the original work.

Gold went on to detail how a different mechanism applies in the case of other candidate drugs, for child cancers and neurodegenerative diseases. There are candidate drugs going through clinical trials that adhere to the same open protocols. If successful, the trials should lead to a data package that can be filed with the US Food and Drug Administration or similar authorities. That confers data exclusivity that bars anyone else from marketing the drug for five or ten years - although they are at liberty to develop an alternative. The incentive for companies should be that the drug that has been tested is low risk, and they can recoup their costs rapidly because they have not had to finance the clinical trials.

That work comes in fields where there is plenty of competition for new medication. In his input statement, Matthew Todd of University College London outlined his effort to expedite investigation of treatments for diseases that are neglected by the industry. He and colleagues have been mounting fully transparent projects, accessible on the world wide web, since 2005, on antiparasitics, antifungals, and antimalarial agents. They hope to develop work on antibiotics as well.

As with the Montreal initiative, this work is organized around clear principles that ensure complete openness. These are:

- All data are open and all ideas shared
- Anyone can take part
- No patents
- Suggestions are the best form of criticism
- Public discussion is favored over private email
- An open project is not owned by any one lab.

Open notebooks are again the order of the day. They require a real commitment, as Todd related: “I just had my first PhD student submit on the open source malaria project. And the thesis has gone out for review, and the lab notebook has been zipped up and put on the repository. So you can see every experiment he did, it's quite a thing.”

The tools underlying the broader collaboration here include GitHub, more familiar to software developers, but useful as an open platform for communicating, assigning tasks, and making molecular data visible, and social media for other interactions between anyone interested in the projects.

The result has been a wealth of inputs into the projects. “When you make something open like this, people give for free, they just can't help themselves. And the surprise to us over the last decade or so is how much the pharma industry has given, in terms of resources, people time, and advice, and molecule contributions and other things. That's been a big deal.” As he concluded, this social experiment has shown that if there is open sharing, with no outsiders, people will contribute freely.

Which is all very well, but how is the drug going to get made if it shows clinical promise? It is not clear who owns the results, and Creative Commons is not ideal for drug development, Todd admitted. “We don’t really have a good license for open source drug discovery, and we need to make one that covers all the different kinds of inputs.”

However, the regulatory data exclusivity that the Montreal researchers are exploring is a promising possibility. It fits the criteria that there is a way of doing the work openly but provides for reward after a medication is shown to work. Thus, there are ways of securing incentives to bring a drug to market without any patent protection.

The discussion in this last session focused on life science, indeed on one domain within the life sciences. Perhaps it can yield ways forward for open research in other disciplines, although it was unclear whether there are close precedents in other fields. Astronomers are exceptionally good at data sharing, it was said, but they do not have to grapple with commercial considerations.

There are examples of data sharing in other contexts - from open seed networks to Landsat data, but it appears there is still thinking to do to establish models for what can happen in a more open world to arrange the work that comes between the science and a marketable, or marketisable product.

8. Closing discussion

If, as several people agreed seemed likely, we are approaching a tipping point beyond which open access is the default for all scientific publications and data, there are a lot of things to get right as the much broader transition to open science takes hold. Much of the discussion highlighted unintended consequences of the old system, which strengthens calls to pay attention to possible unintended - and equally undesirable - outcomes of any reconfigured system. The best safeguard will be to stipulate that a greater degree of equity and inclusion are *intended* consequences of any changes to the system.

System is a key word here, and Nowotny urged that a systemic point of view is essential in contemplating the changes. It must acknowledge different perspectives and take account of macro and micro-levels of organization, and pay close attention to the governance of complexity.

Other aspects that called for further thought highlighted in the closing discussion included the breadth of assessment of research and research proposals - prospective *and* retrospective. It is easy to agree that wider criteria are needed, but specifying what they are and how to operationalize them is harder.

Similarly, there was agreement that costs must be transparent and fairly shared, and incentives structured in ways that foster trust and collaboration. As with almost every other topic here, it is crucial to involve researchers in discussion of how to do this - a sentiment that ran through the entire day.

There are revolutionary impulses in play. But it is likely, it was suggested, that change will be incremental, and will have to deal with conflicts and contradictions along the way. Specific solutions should be framed taking account of what we really want open science to do, and options for handling publications, data, repository specifications and standards, will vary. Act experimentally, not aiming for perfection is good counsel, and try and exercise “anticipatory intelligence”. For example, we need to bear in mind that artificial intelligence may yet change the game. “AI won’t care about open access”, perhaps, and may open up new ways of dealing with knowledge and its distribution. And the related developments in analysis of big data, with the advent of “non-hypothesis driven science” will co-evolve with the progress of open access infrastructures.

It is also vital to evaluate new arrangements in the light of threats to free inquiry emerging in some nations today. It is all very well to talk about freeing scientific knowledge, but if freedom of inquiry is being eroded the words are hollow.

At the same time, there are many interests to bring more fully into the discussion. Researchers, especially young researchers, are under-represented. In international scientific relations, trust has been eroded and needs to be rebuilt. And finally, the debate affirmed that the ultimate owner of scientific knowledge should be the public. So any adjustments to the system can be judged partly on whether they make scientific knowledge more relevant to the needs of those now outside research.