

# **RAMPING UP MPXV VACCINE PRODUCTION: A GLOBAL SURVEY**

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## INTRODUCTION

The vaccine deployed in the current monkeypox virus (MPXV) outbreak, Jynneos, can trace its origins to a vaccine developed by German public scientists more than half a century ago. In the 1950s, the Bavarian State Vaccination Institute manufactured a smallpox vaccine using a poxvirus called vaccinia.<sup>1</sup> A senior official at the Institute believed the strain of vaccinia deposited at another institute in Ankara was safer.<sup>2</sup> He also thought that “passaging” the virus—or growing it in cells, and then transferring it to fresh cells every few days—could make vaccinia even more safe.

At his direction, Dr. Anton Mayr passaged the vaccinia virus more than 500 times in chick embryo fibroblast (CEF) cells, calling the resulting virus Modified Vaccina Ankara.<sup>3</sup> MVA was used in the German smallpox vaccination campaign in the 1970s.<sup>4</sup> Decades later, Bavarian Nordic further passaged MVA, producing Modified Vaccinia Ankara-Bavarian Nordic (“MVA-BN”)—or Jynneos.

What would it take to expand the production of MVA-BN? In this report, we explore the production process for MVA-BN, systematically review manufacturers with experience in similar processes, and survey intellectual property barriers. **Public Citizen can identify nine global vaccine manufacturers that use the chick embryo fibroblast cells central to MVA-BN production. Six of the manufacturers are located in low-and-middle income countries. CEF-based products manufactured in LMICs sell for \$4 or less per dose.** With sufficient resources, LMIC manufacturers may be able to quickly receive technology and deliver MPXV doses at a fraction of the current estimated price of \$110.<sup>5</sup>

## PRODUCTION PROCESS

MVA-BN is an attenuated live viral vaccine—one of the oldest and most widely used vaccine platforms. MVA-BN is produced using an egg-based production process that Bavarian Nordic has adapted for commercial-scale manufacturing. MVA production relies on preparing CEF cells derived from special kinds of embryonated eggs; inoculating, harvesting and purifying the virus; and filling-and-finishing the bulk drug

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<sup>1</sup> For full history, see Zain Rizvi, How a Danish Company Grabbed Control of the Monkeypox Vaccine, The American Prospect (September 22 2022). <https://prospect.org/health/how-danish-company-grabbed-control-of-monkeypox-vaccine/> Anton Mayr, Smallpox vaccination and bioterrorism with pox viruses, Comparative Immunology, Microbiology and Infectious Diseases (2003).

<sup>2</sup> Bavarian Nordic A/S v. Acambis Inc., 486 F. Supp. 2d 354 (D. Del. 2007).

<sup>3</sup> The initial passages were done by Dr. Anton Mayr. Anton Mayr, Smallpox vaccination and bioterrorism with pox viruses, Comparative Immunology, Microbiology and Infectious Diseases (2003).

<sup>4</sup> A. Volz and Gerd Sutter, Modified Vaccinia Virus Ankara: History, Value in Basic Research, and Current Perspectives for Vaccine Development, Adv Virus Res, 97:187-243 (2017).

<sup>5</sup> New resources could help ensure that the production of existing vaccines is not interrupted. See <https://www.citizen.org/article/letter-to-bavarian-nordic-urging-equitable-access/> (Canadian price) and <https://twitter.com/zainrizvi/status/1577382747676499970> (European Commission price).

substance into vials. While methods to prepare CEF cell cultures for academic research at lab-scale are widely known, information about commercial-scale manufacturing is limited by a lack of transparency. Many details of the production process are kept secret. Nonetheless, based on public records, we can sketch out major steps below.

## CEF Preparation

CEF cells are freshly prepared from specific pathogen-free (SPF) embryonated eggs. SPF eggs are drawn from flocks that are regularly tested for a wide range of pathogens in highly regulated farms.<sup>6</sup> SPF eggs are the “most critical biosimilar raw material,” according to BVN.<sup>7</sup> The head of Bavarian Nordic estimates that 5000 eggs are used per batch of vaccine.<sup>8</sup>

Fertilized SPF chicken eggs are incubated.<sup>9</sup> After disinfecting the egg, the embryos are harvested, and the head is removed.<sup>10</sup> Then, the embryos are macerated, and trypsin, a protease, is added.<sup>11</sup> Primary CEF cells are isolated by centrifugation.<sup>12</sup>

The cells are then seeded in a bioreactor. Bavarian Nordic has historically used a single-use plastic bag, attached to a rocking platform, known as a WAVE Bioreactor Unit.<sup>13</sup> To reduce the risk of adventitious agents (i.e., contaminants) from animal sources, a serum-free medium comprising epidermal growth factor and antibiotics is used to incubate the cells.<sup>14</sup> The rocking motion of the bioreactor produces waves, which provide mixing and oxygen transfer to help the cells grow. The WAVE Bioreactor units were delivered, installed, and commissioned at the BVN facility in less than three months.<sup>15</sup>

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<sup>6</sup> [https://www.aphis.usda.gov/animal\\_health/vet\\_biologics/publications/memo\\_800\\_65.pdf](https://www.aphis.usda.gov/animal_health/vet_biologics/publications/memo_800_65.pdf)

<sup>7</sup> <https://www.sec.gov/Archives/edgar/data/1576915/000104746916009516/a2226987zf-1.htm>

<sup>8</sup> <https://seekingalpha.com/article/4536765-bavarian-nordic-s-bvnkf-ceo-paul-chaplin-on-q2-2022-results-earnings-call-transcript>

<sup>9</sup> <https://patents.google.com/patent/US10087423B2/en>

<sup>10</sup> <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5575744/> and

<https://patents.google.com/patent/US8329466B2/en>

<sup>11</sup> <https://patents.google.com/patent/US8329466B2/en>

<sup>12</sup> [https://www.ema.europa.eu/documents/assessment-report/imvanex-epar-public-assessment-report\\_en.pdf](https://www.ema.europa.eu/documents/assessment-report/imvanex-epar-public-assessment-report_en.pdf)

<sup>13</sup> In 2019, the company said it was expecting to transition some products to large bioreactors beyond WAVE units for industrial manufacturing but it is not clear whether that took place for Jynneos.

<https://seekingalpha.com/article/4305009-bavarian-nordic-s-bvnkf-ceo-paul-chaplin-on-q3-2019-results-earnings-call-transcript>, <https://www.biospace.com/article/releases/wave-biotech-llc-release-wave-bioreactor-r-used-in-new-vaccine-production-facility-/>. Roller bottles are used in the small-scale process. <https://patents.google.com/patent/US10087423B2>

<sup>14</sup> <https://patents.google.com/patent/US8329466B2/en>

<sup>15</sup> <https://www.biospace.com/article/releases/wave-biotech-llc-release-wave-bioreactor-r-used-in-new-vaccine-production-facility-/> and [https://cdmo.bavarian-nordic.com/BN\\_CDMO\\_Brochure\\_web\\_180119.pdf](https://cdmo.bavarian-nordic.com/BN_CDMO_Brochure_web_180119.pdf) and <https://seekingalpha.com/article/4305009-bavarian-nordic-s-bvnkf-ceo-paul-chaplin-on-q3-2019-results-earnings-call-transcript>

## Virus Inoculation, Harvest and Purification

The CEF cells are infected with the working seed virus derived from the master seed virus (MVA-BN) and incubated to allow the virus to replicate. No further passaging is required. Process validation studies have shown that the number of CEF cells must be strictly controlled at this step to ensure process consistency.<sup>16</sup>

According to European Medicine Agency records, after the incubation period, the virus is harvested, pooled and homogenized, subject to ultrasonication and centrifugation. Newer processes may have been developed since the EMA published its review.<sup>17</sup>

Residual impurities are a significant challenge with egg-based production. To further remove impurities, the harvest is concentrated and purified using tangential flow filtration, followed by DNA digestion using benzonase and a final diafiltration step with the buffer (10 mM Tris, 140 mM NaCl, pH 7.7).<sup>18</sup> The drug substance is frozen.

## Fill-and-Finish

The bulk drug substance is formulated by mixing the thawed drug substance with the same buffer described above to reach the target TCID<sub>50</sub> titre. The bulk drug substance undergoes more than 30 analytical tests.<sup>19</sup> One of tests alone takes approximately 80 days. Finally, the bulk is filled into vials, and the process of packaging is finished. For Jynneos, this requires a Biosafety Level 2 (BSL-2) facility. “Each 0.5 mL dose is formulated to contain  $0.5 \times 10^8$  to  $3.95 \times 10^8$  infectious units of MVA-BN live virus in 10 mM Tris (tromethamine) and 140 mM sodium chloride at pH 7.7.”<sup>20</sup> Producing one batch of Jynneos vaccine takes six months.<sup>21</sup>

Large-scale MVA production has been characterized as “inefficient” and the use of CEF cells “cumbersome.”<sup>22</sup> “The production of CEF cells in bulk involves many slow and inefficient manufacturing steps both upstream and downstream.”<sup>23</sup> Some have advocated for the use of more modern tools, like continuous cell lines that do not require extracting

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<sup>16</sup> [https://www.ema.europa.eu/documents/assessment-report/imvanex-epar-public-assessment-report\\_en.pdf](https://www.ema.europa.eu/documents/assessment-report/imvanex-epar-public-assessment-report_en.pdf)

<sup>17</sup> A new patent application suggests BVN may have developed a new method using lysis and depth filtration for WAVE units, but it is not clear whether it has been adapted.  
<https://patents.google.com/patent/US10087423B2/en>

<sup>18</sup> [https://www.ema.europa.eu/documents/assessment-report/imvanex-epar-public-assessment-report\\_en.pdf](https://www.ema.europa.eu/documents/assessment-report/imvanex-epar-public-assessment-report_en.pdf)

<sup>19</sup> [Bavarian Nordic A/S \(BVNKF\) CEO Paul Chaplin on Q2 2022 Results - Earnings Call Transcript | Seeking Alpha](#)

<sup>20</sup> <https://fda.report/media/131802/September+24%2C+2019+Summary+Basis+for+Regulatory+Action+-+JYNNEOS+.pdf>

<sup>21</sup> [Bavarian Nordic A/S \(BVNKF\) CEO Paul Chaplin on Q2 2022 Results - Earnings Call Transcript | Seeking Alpha](#)

<sup>22</sup> <https://www.govinfo.gov/content/pkg/FR-2021-06-10/html/2021-12182.htm>

<sup>23</sup> <https://www.govinfo.gov/content/pkg/FR-2021-06-10/html/2021-12179.htm>

primary cells from embryonated eggs.<sup>24</sup> However, the use of a traditional egg-based process also means there are many manufacturers with relevant experience around the world.<sup>25</sup>

## PRODUCTION CAPACITY

MVA-BN production is based on primary CEF cell cultures. Several other kinds of vaccines are manufactured using the same cell cultures, including vaccines for measles, mumps, rabies and tick-borne encephalitis.<sup>26</sup>

To identify manufacturers with experience propagating viruses in CEF cells, we systematically reviewed regulatory records for all F.D.A. approved and World Health Organization prequalified vaccines. To identify CEF-based products that were not FDA authorized or WHO prequalified, we used the terms “chick embryo fibroblast AND vaccine” in two search engines (Google, Pubmed).

We searched for manufacturing information in the package insert, the clinical review memo, approval letters, vaccine studies and related documents. Vaccines were included in our review if their production was based on CEF cells.<sup>27</sup> Vaccines were excluded if they were produced by Bavarian Nordic, or if they were a combination product containing another CEF-based product already included in the list. For vaccines that met the inclusion criteria, we conducted additional online searches to identify global pricing.

From the WHO’s prequalified vaccine list, we reviewed 167 vaccine records and found manufacturing information for 142 vaccines. From the FDA approved vaccine list, we reviewed 92 vaccine records, and found manufacturing information for 88 vaccines. From the WHO and FDA lists, we identified 11 vaccines that were produced using CEF cells, excluding duplicates. We identified three CEF-based vaccines through additional searches.

Of the total 14 vaccines, we excluded three vaccines produced by BVN (Rabipur<sup>28</sup>, RabAvert, Mvabea) and two vaccines that were a combination product (ProQuad, composed of rHA M-M-R II; Biological E. Limited’s Measles and Rubella vaccine, composed of Bio Farma’s measles virus).

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<sup>24</sup> <https://www.govinfo.gov/content/pkg/FR-2021-06-10/html/2021-12182.htm> and <https://www.govinfo.gov/content/pkg/FR-2021-06-10/html/2021-12179.htm>.

<sup>25</sup> This process uses CEF cells. Other egg-based processes use virus that is injected into an embryonated egg.

<sup>26</sup> See Title 21 CFR 630.32 (now repealed) from 1996 setting standards for measles vaccines. (“Virus shall be propagated in chick embryo tissue cultures.”). <https://www.govinfo.gov/content/pkg/CFR-1996-title21-vol7/html/CFR-1996-title21-vol7-sec630-32.htm>

<sup>27</sup> Not merely sufficient that the virus had been passaged historically in CEF cells.

<sup>28</sup> We included Chirorab, which Bharat Biotech says use the same technology as Rabipur. We counted Chirorab as a CEF-based vaccine identified through additional searches.

Nine vaccines produced by nine different manufacturers met our inclusion criteria. The results are detailed in Table 1 below. Six of these manufacturers are located in low-and-middle income countries. CEF-based products manufactured in LMICs are sold for \$4 or less per dose.

**Table 1: Manufacturers with CEF Experience**

Manufacturer	Location	CEF-Based Product	FDA Approval or WHO PQ	Public Prices
<b>GlaxoSmithKline (GSK)</b>	Belgium	Measles and mumps virus used in Measles, Mumps, Rubella (MMR) vaccine (Priorix) <sup>29</sup>	Y	\$4.47 <sup>30</sup> (UNICEF)
<b>Bio-Manguinhos/Fiocruz</b>	Brazil	Measles and mumps virus used in MMR vaccine <sup>31</sup>	N <sup>32</sup>	-
<b>Chiron Behring Vaccines (Bharat Biotech)</b>	India	Rabies virus used in vaccine (Chirorab) <sup>33</sup>	N <sup>34</sup>	-
<b>Serum Institute of India</b>	India	Mumps virus used in MMR vaccine <sup>35</sup>	Y	\$1.7- \$3.56 <sup>36</sup> (UNICEF)
<b>Zydus Cadila</b>	India	Rabies virus used in vaccine (VaxiRab N) <sup>37</sup>	Y	\$4 <sup>38</sup> (India)

<sup>29</sup> <https://extranet.who.int/pqweb/content/priorix>, <https://extranet.who.int/pqweb/file/18627257/download> and <https://www.fda.gov/media/159545/download> (“Each virus strain is manufactured separately by propagation in either chick embryo fibroblasts cultures (for mumps and measles)”).

<sup>30</sup> <https://www.unicef.org/supply/documents/measles-mumps-and-rubella-vaccine-mmr-price-data>

<sup>31</sup> Bio-Manguinhos received a full technology transfer from GSK to manufacture the MMR product, which relies on CEF. <https://www.bio.fiocruz.br/index.php/br/produtos/vacinas/triplice-viral>. ANVISA Filing, [https://consultas.anvisa.gov.br/api/consulta/medicamentos/arquivo/bula/parecer/eyJhbGciOiJIUzUxMi9.eyJqdGkiOiJxNjE4OTkwNiIsIm5iZiI6MTY2NTAwMTA5NywiZXhwIjoxNjY1MDAxMzk3fQ.E\\_7oAGYgfl\\_HS46vODPBdgZm|BheSqeRbG94yRhTT8Uso7CAkVZ4zMzG4-S9zqpG8WqvkaAJXk3hViZt2MNsLA/?Authorization=:](https://consultas.anvisa.gov.br/api/consulta/medicamentos/arquivo/bula/parecer/eyJhbGciOiJIUzUxMi9.eyJqdGkiOiJxNjE4OTkwNiIsIm5iZiI6MTY2NTAwMTA5NywiZXhwIjoxNjY1MDAxMzk3fQ.E_7oAGYgfl_HS46vODPBdgZm|BheSqeRbG94yRhTT8Uso7CAkVZ4zMzG4-S9zqpG8WqvkaAJXk3hViZt2MNsLA/?Authorization=:) (“A vacina sarampo, caxumba, rubéola (atenuada) é uma preparação mista liofilizada das cepas de vírus atenuados de sarampo (Schwarz), caxumba (RIT 4385 - derivada da cepa Jeryl Lynn) e rubéola (Wistar RA 27/3), e, separadamente obtidas por propagação em culturas de tecido de ovos embrionados de galinha (sarampo e caxumba) ou células diplóides humanas MRC-5 (rubéola).”)

<sup>32</sup> Bio-Manguinhos has a prequalified yellow fever vaccine.

<sup>33</sup> <https://www.bharatbiotech.com/images/press/ChiroRab-Press-Release-Nov-13-2019.pdf>

<sup>34</sup> While Bharat Biotech has received PQ for Rabipur, it is not clear whether this extends to Chirorab, the vaccine currently being produced by the company.

<sup>35</sup> <https://extranet.who.int/pqweb/content/measles-mumps-and-rubella-vaccine-live-attenuated-2> and <https://extranet.who.int/pqweb/file/18627085/download> (“The mumps virus is grown on chick fibroblasts from SPF eggs.”)

<sup>36</sup> <https://www.unicef.org/supply/documents/measles-mumps-and-rubella-vaccine-mmr-price-data>

<sup>37</sup> <https://extranet.who.int/pqweb/content/vaxirab-n> and <https://extranet.who.int/pqweb/file/18628953/download> (“Virus is propagated in chick embryo fibroblast cell culture and Inactivated by  $\beta$ -propiolactone.”)

<sup>38</sup> <https://www.1mg.com/drugs/vaxirab-n-2.5iu-injection-232000>

<b>PT Bio Farma</b>	Indonesia	Measles virus used in vaccine <sup>39</sup>	Y	\$0.27 <sup>40</sup> (UNICEF)
<b>Pfizer</b>	Ireland	Tick-borne encephalitis virus used in vaccine <sup>41</sup>	Y	~\$300 <sup>42</sup> (U.S. Private)
<b>Biovac</b>	South Africa	Measles and mumps virus used in MMR vaccine (Morupar) <sup>43</sup>	N	-
<b>Merck</b>	U.S.	Measles and mumps virus used in MMR vaccine (rHA M-M-R II) <sup>44</sup>	Y	\$23.67 (CDC)

These manufacturers likely possess knowledge that would allow them learn how to propagate MVA in CEF faster than other manufacturers. These manufacturers may also have established supply chains for key materials, like SPF eggs, that could be drawn upon to expand production. Finally, LMIC manufacturers have a different cost structure, including for raw materials and labor, that could help lower the price of vaccines, increasing demand and making doses more accessible.<sup>45</sup>

## PRODUCTION BARRIERS

Ramping up production for the MPXV vaccine quickly will require technology transfer, including the sharing of biological resources, know-how and patents. Resources include the working seed virus (MVA-BN). Know-how will include answers to key questions:

<sup>39</sup><https://extranet.who.int/pqweb/content/measles-vaccine> and <https://extranet.who.int/pqweb/file/18626927/download>. (“Each dose of 0.5 ml contains not less than 1,000 CCID50 (cell culture infective doses 50%) of Measles virus strain CAM 70, prepared in SPF chicken embryo.”) Biological E says the bulk substance it obtains from Bio Farma is grown in CEF cells.

<https://extranet.who.int/pqweb/content/measles-and-rubella-vaccine-live-attenuated-freeze-dried> and <https://extranet.who.int/pqweb/file/18627481/download> (“Measles virus is propagated in chicken embryo fibroblast (CEF) cells”)

<sup>40</sup> <https://www.unicef.org/supply/documents/measles-vaccine-price-data>

<sup>41</sup> <https://labeling.pfizer.com/showlabeling.aspx?id=15600> (“TICOVAC is prepared from tick-borne encephalitis (TBE) virus propagated in chick embryo fibroblast (CEF) cells.”)

<sup>42</sup> <https://www.goodrx.com/ticovac>

<sup>43</sup> [https://repository.up.ac.za/bitstream/handle/2263/20793/Visser\\_Combination\(2012\).pdf?sequence=1](https://repository.up.ac.za/bitstream/handle/2263/20793/Visser_Combination(2012).pdf?sequence=1) (“Measles virus (Schwarz strain in chick embryo cell line); Mumps virus (Urabe AM9 strain in chick embryo cell line”)

<sup>44</sup> <https://extranet.who.int/pqweb/content/rha-m-m-r-ii> and <https://www.fda.gov/media/75191/download> (“M-M-R II vaccine is a sterile lyophilized preparation of (1) Measles Virus Vaccine Live, an attenuated line of measles virus, derived from Enders' attenuated Edmonston strain and propagated in chick embryo cell culture; (2) Mumps Virus Vaccine Live, the Jeryl Lynn™ (B level) strain of mumps virus propagated in chick embryo cell culture;”)

<sup>45</sup> Syarifah Munira et al., A Cost Analysis of Producing Vaccines in Developing Countries, Vaccine (2019).

- What is the scale of commercial production? What equipment, materials, and in-process controls are used? What is the design of the facilities? What are the labor requirements?
- How long are the CEF cells incubated? What is the composition of the medium used to incubate the cells? What conditions will help optimize MVA yield?
- How is the process controlled to reduce variability and assure product quality?
- What analytical methods are required and how are these analytical methods used throughout the process to assess the quality of process intermediates and of the finished product?
- What specifications should companies aim to meet when producing at scale?

In addition to know-how, patents may pose a barrier to production. To review relevant patents, we conducted a preliminary landscape, using patent disclosures by the head of Bavarian Nordic, and conducting a search in select databases for patents assigned to Bavarian Nordic.<sup>46</sup>

While our analysis is non-exhaustive, we identified 18 U.S. patents that appear relevant to liquid-frozen MVA-BN for MPXV.<sup>47</sup> Our preliminary analysis indicates that many of the critical patents covering the vaccine—including its composition—have expired.<sup>48</sup> Most unexpired patents claim methods of use for MVA-BN and the vaccine production process. Because some elements of the production process are secret, we cannot definitively ascertain which patents cover the current MVA-BN process.

To facilitate expanded production, Bavarian Nordic could publicly clarify its patent claims and provide licenses. Governments could also issue licenses for analogous national patents, if any, to those listed below to ensure freedom to operate for other manufacturers.

**Table 2: BVN patents that appear relevant to liquid-frozen MVA-BN for MPXV**

Name	U.S. Patent Number	Grant Date
<b>1. Modified vaccinia ankara virus variant</b>	7,189,536	03/13/2007
<b>2. Modified Vaccinia Ankara virus variant and cultivation method</b>	7,445,924	09/04/2008
<b>3. Method for the cultivation of primary cells and for the amplification of viruses under serum free conditions</b>	7,695,939	04/13/2010
<b>4. Modified Vaccinia Ankara virus variant</b>	7,923,017	04/12/2011
<b>5. Modified vaccinia ankara virus variant and cultivation method</b>	7,964,396	06/21/2011
<b>6. Method for the cultivation of primary cells and for the amplification of viruses under serum free conditions</b>	7,964,397	06/21/2011

<sup>46</sup> Patents by Paul Chaplin (2018), <https://doi.org/10.1371/journal.pone.0195897.s002>.

<sup>47</sup> We did not review patent applications. Some may not yet be published.

<sup>48</sup> U.S. Patent 6,761,893.

7. Purification of vaccinia virus- and recombinant vaccinia virus-based vaccines	8,003,363	08/23/2011
8. Purification of vaccinia viruses using hydrophobic interaction chromatography	8,003,364	08/23/2011
9. Purification of vaccinia virus- and recombinant vaccinia virus-based vaccines	8,012,738	09/06/2011
10. Purification of vaccinia virus- and recombinant vaccinia virus-based vaccines	8,211,686	07/03/2012
11. Method for the cultivation of primary cells and for the amplification of viruses under serum free conditions	8,329,466	12/11/2012
12. Purification of vaccinia virus- and recombinant vaccinia virus-based vaccines	8,415,132	04/09/2013
13. Purification of vaccinia viruses using hydrophobic interaction chromatography	8,470,578	06/25/2013
14. Method for the cultivation of primary cells and for the amplification of viruses under serum free conditions	8,673,318	03/18/2014
15. Use of a modified poxvirus for the rapid induction of immunity against a poxvirus or other infectious agents	8,808,709	09/19/2014
16. Immediate protection against pathogens via MVA	8,961,998	02/24/2015
17. Purification of vaccinia viruses using hydrophobic interaction chromatography	9,109,201	08/18/2015
18. Method for harvesting expression products	10,087,423	10/02/2018

## A PATH FORWARD

The continued spread of MPXV around the world suggests that the virus may establish roots in new communities, underscoring the need to ensure sustainable production of MVA-BN.<sup>49</sup> **Public Citizen can identify nine global vaccine manufacturers that use the chick embryo fibroblast cells central to MVA-BN production. Six of the manufacturers are located in low-and-middle income countries. CEF-based products manufactured in LMICs sell for \$4 or less per dose—a fraction of the current estimated MVA-BN price of \$110.**<sup>50</sup>

The U.S. government and other large funders should push Bavarian Nordic to share technology and work with manufacturers in developing countries. This can help scale low-cost production and bring MVA-BN to the world.

<sup>49</sup> 102 countries where MPX has not been historically reported. 7 where MPX has been historically reported. <https://www.cdc.gov/poxvirus/monkeypox/response/2022/world-map.html>

<sup>50</sup> New resources could help ensure that the production of existing vaccines is not interrupted. See <https://www.citizen.org/article/letter-to-bavarian-nordic-urging-equitable-access/> (Canadian price) and <https://twitter.com/zainrizvi/status/1577382747676499970> (European Commission price).



[www.citizen.org](http://www.citizen.org)

