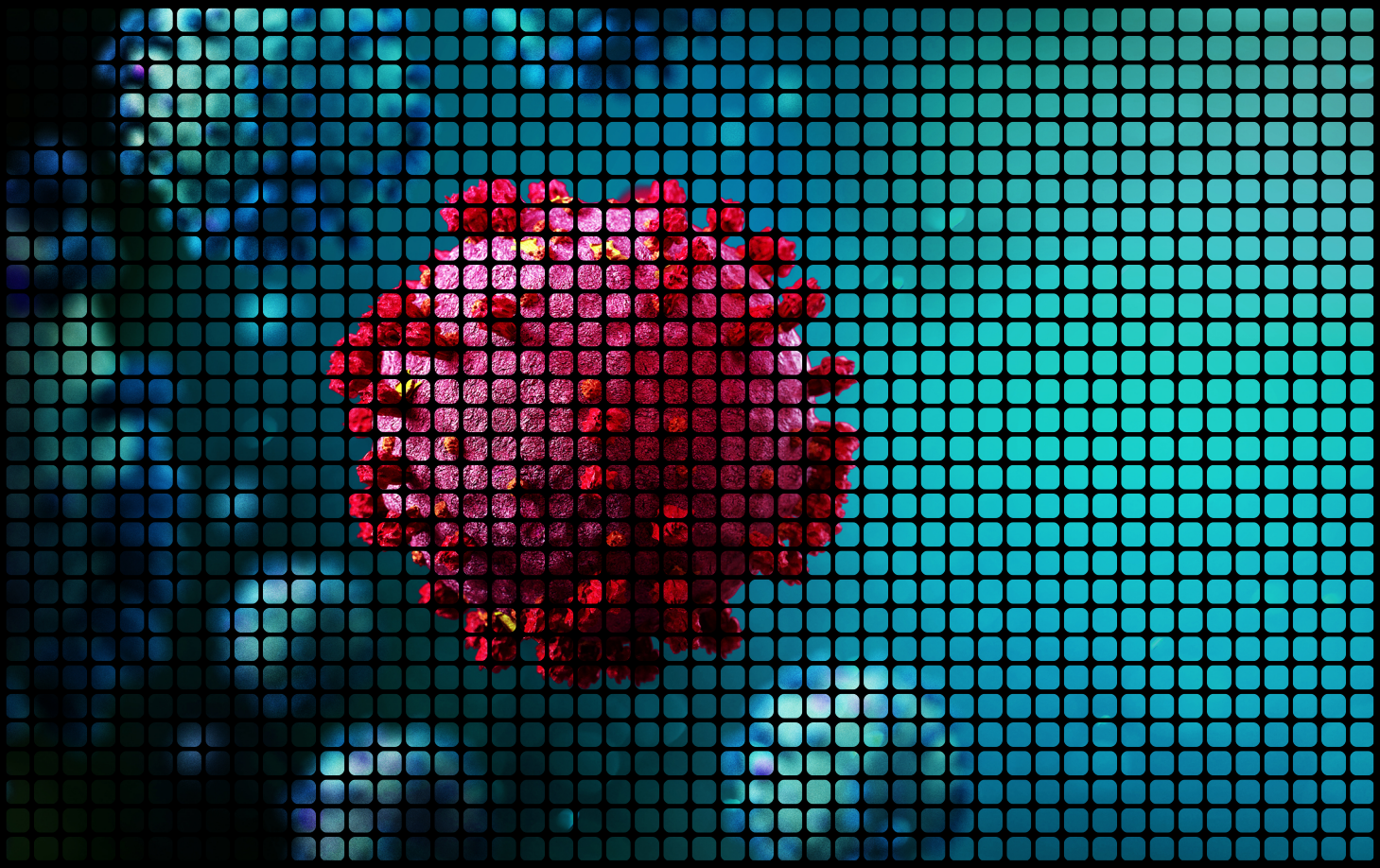

Digital Research Report

How COVID-19 is Changing Research Culture

Landscape trends and cultural changes in the global research system

Simon J. Porter and Daniel W. Hook

JUNE 2020

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1 Introduction

The global impact of the COVID-19 virus has been much larger than could have been foreseen at the time of the initial cases in Wuhan in late 2019. The lockdown imposed almost globally, together with the tireless work of healthcare professionals, will limit the final death toll from COVID-19 to numbers in the hundreds of thousands rather than millions. The effects of COVID-19 will not be limited to the lives of those financially, mentally and physically impacted, or to those who lost their lives and their loved ones. They will not even be limited to the 7.7bn people currently living on Earth. The social, economic and political fallout from COVID-19 will last for at least a generation, while the implications for public health are simply unquantifiable. That said, not all the impacts of COVID-19 need be negative [Derrick, 2020]. (In the interests of brevity of expression we have sometimes chosen to use the contraction COVID in place of COVID-19 in this report.)

"In five months, a volume of work has been generated that even the most intensive of emergent fields, such as deep learning or nanotechnology, have taken years to create."

We live at a time of intersection in which the COVID crisis has provided, for many, time for introspection bringing some issues into sharp relief. There are growing disparities in wealth not only between nations but within nations. We live in the start of what some refer to as the exponential industrial revolution [Davis, 2020]: Powered by artificial intelligence, many aspects of the coming revolution will change the jobs that humans do. Much of this AI revolution will have the effect of disrupting and replacing jobs rather than simply changing them [Frey, 2019]. This is highly likely to lead to greater wealth inequity not only between countries but within countries [Lee, 2018]. At the time of writing, governments around the world have taken unprecedented measures to shore up economies hit by lockdown. Some academics speculate that this is a time for universal basic income [Lee, 2020].

During the last few months governments have taken necessary steps to ensure that their citizens can eat and live, and in doing so have increased levels of national debt. Paying down this debt will be the natural impulse of governments but it is yet to be seen on what terms this can be done. From a financial standpoint, there are three routes out of the crisis once mechanisms to control COVID have been established: a) return to austerity; b) introduction of a progressive tax regime that asks the richest to pay the debts; c) outgrow the debt by stimulating the economy. In all likelihood, there will be a mix of these policies. It is clear that, for those countries who have followed Austerity over the last decade, there have been serious infrastructure implications that have resulted in challenges with COVID. A progressive tax regime would need to be introduced carefully in order to preserve incentives for people to be creative and take risks, while simply attempting to outgrow the debt might appear to be too much of a *laissez-faire* approach. Nevertheless, both of the latter options would signal a return to Keynesian economic ideals.

While Keynesian ideas may be reemerging as a result of COVID-19, there are related areas of debate that have been on the rise for the last thirty years. Specifically, the implementation of the Millennium and then the Sustainable Development Goals, and the corresponding academic work on the circular economy. In the corporate world, this has manifested in debates over corporate social responsibility and governance, discussions of shareholder value versus stakeholder value, and the fitness of GDP as a defining measure of economic growth in an increasingly multifaceted and interconnected world [Raworth, 2017, Flammer et al., 2017].

Following several years in which expertise was questioned and disregarded [Kakutani, 2018, Nichols, 2017], in this crisis, people and gov-

ernments have been quick to thrust science, scientists and experts back into the spotlight. Whether this is a cynical tactic, an authentic decision or an unavoidable necessity is debatable. However, it is possible that we are looking at a return to an 'Age of Reason' and the beginning of a new world–one in which economics, healthcare provision, and international cooperation could look wildly different from how they do now. They could, if we are lucky, look much more like the collaboration that we see in the world's research system [Skipper, 2020].

What could this mean for universities? There is certainly a risk of a decrease in research funding as governments come under pressure to manage national debts. At the same time, international student income will impact many institutions in the research economies that have diversified their business models to court that market [Conlon, 2020]. Many research institutions are asking what their future might look like and what their role is in a post-COVID world. Perhaps government policy will again turn toward pushing research institutions toward more applied research that more directly benefits the economy in the short term. Perhaps, given increased public sensitivity, it will not be socially acceptable to cut research funding so long as it is seen to be aligned with public health concerns and wider societal concerns. Is now a time for increased investment and a redefinition of impact in terms of the Sustainable Development Goals [Wastl et al., 2020] as suggested in another of our reports? Should we be funding the social sciences in a more coherent manner? Is the role of a university going to align more strongly with continuous development and life-long learning as we move into an uncertain labour market, disrupted by COVID and quickly being influenced by AI?

Setting aside the future of universities, COVID has posed more immediate challenges for research colleagues around the world. Researchers have quickly re-oriented their studies to meet public health needs [Hook and Porter, 2020, Fry et al., 2020]. These efforts have not only been in virology, immunology and epidemiology but also in less obvious areas such as mental health, as the effects of the lockdown change people's lives, and economics and environmental studies, as the financial and ecological environment responds to the downturn in productivity. This change in research activity has led to a corresponding shift in research behaviours—this is not business as usual. In five months, a volume of work has been generated that even the most intensive of emergent fields, such as deep learning or nanotechnology, have taken years to create.

As of the 1st of June, there have been upwards of 42,703 scholarly articles that have appeared, 3105 clinical trials, 422 datasets, 272 patents, 757 policy documents, and 156 grants. The response has been immediate and intensive. Indeed, the research world has moved faster than many would have suspected possible. To give some context, the area of 'Deep Learning' in AI is one of the fastest growing fields today and comprises around 150,000 papers. When deep learning started out, it took around seven and a half years to go from a few hundred papers a year of output to more than 11,000. In the case of COVID, the same volume has been reached in just four and a half *months*.

When a field develops so rapidly and so many researchers across different geographies and disciplines focus their attention on a problem of this nature, changes in the research community naturally arise: New behaviours, new collaboration trends and new uses of technology will all shape the field. Already we see a new relationship between medical sciences and preprint servers emerging, perhaps unsurprising given the speed that is required in this new field [Brainard, 2020, Hook and Porter, 2020]. At the same time, we are seeing many notable scholarly publishers making articles available instantly via Open Access in order to ensure

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"We are seeing many notable scholarly publishers making articles available instantly via Open Access in order to ensure all researchers have access to published material."

all researchers have access to published material. It is important to note also that, while the locus of this research is in the medical field, there are significant contributions from fields such as economics, psychology, engineering and computer science.

Funding commitments to support research into COVID are already being made across the globe at regional and national levels, as well as internationally coordinated schemes [Wintour, 2020]. The first grants have already been allocated with around $20m US already awarded as a rapid response to the situation, usually through specialist calls or rapidly deployed COVID-specific schemes[1]. The speed at which significant parts of the research community will be asked to change course will likely require new mechanisms to be found to ensure that the right research can be funded as quickly as possible. As the international community transitions from a tactical response to a more strategic footing, it will be important to quickly understand the roles that researchers and organisations within this newly configured research community are playing, both between themselves, as well as in their collaborations with industry.

"The speed at which significant parts of the research community will be asked to change course will likely require new mechanisms to be found to ensure that the right research can be funded as quickly as possible."

Efficiency of work and global access to research outcomes, for the good and protection of all, need to be at the centre of international policy collaborations in this area. This suggests a clear need for coordination of funding and research programmes around COVID. In the wake of initiatives like this, born of necessity, will we see templates for a new level of collaboration and coordination in the research world? One thing is clear – we are just at the beginning of this journey.

At Digital Science, we would argue that *Dimensions* is uniquely positioned to meet the needs not only of researchers who are getting to grips with accelerated changes in how to publish in COVID-related fields, but also for academic institutions who will have to deal with a fundamentally changed research landscape as the world emerges from lockdown, but when international travel is severely limited.

In this new world, we believe that *Dimensions* as a new paradigm for search and analysis is critical for the success of researchers and research institutions. Any discovery and analysis tool needs to be able to:

1. support rapid research communication by being frequently updated;
2. include inputs from research communications that come earlier in the research cycle such as preprints and datasets;
3. help researchers rapidly contextualise research so that, if peer review is unavailable, researchers have the best chance of understanding the provenance of a piece of research;
4. help researchers to identify collaborators who may be able to assist in the translation of a piece of research;
5. place research institutions in a stronger position to justify the value of their research to policy makers;
6. understand the global research landscape in a more holistic manner and with greater ability to manipulate data to gain insights.

The current report is a study in the emergence of COVID research. It is necessarily a high-level overview as there has been a data deluge with which one could spend many years. To understand some of the nuance of the developments that we have seen over the last five months, we have picked just a few stories that we can tell you with the data in *Dimensions*.

[1] see for example, https://mrc.ukri.org/funding/browse/2019-ncov-rapid-response-call/2019-ncov-rapid-response-call/

2 Classifying and Quantifying COVID-19

In the first two weeks of May, the rate of addition of new articles on COVID being indexed into *Dimensions* increased to just under an average of 650 items per day (Figure 1). The majority of these articles will have full text available and consequently are fully indexed and classified. All items will have their metadata enhanced with links into the rest of the *Dimensions* corpus. Authors and their affiliations are mapped to individuals and institutions, as well as links made to references, clinical trials, and patents. This year, *Dimensions* has already recorded over 42,703 publications concerning different aspects of COVID (Figure 2), a volume that surpasses the total yearly output of even the largest research institutions. The speed at which articles are being made available, despite the fact that much of the research is still being published as traditional journal articles, reflects the way in which systems are adapting in the research community to ensure that knowledge about COVID is disseminated as quickly as possible.

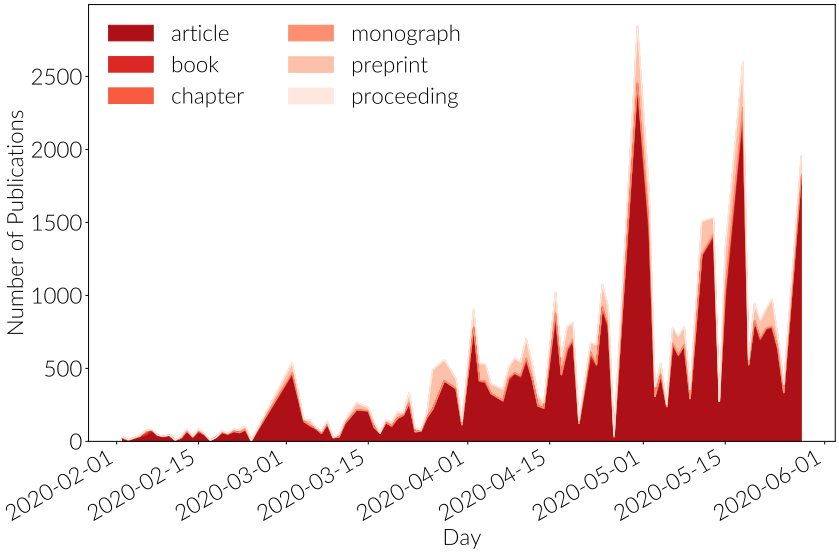

Figure 1: *COVID articles per day based on the search shown in the box below.* (data)

As mentioned in the Introduction, identifying COVID research papers is challenging. The *Dimensions* team has worked with immunologists and virologists to assemble a search string that should be inclusive of COVID articles but which, at the same time, should minimise false positives. Added to this string is the specification of the year being 2020, to filter out higher instances of false positives in prior years. The string looks for the following terms in both the title, abstract, and crucially full text of publications:

```
"2019-nCoV" OR "COVID-19" OR "SARS-CoV-2" OR "HCoV-2019" OR "hcov" OR "NCOVID-19" OR "severe acute respiratory syndrome coronavirus 2" OR "severe acute respiratory syndrome corona virus 2" OR (("coronavirus" OR "corona virus") AND (Wuhan OR China OR novel))
```

Easy access to this search was facilitated through the link:

https://covid-19.dimensions.ai

Results are also made available and updated daily in a Google doc for those who wish to have easier systematic access to data. A fileset containing these these data is also frequently updated at https://doi.org/10.6084/m9.figshare.11961063.v21.

"The *Dimensions* team has worked with immunologists and virologists to assemble a search string that should be inclusive of COVID articles and which should minimise false positives."

3 Publications Trends

3.1 Open Versus Closed, and Fast Versus Sure

"The question of whether the system of scholarly communication is fit for purpose in the context of modern research is again being tested."

The question of whether the system of scholarly communication is fit for purpose in the context of modern research is again being tested. The prodigious rise in COVID-19 research has already caught the attention of many in the scientometric and scholarly communications communities (for example Brainard [2020], Colavizza et al. [2020], Torres-Salinas et al. [2020]) as well as the broader academic community. We are experiencing an understandably rapid emergence of a new research field, which is highlighting social issues in research at large [Viglione, 2020, Minello, 2020] while at the same time, laying bare the tensions that we know to underlie scholarly communications—speed to publish, format of publication, verification of results, and access to those results.

Specifically, Hook and Porter [2020] noted that preprints have rapidly become established as a mainstream research output. Significant work has been carried out to assess the challenges of preprints, specifically around peer review and trust [Chiarelli et al., 2019, Kwon, 2020] as well as potential solutions [Johansson and Saderi, 2020]. Figure 2 shows the speed at which preprints have become a key part of COVID research, starting at relatively low levels in early January and accounting for around one quarter of research output by the beginning of May.

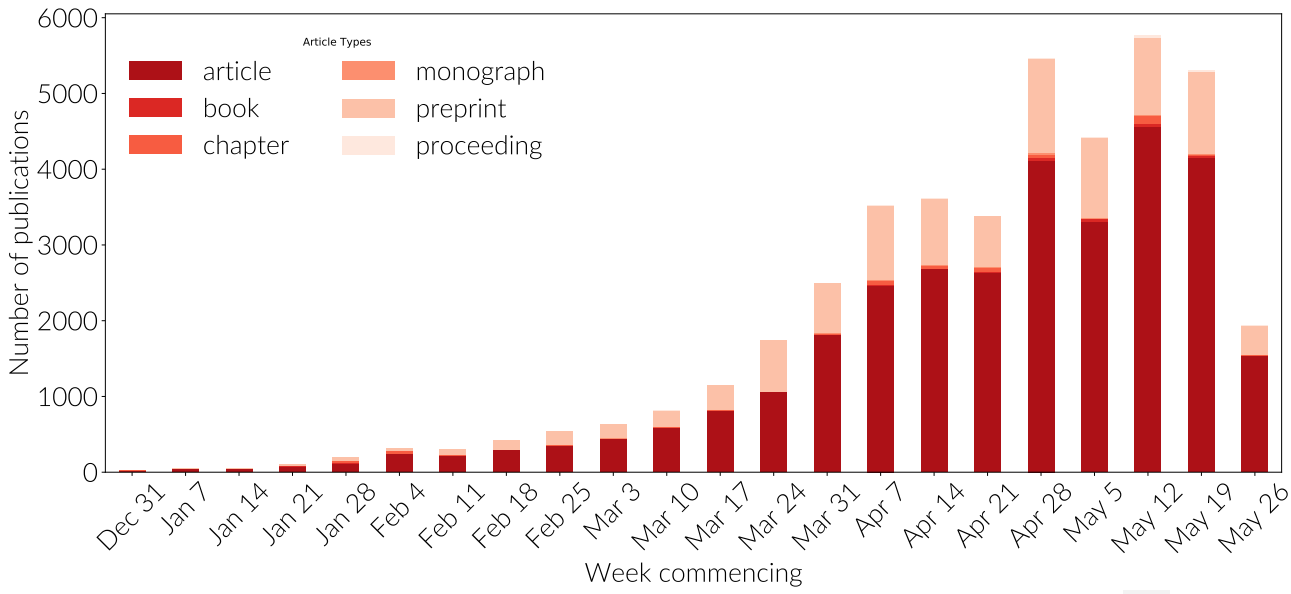

Figure 2: *Research output results from querying with the boxed COVID search definition in Dimensions. Outputs are grouped week by week and are* not *shown cumulatively. Output types as per the legend.* (data)

The first striking feature in Figure 2 is the strong development of preprint publication in a field (outputs in this graph are strongly skewed toward medicine) that has not historically been comfortable with preprint publication. The overriding reason for this emergent profile is likely to be aligned with the need for rapid communication between researchers, although other reasons might include the early activity of epidemiologists, who are more familiar with preprints. The reason that preprint activity has been stemmed as a percentage of overall production is probably due to many publishers increasing the speed of their peer review process [Eisen et al., 2020], while others made COVID publications available Open Access [Carr, 2020a,b].

The second striking feature in Figure 2 is that in April appears to have been a month of plateau, whereas May has seen a resurgence in publication with a double peak. This suggests some kind of compounding behaviour—perhaps a transition of prior preprint publications becoming accepted and published as different waves of behaviour interfere. Recall that this graph does not show *cumulative* research output counts, rather it shows *total* research output counts for each week. This implies that, like the COVID virus itself in many countries today, the peak of publication in the field will soon pass. Hence, we are seeing the initial phase of development and maturation of a whole research field in microcosm, which is fascinating from a research on research perspective, as we are seeing the evolution of a field at many times the normal rate.

Figure 3 draws together data from *Unpaywall* and *Dimensions* to illustrate the proportion of COVID research available through various access modes: closed, hybrid, gold and green.

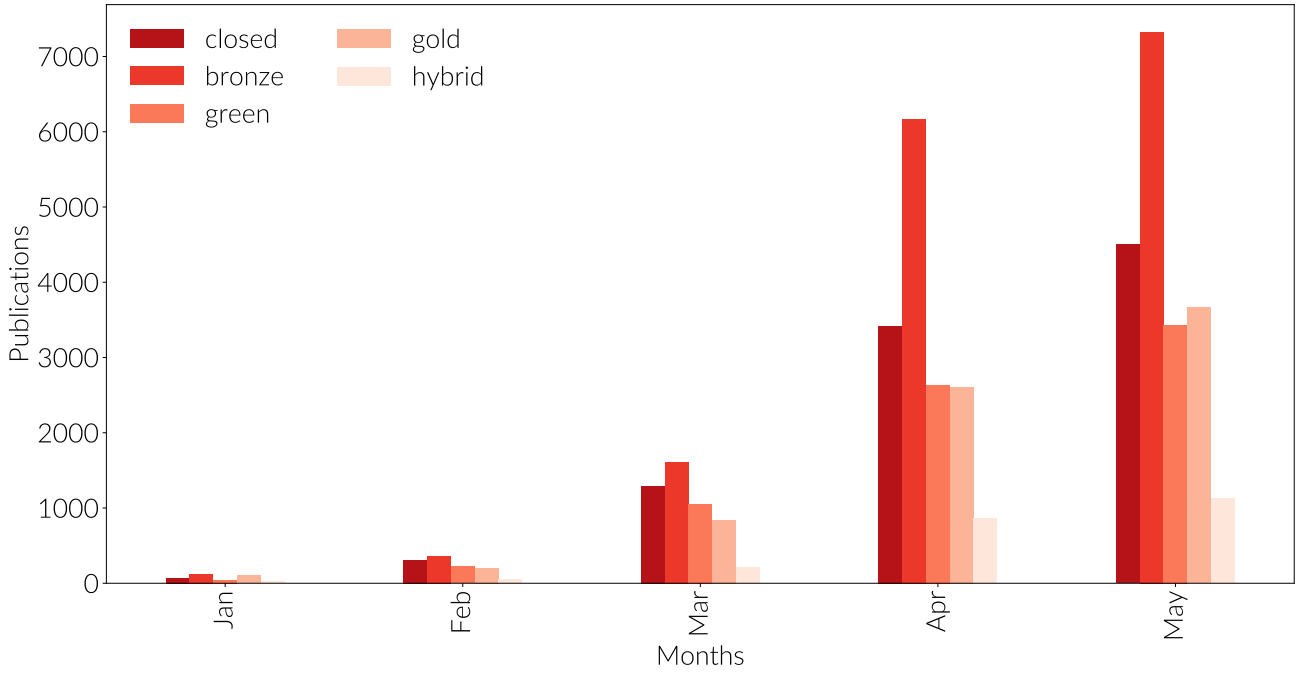

Figure 3: *Journal publication results from querying with the boxed COVID search definition in Dimensions. Open Access classification derived from Unpaywall. Outputs are grouped month by month and are* not *shown cumulatively. Open Access mode as per the legend.* (data)

Developments whereby publishers have made COVID-themed publications freely available to the whole community have resulted in significant growth in Bronze Open Access in COVID over the period in Figure 3. As noted above, this is likely to have diminished the uptake of preprints. Despite the strong growth of Bronze, Gold and Green OA, the continuation of closed access in this critical area is an interesting social artefact, which has attracted comment from academics and funders who track the progress of scholarly communication [Larivière et al., 2020, Kiley, 2020].

3.2 Regional Focal Points

To date, over 8,305 organisations have been involved in supporting COVID research, with over 71,806 individual researchers identified. Figure 6 plots the institutions working on COVID research. The highest intensity of research into COVID-19 began in China and gradually migrated west, mirroring the movement of the virus itself.

In Figure 4 we present the first of two analyses that make use of *Di-*

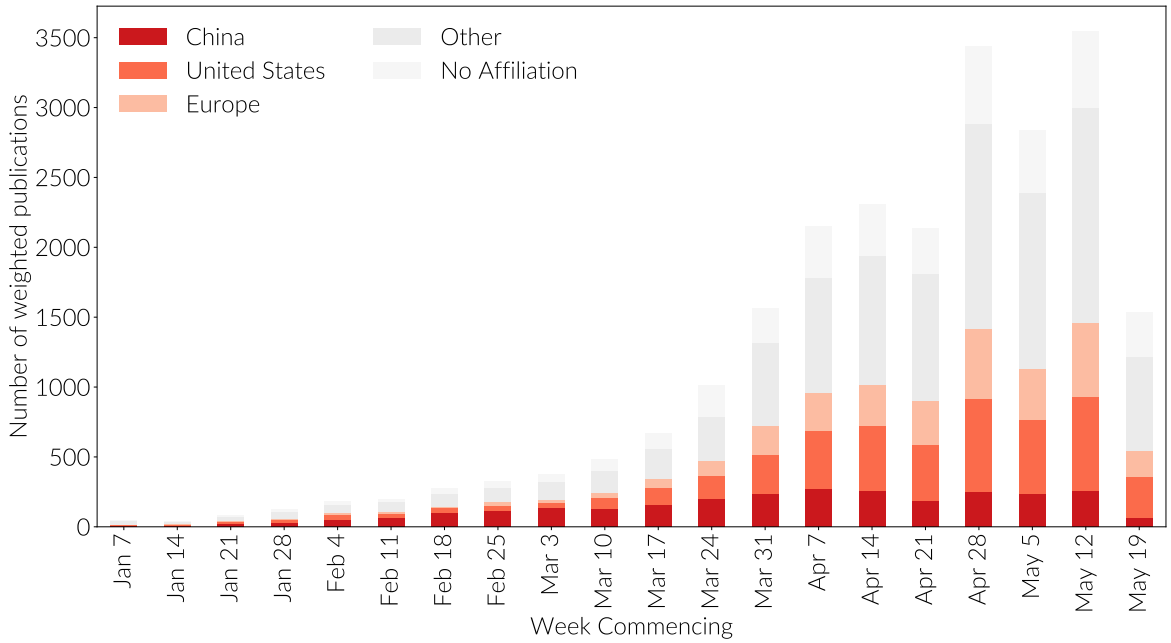

Figure 4: *Weighted publication counts attributed by country in proportion to researcher affiliation. This graph is not cumulative. Papers are binned by the week commencing on the dates given; the final week is incomplete.* (data)

mensions' institution name disambiguation data enhancements via the GRID system (see http://grid.ac for more information). Each publication where the institutions associated with the authors of the paper can be resolved to items in the GRID database is partitioned among the countries in which contributing institutions are situated. A normalisation is applied such that each paper continues to contribute a count of one across all contributing countries. Hence, if a paper is co-authored with two authors associated with institutions in the US and three authors associated with institutions in China, then 3/5 of the paper will be attributed to China and 2/5 of the paper to US. The graph is not cumulative but rather it represents the number of papers appearing in the week commencing at the date marked on the axis. The top 12 producing countries (over the full time period) are listed explicitly, countries outside the top 12 producers in aggregate over the period are agglomerated into 'other', authors (proportions of the paper) associated with institutions that contributed but which are unknown to GRID or which cannot trivially be mapped to GRID are listed as 'No Afiliation'.

From Figure 4 we see, unsurprisingly given the earlier need for a vaccine, that China took a leading position in COVID-19 research. China has then plateaued in COVID-19 research volume as US and European institutions have gradually increased their contributions as COVID-19 arrived on their shores. However, China's first-mover advantage established its publications as foundational to this new field in highly respected journals.

"The highest intensity of research into COVID-19 began in China and gradually migrated west, mirroring the movement of the virus itself."

Table 1 lists journals ordered by the number of COVID-related citations they have received. A COVID-related citation is defined to be a citation to an article that is returned from *Dimensions* in response to the boxed query. The 'No. of Pubs' column lists the number of COVID research outputs published by the venue until 24th May 2020 - note the high volumes for the preprint sites medRxiv, bioRxiv, and SSRN. The paper totals in the table are not rounded fractional counts but whole papers that involve either a US-based, China-based or EU-based author respectively–hence, there will be double counting between the US, CN and EU columns in the case of collaborative research. Our own analysis (below) shows significant collaboration within established international networks, albeit at

a low rate relative to 'normal running'. This analysis is supported by the results of Fry et al. [2020]. The EU is defined to include the EU-27 countries, the UK, Norway and Switzerland.

Journal	No. of Pubs	Total Cites	No. of Pubs			Citations		
			US	CN	EU	US	CN	EU
The Lancet	188	11643	64	41	115	1232	9614	2410
New England Journal of Medicine	181	10599	114	20	35	3267	4496	1101
JAMA	136	6781	108	13	10	1618	4305	588
medRxiv	2867	4431	994	765	1010	1725	2423	1560
Journal of Medical Virology	271	2983	50	148	51	460	2543	334
bioRxiv	880	2455	391	189	291	802	1397	616
Radiology	52	2370	18	20	12	463	1897	52
Nature	22	2247	9	13	7	119	1957	212
The Lancet Infectious Diseases	114	2161	32	34	53	524	1139	828
The Lancet Respiratory Medicine	58	1971	21	13	34	270	1479	431
Clinical Infectious Diseases	136	1661	51	59	31	297	1359	200
Science	76	1536	43	24	25	1072	890	671
International Journal of Infectious Diseases	128	1374	27	68	34	635	1093	433
Eurosurveillance	64	1328	4	9	55	177	495	1018
The BMJ	399	1279	38	12	339	74	383	775
International Journal of Antimicrobial Agents	40	1041	6	11	14	0	110	667
Cell	18	1005	8	5	9	276	70	929
Emerging Microbes & Infections	43	846	9	35	3	91	805	8
Journal of Infection	146	840	8	103	39	25	788	116
SSRN Electronic Journal	1655	705	576	436	520	316	354	142

Table 1: *Regional representation of COVID-19 research by publication venue. Publication venues include journals and preprint servers and are selected (and ordered) by number of citations to COVID-19 articles (Total Cites column). COVID-19 research is defined relative to the boxed query in this report. All numbers are derived from Dimensions on 24th May 2020. Note that arXiv.org contains 1013 publications related to COVID, however, the quality of address metadata and citation details of these papers in Dimensions does not currently allow it to be included in this analysis.* (data)

While the US and EU have both now published more than China in journals such as The Lancet, New England Journal of Medicine and JAMA, China continues to enjoy the lion's share of the citations, as is clear from Figure 5. China is the early dominant publisher in COVID-19, as seen in Figure 4, many of which were in journals such as The Lancet. Both Chinese-affiliated authors and the journals in which they published their early results saw significant and sustained citation activity. As COVID established as a field in late January, the key papers that founded the field started to appear and these papers were heavily populated by Chinese authors. Work written by Chinese authors from the week commencing 30th January 2020 has already received around 5000 citations, and similarly in the following week. Note that attention to US and European liter-

ature is at a significantly lower level throughout the same period. While research in the field is clearly moving quickly, it currently remains anchored to China's early publications.

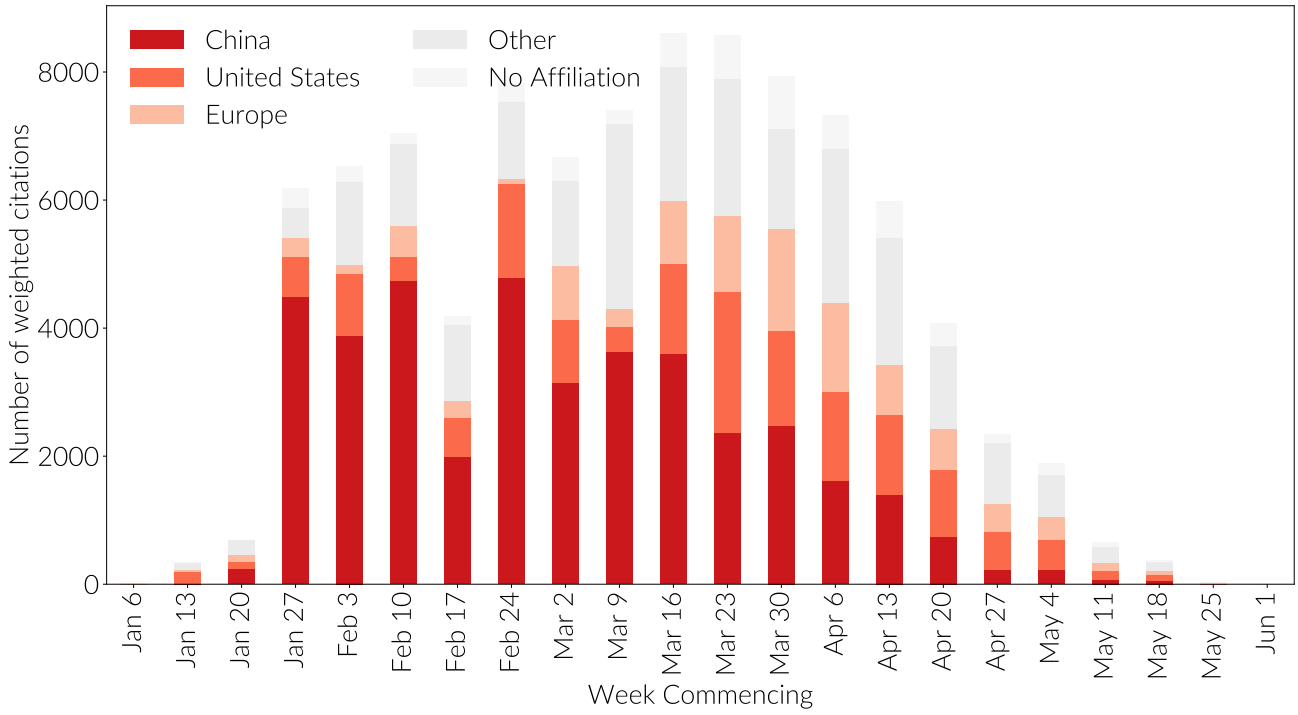

Figure 5: *Fractional citations to all COVID-19 publications by receiving country determined by researcher affiliation. Totals by week in which citations were made. COVID-19 research is defined relative to the boxed query in this report. Only citations from other COVID-19 papers have been considered. All numbers are derived from Dimensions on 24th May 2020.* (data)

It is clear from Figure 6, which shows a density map of global COVID-19 paper production, that there are three to four major centres of research: an extended area in China composed of several cities—Wuhan, where the virus is alleged to have started, Beijing and Shanghai; Europe, specifically Italy and the UK, two of the harder hit countries; the US's East Coast research corridor including Boston and New York; and finally, a lighter focus from the Californian institutions on the West Coast.

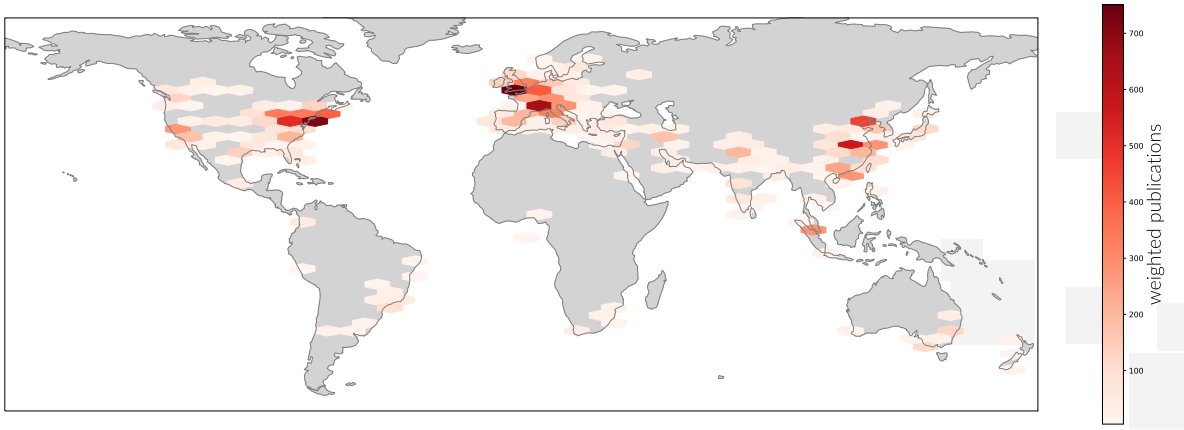

Figure 6: *Centres of COVID-19-focused research by publication production. COVID-19 research is defined relative to the boxed query in this report. All numbers are derived from Dimensions on 24th May 2020.* (data)

Tables 2 and 3 list the top COVID-publication-producing institutions in the world. Table 2 lists research institutions and universities, whereas

Table 3 lists research hospitals. At the time of writing, the top producing institution is China's Huazhong University of Science and Technology, with University of Hong Kong and Zhejiang University also contributing significantly to Greater China's production rate. Three of the top producing hospitals in Table 3 are also Chinese. These tables looked significantly different in April when the US and Europe were still at an earlier stage in their research response to COVID.

Institution	Publications
Harvard University	442
Huazhong University of Science and Technology	404
University of Oxford	359
Johns Hopkins University	330
University of Toronto	329
University College London	290
University of Milan	288
Stanford University	267
University of Hong Kong	259
University of Washington	254

Table 2: *Top institutional producers of research on COVID-19 since the beginning of 2020.* (data)

Institution	Publications
Massachusetts General Hospital	197
Zhongnan Hospital of Wuhan University	180
Renmin Hospital of Wuhan University	173
Mayo Clinic	151
Brigham and Women's Hospital	114
Cleveland Clinic	90
The University of Texas MD Anderson Cancer Center	90
San Raffaele Hospital	86
Erasmus University Medical Center	85
Vanderbilt University Medical Center	82

Table 3: *Top healthcare producers of research on COVID-19 since the beginning of 2020.* (data)

3.3 Collaboration and Classification

A lot of the diagrams and tables in the prior sections suggest that COVID research has been quite localised to specific countries. This is indeed far more the case than we might generally expect. Figure 7 gives a high-level insight into the nature of the research relationships.

Nature asserted that politicians can learn from researchers' collabora-

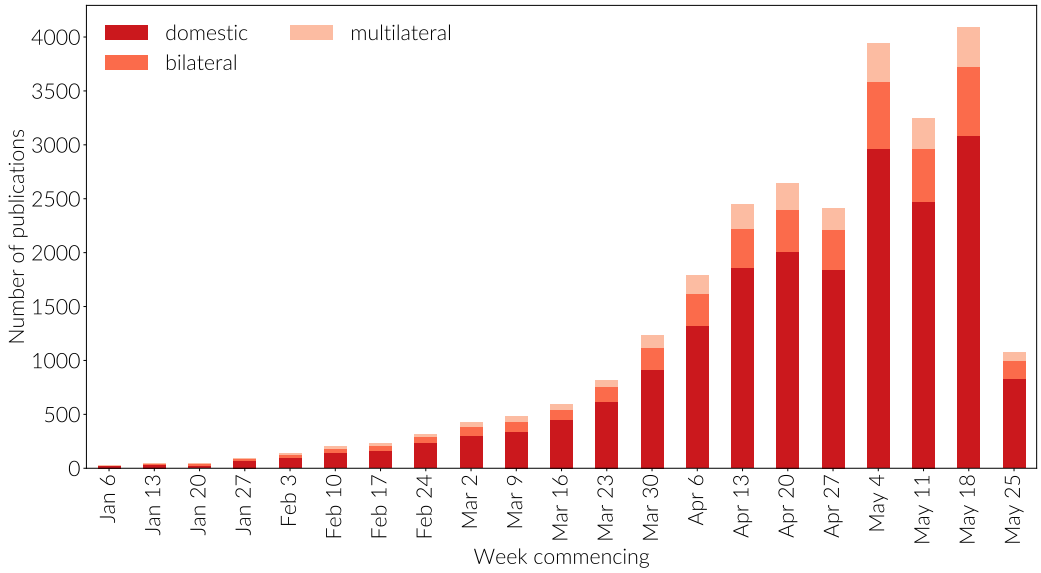

Figure 7: *Count of domestic, bilateral, and multilateral country collaborations. This graph is not cumulative. Papers are grouped by the week commencing on the dates given; the final week is incomplete.* (data)

tion habits [Skipper, 2020], but while we see strong collaborations on the scaffolding of established academic networks [Fry et al., 2020], it is clear from our analysis that the overall proportion of bilateral (specifically two countries) and multilateral (more than two countries) research collaborations is still embryonic. Indeed, Figure 7 shows that while the proportion of internationally co-authored work is steady, the vast majority of research on COVID to date has been authored within countries. It is well established that international collaboration is rising across subjects [Adams, 2013] so we interpret this graph to show the early stage of the field.

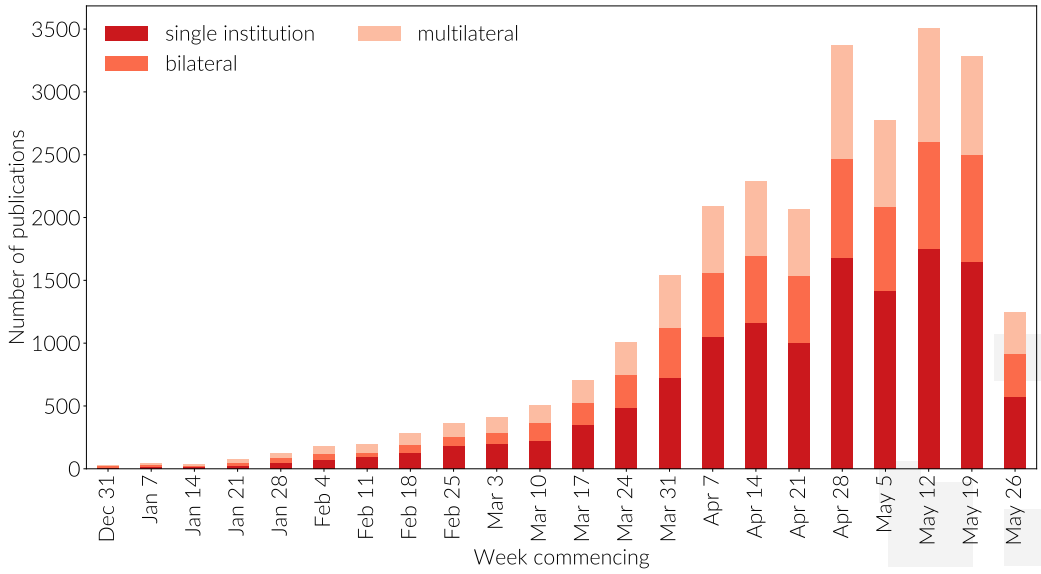

Figure 8: *Institutional collaboration modes for COVID-19 research. This graph is not cumulative. Papers are grouped by the week commencing on the dates given; the final week is incomplete. Publications counting toward 'single institution' have only a single institutional affiliation, bilateral publications are affiliated with two institutions, and multilateral publications are those that are affiliated with more than two institutions. There is no sensitivity in this plot to the country in which institutions are situated.* (data)

There are several factors beyond the nascent stage of COVID-19 research that may have contributed to early trends in international collaboration. Firstly, China is a strong contributor to the data in the early

months of Figure 7. China's research capacity has been growing so rapidly that the rest of the world lacks the capacity to keep up with China's expanding research base and hence, despite becoming the favoured collaboration partner with a growing number of countries around the world, the international footprint–the ratio of domestic to international papers in China–is currently against the world trend. The international picture is mirrored at institutional level as can be observed in Figure 8. A remarkable feature of both of these graphs is the stability of the proportion of the different partitions: single-institution to bilateral to multilateral. While one might expect these proportions to develop toward a more collaborative balance with time this is not what can be observed in these plots. Instead a static proportionality seems to have emerged, which is unchanged by an increasing number of countries (including the most well-developed research economies) joining the COVID-19 effort.

"China's research capacity has been growing so rapidly that the rest of the world lacks the capacity to keep up with China's expanding research base."

A large proportion of the research in Figure 7 is medical. Table 4 shows a breakdown of researchers who have contributed to COVID-19 research by principle field of research. Hence, we may speculate that a further potential effect at play in Figure 7 is that many researchers may feel pressure to make headway with a vaccine. As a result they are, in the early period of their research, focusing on developing their understanding of COVID-19 rather than developing international collaborations. This tendency may be compounded by the nature of funding that is emerging in many countries, which is small scale, and targeted at small groups or individuals. This may make sense since the complexity of developing a COVID-19 vaccine was, in the early period of the research, not well understood. It appears simply to take time to establish relationships on a new research topic, even when connections are already in existence.

Field of Research	Researchers
11 Medical and Health Sciences	13591
06 Biological Sciences	1283
03 Chemical Sciences	257
09 Engineering	186
08 Information and Computing Sciences	177
01 Mathematical Sciences	128
07 Agricultural and Veterinary Sciences	126
17 Psychology and Cognitive Sciences	122
14 Economics	98
16 Studies in Human Society	56
02 Physical Sciences	54
15 Commerce, Management, Tourism and Services	48
04 Earth Sciences	47
05 Environmental Sciences	22
13 Education	17
18 Law and Legal Studies	17
10 Technology	8
22 Philosophy and Religious Studies	8
20 Language, Communication and Culture	5
12 Built Environment and Design	2
21 History and Archaeology	2

Table 4: *Established researchers by (ANZSRC) 2-Digital level Field of Research. A researcher is 'established' for the purposes of this table by having a publication history of more than 15 years.* (data)

Emergent fields are challenging to explore. It is something of a holy grail in research policy and analytics to be able to not only identify emergent fields of research, but also to understand which researchers are key and where the critical clusters and collaborations lie. To explore this land-

scape we engage in a kind of 'tomography' of emergent fields by presenting Figures 9 and 10.

Each of the two figures has the same basic structure, but different colouring has been applied to emphasise different aspects. While Table 4 imposes a 15 year filter to classify 12,816 researchers into high-level categories, the two figures here impose no such restriction and hence show a much broader collaborative map. In these figures there are 50,979 researchers, each of whom has published a COVID-19 paper. These researchers are derived from the *Dimensions* person graph and hence are not dependent on address information from COVID-19 papers to derive these visualisations. The 488,188 researcher-researcher links represented in the diagram are not identical (i.e. links between co-authors are not duplicated with multiple co-authored papers), and relate to any relationship that has been established through the whole research career of the researchers involved, not only the COVID-19 period of research. Thus, these figures show the full 'COVID-activated' network of researchers.

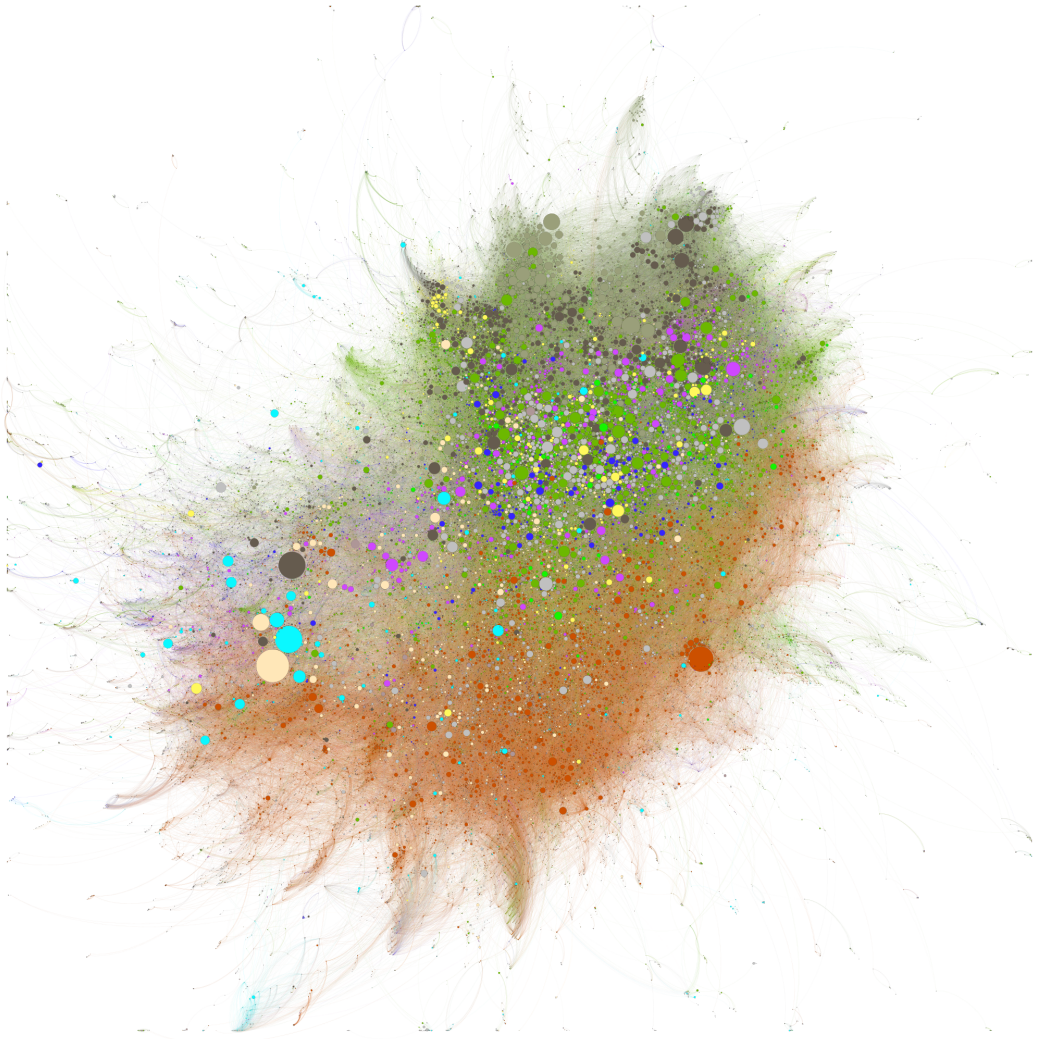

Figure 9: *Research Collaboration amongst COVID-19 Researchers. Researchers coloured by primary RCRC category. Clinical Research (green), Infectious Diseases (orange), Cancer (dark brown), Genetics (light brown), Cardiovascular (olive), Lung (dark blue), Digestive Diseases (purple), Neurosciences (yellow), and Bioengineering (light blue). Clustering is based on proximity of co-authorship. Node size is determined by number of publications in whole research career.*

In Figure 9 the confused distribution of colours makes it clear that COVID-

19 is already highly interdisciplinary with respect to the NIH's RCDC categorisation scheme, which classifies different disease areas. Broadly, three areas emerge: first, the area characterised by the mix of cardiovascular (olive), clinical (green), lung (dark blue), neurosciences (yellow) and digestive diseases (purple); second, an area to the south of this highly mixed patch that is dominated by infectious diseases (orange); lastly, the peripheral group on left of the figure with a prevalence of light clustering of bioengineering (light blue) and genetics (light brown). This complex landscape indicates how multifaceted this research area has already become. Under this categorisation, neither preventive medicine nor epidemiology/public health, both mainstays of the overall body of research in this area, emerge as coherent collaborative blocks.

Figure 10: *As Figure 9 but with researchers coloured by country of current affiliated institution. China (light blue), US (green), UK (orange), Germany (dark blue), France (pink), and Italy (yellow).*

Figure 10 shows the same background as Figure 9 but is coloured by the current country of the institutional affiliation of each researcher. It is clear from this version of the graph that the clustering, and hence the overall structure of the network, is much more influenced by geographic collaborations than by subject collaborations. This is entirely in line with

our findings from Figure 7, where we saw a high-percentage of domestic collaboration and Figure 8 where we even saw that institution-specific localisation was still significant at this time. We see distinct 'banded' collaborative structures for each of the main COVID-researching countries: China (light blue) on the left, collaborating most strongly with the US (green), which is highly integrated with the UK (orange) and Germany (dark blue), which are, in turn, integrated with France (pink) and Italy (yellow). The European countries show a high degree of integration, with the UK being highly collaborative and hence more diffuse in the picture.

Both Figure 9 and Figure 10 are subtle to interpret. However, one way to think of this network is as follows. All the researchers represented in the plot have published a COVID-19 paper. Since we have clustered them based on their prior collaboration history as well as the COVID-19 collaborations, we can think of each link as having a particular state of colour: If a collaboration between two researchers does not contain a co-authored COVID-19 publication then we could colour the link grey, and if it does contain a COVID-19 publication then we could colour the link red. To assess how much of the collaboration graph has been accessed/created as a result of COVID-19 we can look at the proportion of the graph with grey links versus red links. In this case, we would find that 57% of the connections are COVID-19 related (which would drop to 45% if we considered only established researchers). Hence, COVID-19 has lead to significant new collaborations, while at the same time accessing a large proportion of the existing collaboration network.

Ironically, this is precisely the type of thinking that disease modellers and epidemiologists would use in agent-based models to study the spread of a disease. In this case, the disease would be 'doing research into COVID-19', exposure would start with reading something in the media or in the research literature, infection would be starting research, and recovery would be publishing a paper. Indeed, understanding the sociology of research that is emerging from the COVID-19 microcosm might well benefit from disease modelling techniques.

To complete this section, we examine the subject interactions that the COVID-research environment has generated. When looking into a new field, researchers may need to acquire new skills, and one way to do that is to collaborate. Collaborations between different subject areas can be particularly interesting to understand. Figure 11 shows the 'disciplinary intersection' of new collaborations between researchers that have resulted in papers published on COVID-19. The colour of each pixel or intersection in the diagram is determined by the number of researchers who have not previously collaborated on a paper and their principal research interest. Hence, if two researchers have not previously co-authored and one is a psychologist (17) and the other a medic (11) then this would contribute to the 17/11 intersection pixel (also the 11/17 pixel). The proportion of these new collaborations to existing collaborations in each pixel determines the strength of the colour. Note that this means that each pixel effectively has its own normalisation - the number of papers in some cases may be very small but a cut-off of 10 researchers has been put in place to remove low level activity. Note that pixels do not completely mirror the same data in the sense that the normalisation of the volume of papers in one field is not the same as the normalisation in the other direction. Hence, in some cases the cutoff will cause a pixel to be greyed in one combination when it is more relevant in the opposite pairing, and this effect can affect colour intensity as well.

The plot has three distinctive features: firstly, that there is a background of same-subject new collaborations that show up (these are the pink pixels on the diagonal running top left to bottom right); secondly, both

medicine and biological sciences have seen increased new collaborations across a broad spectrum of different research fields; finally, there are no significant new research relationship pairings in relevant volumes outside medicine/biological science and in-field connections.

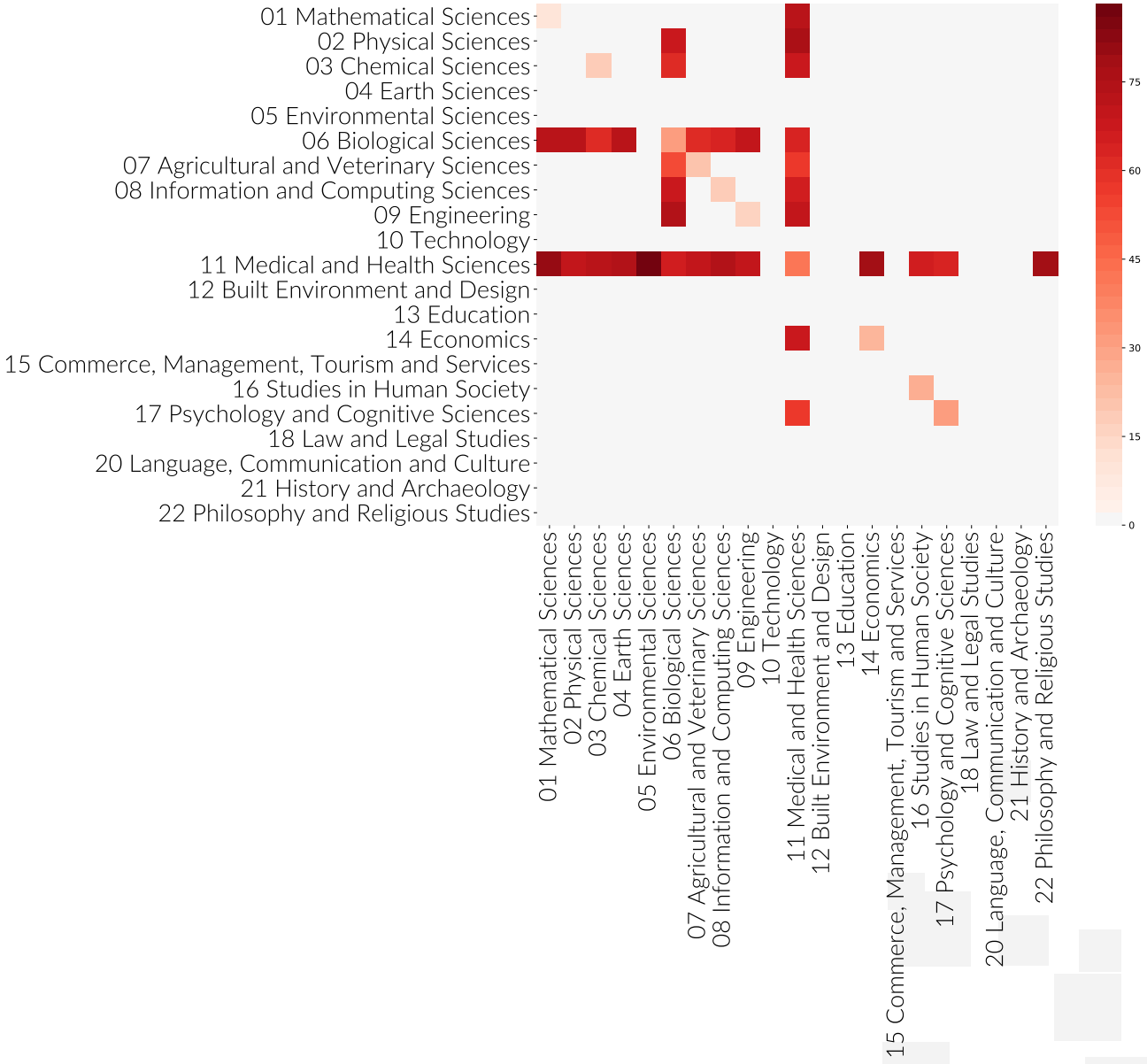

Figure 11: *Percentage New Research Collaborations by Disciplinary Intersection. The colour of each pixel represents the level of new researcher-researcher co-authorship pairings seen on COVID-19 papers compared with pre-COVID. Each researcher in the pairing has a principal research categorisation and the combination of these two determines the relevant pixel. The intensity of the colour in the pixel corresponds to the proportion of new collaborations to existing collaborations in the relevant subject pairing. There is a 10 researcher cut-off for each pixel to prevent flagging low volume collaboration signals from clouding the picture.* (data)

4 The Landscape of Support for COVID Research

We have spent the majority of this report so far understanding the publication and citation landscape as this is, for obvious reasons, the fastest moving part of the scholarly communications infrastructure. However, in the last five months funding agencies have quickly grasped the nature of the situation and moved to allocate funding. In most countries this has taken the form of the establishment of special funding programmes that have tended to be nationally focused. At an international level, we are also now seeing the development of frameworks and agreements to commit to levels of sustained funding for COVID research [Wintour, 2020].

A significant amount of research to find a COVID vaccine will take place in industry and hence cannot easily be quantified. However, in *Dimensions* at the time of writing 156 grants totalling at least 20.8m USD have been awarded to COVID-themed researchers in public institutions. This is not a large amount yet from which to see any specific trend, but we can examine historical grant funding data to gain a nuanced understanding of funding to this field.

"In *Dimensions* at the time of writing 156 grants totalling at least 20.8m USD have been awarded to COVID-themed researchers in public institutions."

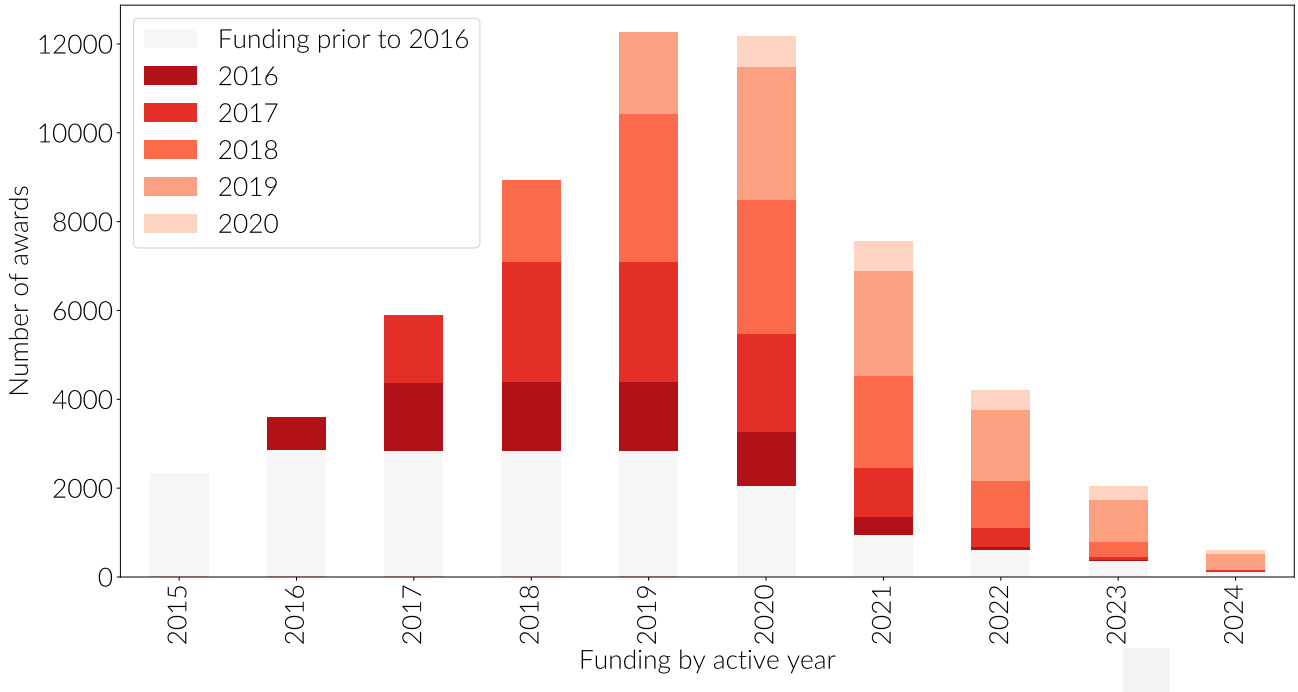

Figure 12: *Funding pipeline for COVID-19 authors. Funding coloured by the year of award.* (data)

Figure 12 takes the researchers identified in the previous section by their publications and examines the number of active research grants that they have available to them. Each researcher in the 'COVID active' set identified previously will, if they have been associated with one or more grants, have a grant footprint in *Dimensions*. We can then look at their currently active grants and look at date of award and date of expiration to aggregate a funding landscape plot. This is the plot shown in Figure 12. From this we can determine that in 2020, this group of researchers holds around 11,000 active grants, of which around 1,800 were awarded in 2015, around 1,000 were awarded in 2016, and so on. Note that in most years there will be some funding that will be awarded to start in the next year, hence there will be a step in the size of each year colour following the year of award. As we go into the future, grants will finish and so the

colour associated with each year will decrease in size with time.

From this graph we can see that there are many active grants supporting these researchers and hence there is no dependence on a small number of grants. This funding pipeline is also useful for understanding where capacity for undertaking COVID-19 research will come from. In 2021, we can see that just over 2/5 of the currently active projects in 2020 will have completed, freeing up attention to focus on COVID-19 research almost immediately. A further 1/5 of projects funded in 2019 and 2020 may be sufficiently young to be refocused towards COVID-19 research questions, with a remaining 2/5 of current projects less able to be freed up for COVID-19 research until 2022.

5 Translating COVID Research

Given the locus of current attention around finding a vaccine, one important stage in the translation in COVID-19 research toward production has been clinical trials. *Dimensions*' aggregation of clinical trials into the core dataset gives easy access for an analysis.

Figure 13 shows how quickly China responded to the epidemic, already introducing the first clinical trials in January. The graph shows new trials per month and weights that number based on the countries collaborating in the study. Much of the clinical trial initiation activity in January and February is sponsored by China. This then begins to fall off in March, April and May. We see a similar wave for Europe and the US, but shifted back by two months, beginning in March.

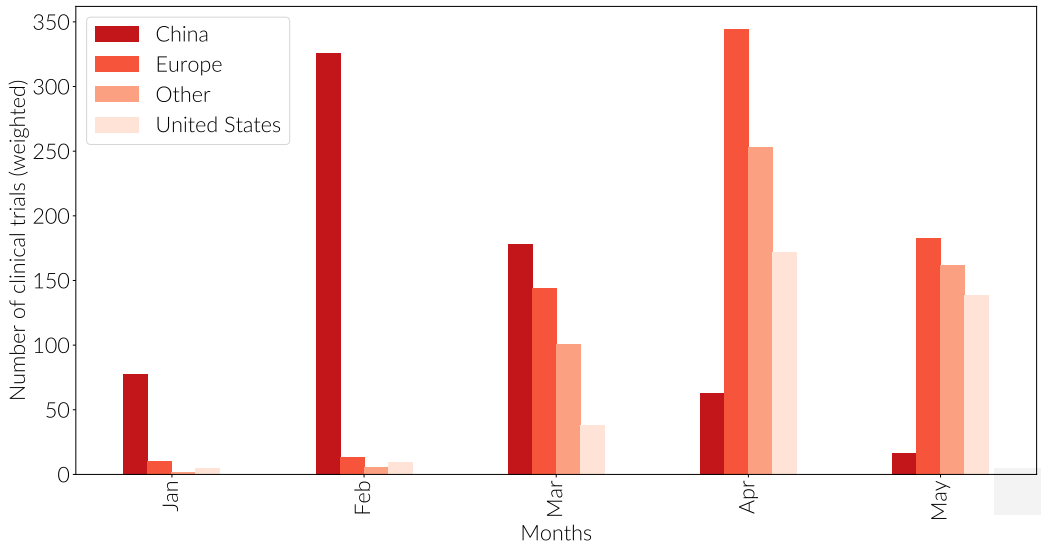

Figure 13: *New clinical trials by country of sponsor collaborators. Each trial is apportioned and credited to the country of each sponsor (this weighting is referred to in the axis label). Europe is defined to include the EU-27 countries, Norway, Switzerland and the UK.* (data)

Beyond these clinical trials profiles, we wish to identify researchers who may be well positioned to understand the vaccine dynamics of COVID-19. With such a large influx of papers published on COVID-19 in such a short space of time, it is quickly becoming difficult to keep track of the field. In time, those who are most active, publishing work in high-impact destinations, and publishing work that attracts academic or media interest, or simply those who have a sustained, long-term track record will emerge. In the short term we need to turn to different proxy measures to identify researchers with specific profiles. If we wished to identify, for

example, research that might be working on molecules or approaches that might be aligned with drug discovery and that might be applied to COVID-19, then we must look into historical data to find likely signals.

We might assume that the majority of leading researchers in academia will emerge from well-funded institutions with a history of research in related fields. In the previous section, we can use the analysis that we showed in aggregate to identify those who have a solid funding history. This can be used as a tool with which to narrow our search criteria substantially, however a different approach is to look at patent data. It is also important to note that while the clinical trial data leads to some interesting trend information, we may wish to cast our net wider and to find researchers who are active in a broader range of topics. For example, artificial intelligence research has been applied to finding vaccines for COVID-19 [Trafton et al., 2020] from which the most important outcomes may not be the immediate target, but rather longer term goals such as downstream AIs that have a better understanding of vaccine creation in general. AI researchers with an interest in medical problems may be valuable collaborators in a post-COVID world.

"AI researchers may be valuable collaborators in a post-COVID world."

To demonstrate our approach, we are narrowing our field of inquiry to vaccine research, and looking for researchers who have published multiple COVID-19 papers, and whose publications have been cited in vaccine related patents. Using the UK Clinical Research Collaboration (UKCRC)

Researcher	Current Institutuion	#1	#2
Yoshihiro Kawaoka	University of Tokyo	25	7
Barney S. Graham	National Institute of Allergy and Infectious D...	17	6
Alessandro Sette	University of California, San Diego	14	6
Ralph S. Baric	University of North Carolina at Chapel Hill	9	12
Michael S. Diamond	Washington University in St. Louis	8	6
Edward C. Holmes	University of Sydney	7	11
Takaji Wakita	National Institute of Infectious Diseases	6	5
Slobodan Paessler	The University of Texas Medical Branch at Galv...	4	9
Nicola Decaro	University of Bari Aldo Moro	4	5
Azaibi Tamin	Centers for Disease Control and Prevention	3	8
Li Feng	Harbin Veterinary Research Institute	3	8

Table 5: *Researchers cited by vaccine patents and having COVID-19 publications. Column #1: Number of publications cited by vaccine patents; Column #2: Number of COVID-19 publications.* (data)

Health Research Classification System that is available as one of the many research classification systems within *Dimensions*, 5,900 patents were identified as being related to vaccine research. These patents in turn cited 8,236 unique publications. The authors of these papers were intersected with the authors of COVID-19 research. Table 5 lists the top ten researchers identified to have published more than four COVID-19 papers, sorted in order of the number of their publications that they have had cited in vaccine patents.

Researcher	Institution	#1	#2
Alessandro D Sette	University of California, San Diego	6	57
Vladimir N Uversky	University of South Florida	6	12
Rolf Hilgenfeld	University of Lübeck	6	11
Kenji Hashimoto	Center for Forensic Mental Health, Chiba Unive...	6	9
Claudio Ronco	Ospedale San Bortolo	9	8
Giuseppe Curigliano	University of Milan	7	5
Emmie De Wit	National Institute of Allergy and Infectious D...	10	3
Nanshan S Zhong	First Affiliated Hospital of Guangzhou Medical...	8	3
Oliver George Pybus	University of Oxford	6	3
Philippe Colson	Méditerranée Infection Foundation	16	2
Ludger Klimek	Zentrum für Rhinologie und Allergologie	10	2

Table 6: *COVID-19 Researchers with Industry Collaborations. Column #1 is number of papers written on COVID-19; Column #2 is overall number of papers written with industry collaborators.* (data)

In a second deeper sweep, we look at the entire publishing history of each COVID-19 researcher, and look for direct evidence of collaboration with industry partners. Table 6 identifies the top researchers with greater than five COVID-19 publications, ordered by the greatest number of publications with industry collaborators.

6 Discussion

We live in interesting times. The speed at which COVID-19 has spread, together with its severity in certain portions of the population, have led not only to large scale public health and policy responses but, as we have described above, an unprecedented research response over just a few recent months. The clear objective of COVID-19 research has been the development of a vaccine. To date, this alone has been a complex undertaking activating research capacity from virologists to immunologists, geneticists, and lung and cardiology specialists. Epidemiologists and their models have not only reasserted their relevance in policy circles, but they have entered the public consciousness in a way that scientists have not seen for several decades. Mental health experts and economists have both seen elevated engagement as the fallout of public health measures has led to wide-ranging impacts. At the same time, we have seen the rise of AI as a tool to support the efforts of all these (and other) specialisms.

"The changes that have been going on in scholarly communication are being accelerated in areas around COVID-19 research. Open Access models, rapid peer review, preprints and next generation search technologies are all playing a role in accentuated ways as a part of this extreme situation."

While researchers grapple with the thorny problems of vaccines, public health, mental health, economies and many other relevant issues, policymakers are beginning to perceive some of the biggest challenges of an era. Many of the battles to come will be ideological, dealing with basic rights: the freedom not to be anonymous, freedom of movement, the right to work, and the right to information.

Before COVID-19, we were already entering a period of immense and

extended technological, social and economic change resulting from the AI industrial revolution. The collision of COVID-19 with the beginning of the revolution will doubtless accelerate certain aspects of the AI revolution: Where people cannot work, they may be safely replaced by robots; the replacement of call centres by AI; the recent rise in popularity of online video conferencing; the new pervasiveness of food delivery services; the delivery of university lectures online. Our social fabric is changing, and what would once have taken years to change, we are seeing change in a matter of months as a matter of necessity.

While times may be interesting, they are also uncertain. The new status quo of social distancing, video conferencing and working from home is likely to alter the foundations of the university and research sectors. Will research continue to be internationally collaborative? If airline tickets move out of the price range of the academic sector, at least in the short term, is the technology infrastructure good enough to allow researchers to collaborate effectively at a distance? Will research funding intensify to address key problems that need to be fixed, or will it be sacrificed on the alter of austerity? Will universities be able to continue to rely on international students, or will they seize the opportunities of continuous education that will be needed in the age of AI? Will the economy move toward a 'green reboot' and research focus be drawn in sync with these policies toward sustainable development goal-oriented topics? Will corporates see the opportunity to invest further in research but, as part of their new stakeholder-driven responsibilities, make their research more openly available in a reversal of Mazzucato's Entrepreneurial State [Mazzucato, 2013]?

"COVID-19 is, in some sense, a natural experiment: A microcosm that allows us to see the future of scholarly communication."

As a closing thought, the research presented here suggests that the changes that have been going on in scholarly communication are being accelerated in areas around COVID-19 research. Open Access models, rapid peer review, preprints and next generation search technologies are all playing a role in accentuated ways as a part of this extreme situation. COVID-19 is, in some sense, a natural experiment: A microcosm that allows us to see the future of scholarly communication. This isn't intended as a cynical or opportunistic comment, but rather as an observation that the results of COVID research may be outcomes that can benefit the whole of research in years to come. There may be approaches taken to scholarly communication that are tried in the COVID-research world that allow us to side-step errors that could be highly damaging, were they to be adopted more widely or introduced slowly and in a way that might be difficult to reverse later.

Reproducibility

Data [Porter and Hook, 2020] and code [Porter, 2020] are available for this publication. All analysis for this report was carried out using the Dimensions Analytics API https://www.dimensions.ai/dimensions-apis/

References

Jonathan Adams. The fourth age of research. *Nature*, 497(7451):557–560, May 2013. URL https://doi.org/10.1038/497557a.

Jeffrey Brainard. Scientists are drowning in COVID-19 papers. Can new tools keep them afloat? *Science*, May 2020. URL https://doi.org/10.1126/science.abc7839.

David Carr. Coronavirus (COVID-19): sharing research data, January 2020a. URL https://wellcome.ac.uk/coronavirus-covid-19/open-data.

David Carr. Publishers make coronavirus (COVID-19) content freely available and reusable, March 2020b. URL https://wellcome.ac.uk/press-release/publishers-make-coronavirus-covid-19-content-freely-available-and-reusable.

Andrea Chiarelli, Rob Johnson, Stephen Pinfield, and Emma Richens. Preprints and Scholarly Communication: An Exploratory Qualitative Study of Adoption, Practices, Drivers and Barriers. *F1000Research*, 8:971, November 2019. URL https://doi.org/10.12688/f1000research.19619.2.

Giovanni Colavizza, Rodrigo Costas, Vincent A. Traag, Nees Jan van Eck, Thed van Leeuwen, and Ludo Waltman. A scientometric overview of CORD-19. Technical report, Scientific Communication and Education, April 2020. URL https://doi.org/10.1101/2020.04.20.046144.

Gavan Conlon. Impact of the Covid-19 Pandemic on University Finances. Technical report, London Economics, May 2020.

Nick Davis. *Future Ready: A Changemaker's Guide to the Exponential Revolution*. Reaching the Future Faster, LLC, March 2020. ISBN 978-1-5445-0758-3.

Gemma Derrick. How COVID-19 lockdowns could lead to a kinder research culture. *Nature*, 581(7806):107–108, May 2020. URL https://doi.org/10.1038/d41586-020-01144-8.

Michael B Eisen, Anna Akhmanova, Timothy E Behrens, and Detlef Weigel. Publishing in the time of COVID-19. *eLife*, 9:e57162, March 2020. URL https://doi.org/10.7554/eLife.57162.

Caroline Flammer, Bryan Hong, and Dylan Minor. Corporate Governance and the Rise of Integrating CSR Criteria in Executive Compensation. *Academy of Management Proceedings*, 2017(1):11206, August 2017. URL https://doi.org/10.5465/AMBPP.2017.136.

Carl Benedikt Frey. *The Technology Trap*. Princeton University Press, Princeton, New Jersey, June 2019. ISBN 978-0-691-17279-8.

Caroline V. Fry, Xiaojing Cai, Yi Zhang, and Caroline Wagner. Consolidation in a Crisis: Patterns of International Collaboration in COVID-19 Research. *SSRN Electronic Journal*, 2020. URL https://doi.org/10.2139/ssrn.3595455.

Daniel Hook and Simon Porter. How Covid-19 is changing research culture, May 2020. URL https://www.researchprofessionalnews.com/rr-news-uk-views-of-the-uk-2020-5-how-covid-19-is-changing-

research-culture/.

Michael A. Johansson and Daniela Saderi. Open peer-review platform for COVID-19 preprints. *Nature*, 579(7797):29–29, March 2020. URL https://doi.org/10.1038/d41586-020-00613-4.

Michiko Kakutani. *The Death of Truth*. William Collins, July 2018. ISBN 978-0-00-831278-7.

Robert Kiley. Open access: how COVID-19 will change the way research findings are shared, May 2020. URL https://wellcome.ac.uk/news/open-access-how-covid-19-will-change-way-research-findings-are-shared.

Diana Kwon. How swamped preprint servers are blocking bad coronavirus research. *Nature*, 581(7807):130–131, May 2020. URL https://doi.org/10.1038/d41586-020-01394-6.

Vincent Larivière, Fei Shu, and Cassidy R. Sugimoto. The Coronavirus (COVID-19) outbreak highlights serious deficiencies in scholarly communication, March 2020. URL https://blogs.lse.ac.uk/impactofsocialsciences/2020/03/05/the-coronavirus-covid-19-outbreak-highlights-serious-deficiencies-in-scholarly-communication/.

Kai-Fu Lee. *AI Superpowers: China, Silicon Valley, and the New World Order*. Houghton Mifflin Harcourt, September 2018. ISBN 978-1-328-54639-5.

Soomi Lee. Why an emergency Universal Basic Income makes sense during the Covid-19 pandemic, March 2020. URL https://blogs.lse.ac.uk/usappblog/2020/03/24/why-an-emergency-universal-basic-income-makes-sense-during-the-covid-19-pandemic/.

Mariana Mazzucato. *The Entrepreneurial State: Debunking Public vs. Private Sector Myths*. Anthem Press, London ; New York, first edition edition edition, June 2013. ISBN 978-0-85728-252-1.

Alessandra Minello. The pandemic and the female academic. *Nature*, April 2020. URL https://doi.org/10.1038/d41586-020-01135-9.

Tom Nichols. *The Death of Expertise: The Campaign Against Established Knowledge and Why it Matters*. OUP USA, New York, NY, April 2017. ISBN 978-0-19-046941-2.

Simon Porter. Code for responding to covid-19 - cultural changes and landscape trends in the global research system, May 2020. URL https://doi.org/10.34747/z3d2-3y36.

Simon Porter and Daniel Hook. Datasets for responding to covid-19 - cultural changes and landscape trends in the global research system, May 2020. URL https://doi.org/10.6084/m9.figshare.c.4997174.

Kate Raworth. *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist*. Chelsea Green Publishing Company, White River Junction, Vermont, March 2017. ISBN 978-1-60358-674-0.

Magdalena Skipper. Researchers: show world leaders how to behave in a crisis. *Nature*, 580(7801):7–7, April 2020. URL https://doi.org/10.1038/d41586-020-00926-4.

Daniel Torres-Salinas, Nicolas Robinson-Garcia, and Pedro A. Castillo-Valdivieso. Open Access and Altmetrics in the pandemic age: Forescast analysis on COVID-19 literature. Technical report, Scientific Communication and Education, April 2020. URL https://doi.org/10.1101/2020.04.23.057307.

Anne Trafton, Jennifer Chu, and David L Chandler. Covid-19 diagnostic based on MIT technology might be tested on patient samples soon, 2020. URL http://news.mit.edu/2020/covid-19-diagnostic-test-prevention-0312. Library Catalog: news.mit.edu.

Giuliana Viglione. Are women publishing less during the pandemic? Here's what the data say. *Nature*, pages d41586–020–01294–9, May 2020. URL https://doi.org/10.1038/d41586-020-01294-9.

Juergen Wastl, Simon Porter, Hélène Draux, Briony Fane, and Daniel Hook. Contextualizing Sustainable Development Research. Technical report, Digital Science, 2020. URL https://doi.org/10.6084/M9.FIGSHARE.12200081.V2.

Patrick Wintour. World leaders pledge 7.4bn to research Covid-19 vaccine. *The Guardian*, May 2020. URL https://www.theguardian.com/world/2020/may/04/world-leaders-pledge-74bn-euros-to-research-covid-19-vaccine.

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