





into an agreement in 2019 to co-develop coronavirus vaccines; however, this was before the identification and spread of SARS-CoV-2<sup>17,18</sup>.

The mRNA vaccine platform for COVID-19 relies on the production of the coronavirus spike protein to elicit an immune response. Moderna, CureVac, Pfizer and BioNTech have all disclosed that the mRNA used in their vaccine candidates encodes a stabilized version of the spike protein that was developed by the NIH. A report by Public Citizen identified a pending patent application on this modified spike protein that was filed by the NIH<sup>19</sup>. The NIH also has four other provisional patent applications on a novel coronavirus vaccine as disclosed in a recent publication<sup>17</sup>. This complex matrix of patents, licenses and agreements between these entities highlights the intricacies involved in biopharmaceutical development. Since patent numbers are redacted in all the SEC filings, we decided to develop our own patent landscape for the respective entities. Patents and patent applications that are relevant to the respective vaccine technology platform and owned or assigned to any of the entities discussed were identified and highlighted (Supplementary Information)<sup>20,21</sup>. A visual representation of the science encompassed in the patents and applications is shown in Fig. 2<sup>22</sup>.

The success of mRNA vaccines in clinical trials highlights the potential of mRNA technology to be the future of medicine. The rapid development and clinical success of COVID-19 mRNA vaccines can be credited to the relationship between

inventors and innovators. As evidenced by our network analysis, key technological advancements were invented in academic labs or small biotech companies and then licensed to larger companies for product development. Despite this success, patents, trade secrets and know-how owned by or assigned to larger companies may impede future research and development of mRNA technology by creating legal barriers that limit access to this technology.

Mario Gaviria<sup>1</sup>✉ and Burcu Kilic<sup>2</sup>

<sup>1</sup>Department of Chemistry, University of Michigan, Ann Arbor, MI, USA. <sup>2</sup>Public Citizen, Washington, DC, USA.

✉e-mail: [mariogav@umich.edu](mailto:mariogav@umich.edu)

Published online: 12 May 2021

<https://doi.org/10.1038/s41587-021-00912-9>

### References

- Zimmer, C., Corum, J. & Wee, S.-L. Coronavirus vaccine tracker. *The New York Times* <https://www.nytimes.com/interactive/2020/science/coronavirus-vaccine-tracker.html> (2020).
- Kilic, B. *Boosting Pharmaceutical Innovation in the Post-TRIPS Era* (Edward Elgar Publishing, 2014).
- Walsh, E. E. et al. *N. Engl. J. Med.* **383**, 2439–2450 (2020).
- Corbett, K. S. et al. *Nature* **586**, 567–571 (2020).
- Wolff, J. A. et al. *Science* **247**, 1465–1468 (1990).
- Kariko, K., Buckstein, M., Ni, H. & Weissman, D. *Immunity* **23**, 165–175 (2005).
- Abinader, L. G. Foundational mRNA patents are subject to the Bayh-Dole Act provisions. *Knowledge Ecology International* <https://www.keionline.org/34733> (2020).
- CellScript & Moderna. Patent sublicense agreement. EX-10.8. <https://www.sec.gov/Archives/edgar/data/1682852/000119312518323562/d577473dex108.htm> (2017).
- CellScript & BioNTech. Patent sublicense agreement. EX-10.15. <https://www.sec.gov/Archives/edgar/data/1776985/000119312519241112/d635330dex1015.htm> (2017).
- Arbutus Biopharma Corporation. Annual report. <https://www.sec.gov/Archives/edgar/data/1447028/000162828018003276/arbutus10k2017.htm> (2017).

- CureVac. Registration form F-1. [https://www.sec.gov/Archives/edgar/data/1809122/000110465920086354/tm2016252-11\\_fl.htm](https://www.sec.gov/Archives/edgar/data/1809122/000110465920086354/tm2016252-11_fl.htm) (2020).
- Silbersher, Z. Does Moderna Therapeutics' pipeline depend upon its patent dispute with Arbutus Biopharma over mRNA delivery? *Markman Advisors* <https://www.markmanadvisors.com/blog/2018/12/17/does-moderna-therapeutics-pipeline-depend-upon-its-patent-dispute-with-arbutus-biopharma-over-mrna-delivery> (2018).
- Arbutus Biopharma Corporation. Form 8-K. [https://www.sec.gov/Archives/edgar/data/1447028/000117184318002661/f8k\\_041218.htm](https://www.sec.gov/Archives/edgar/data/1447028/000117184318002661/f8k_041218.htm) (2018).
- BioNTech and Genevant. License and co-development agreement. EX-10.17. <https://www.sec.gov/Archives/edgar/data/1776985/000119312519241112/d635330dex1017.htm> (2018).
- Pfizer & BioNTech. Research collaboration and license agreement. EX-10.18. <https://www.sec.gov/Archives/edgar/data/1776985/000119312519241112/d635330dex1018.htm> (2018).
- BioNTech. Registration form F-1. <https://www.sec.gov/Archives/edgar/data/1776985/000119312520195911/d939702df1.htm> (2020).
- Herman, B. The NIH claims joint ownership of Moderna's coronavirus vaccine. *Axios* <https://www.axios.com/moderna-nih-coronavirus-vaccine-ownership-agreements-22051c42-2dec-4b19-938d-099afd71f6a0.html> (2020).
- Rizvi, Z. The NIH vaccine. *Public Citizen* <https://www.citizen.org/article/the-nih-vaccine/> (2020).
- Rizvi, Z. Leading COVID-19 vaccine candidates depend on NIH technology. *Public Citizen* <https://www.citizen.org/article/leading-covid-19-vaccines-depend-on-nih-technology/> (2020).
- Gaviria, M. & Kilic, B. mRNA-1273 vaccine patent landscape (for NIH-Moderna vaccine). *Public Citizen* <https://www.citizen.org/article/modernas-mrna-1273-vaccine-patent-landscape/> (2020).
- Gaviria, M. & Kilic, B. BioNTech and Pfizer's BNT162 vaccine patent landscape. *Public Citizen* <https://www.citizen.org/article/biontech-and-pfizers-bnt162-vaccine-patent-landscape/> (2020).
- van Eck, N. J. & Waltman, L. VOSViewer: visualizing scientific landscapes. <https://www.vosviewer.com> (2010).
- Bastian, M., Heymann, S. & Jacomy, M. Gephi: an open source software for exploring and manipulating networks. *Int. AAAI Conf. Weblogs and Social Media* <https://gephi.org/publications/gephi-bastian-feb09.pdf> (2009).

### Competing interests

The authors declare no competing interests.

### Additional information

**Supplementary information** The online version contains supplementary material available at <https://doi.org/10.1038/s41587-021-00912-9>.