



GLOBAL HEALTH CENTRE WORKING PAPER NO.17 | 2018

# IS GLOBAL CAPACITY TO MANAGE OUTBREAKS IMPROVING? - AN ANALYSIS

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# ABBREVIATIONS

Africa CDC	Africa Centers for Disease Control	IDA	International Development Association
CDC	US Centers for Disease Control and Prevention	IDDO	Infectious Diseases Data Observatory
CEPI	Coalition for Epidemic Preparedness Innovations	IHR	International Health Regulations (2005)
CFE	Contingency Fund for Emergencies	IMF	International Monetary Fund
CHAMPS	Child Health and Mortality Prevention Surveillance Network	JEE	Joint External Evaluations
CORDS	Connecting Organizations for Global Disease Surveillance	MERS	Middle East Respiratory Syndrome
CRW	Crisis Response Window	MIDAS	Models of Infectious Disease Agent Study
DRC	Democratic Republic of Congo	NAM	US National Academy of Medicine
DRFIP	Disaster Risk Financing and Insurance Program	NGO	Non-governmental organisation
EMT	Emergency Medical Teams	NPHIL	National Public Health Institute of Liberia
EPC	Ending Pandemics Collective	OCR	Outbreak Crisis response
EUAL	Emergency Use Assessment and Listing	OIE	World Organization for Animal Health
EYE	Eliminating yellow fever epidemics	PEF	Pandemic Emergency Financing Facility
FAO	Food and Agriculture Organization	PIP	Pandemic Influenza Preparedness
FETP	Field Epidemiology Training Program	PPE	Personal protective equipment
FIND	Foundation for Innovative New Diagnostics	R&D	Research and development
GCM	Global Coordination	REDISSE	Regional Disease Surveillance and Enhancement Project
GHSA	Global Health Security Agenda	SPP	Strategic Partnership Portal
GloPID-R	Global Research Collaboration for Infectious Disease Preparedness	UHC	Universal Health Coverage
GOARN	Global Outbreak Alert and Response Network	UN	United Nations
HGHI	Harvard Global Health Initiative	UNICEF	United Nations International Children’s Emergency Fund
IASC	The Inter-Agency Standing Committee	UNSG	United Nations Secretary-General
IATI	International Aid and Transparency Initiative	US	United States
IBRD	International Bank for Reconstruction and Development	USAID	United States Agency for International Development
		USG	United States Government
		WEF	World Economic Forum
		WHE	WHO Health Emergencies Programme
		WHO	World Health Organization

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All views expressed in this paper, and errors, remain our own.



## EXECUTIVE SUMMARY

*In a January 2017 article in the British Medical Journal, we examined seven major reports published in the aftermath of the 2013-2016 Ebola epidemic. We identified areas of consensus, assessed what progress had been made, and highlighted gaps. The following table summarises the state of affairs as of mid-2018 across eight issue areas critical for global capacity to manage outbreaks, and highlights remaining gaps.*

Leadership & Monitoring	
<p><b>Status:</b> Many actors demonstrated leadership by taking the initiative to strengthen various aspects of global outbreak capacity – these include many governments, multilateral organisations, the Global Health Security Agenda (GHSA), foundations, think tanks, companies, and researchers. As a result, many initiatives are currently being implemented.</p>	<p><b>Gaps:</b> Amidst a proliferation of initiatives, there is no governing framework to ensure that efforts sum up to a functional, adequate global system. Currently we are unable to meaningfully assess the state of global capacity. Ideally, the recently-created Global Pandemic Monitoring Board will be a much-needed independent global mechanism to ensure regular in-depth, system-wide tracking and assessment of efforts. It is unclear who will provide needed coordination and system-wide stewardship.</p>
Financing	
<p><b>Status:</b> International financing for outbreak management has started to flow. WHO's new Contingency Fund for Emergencies (CFE) has made 46 emergency allocations totaling \$36m, with more than 80% of allocations released within 24 hours. The World Bank has made available several new channels for countries to access financing for health crises.</p>	<p><b>Gaps:</b> Despite significant investments, only a fraction of required funding seems to have been mobilised. The fate of the G7's 2016 capacity building funding pledge to 76 countries is unclear. The CFE failed to meet its \$100m goal for the 2016-17 biennium and is currently short for 2018-19. The CFE is being spent down quickly, in addition to other gaps in WHO's budget. The US has not made financial commitments beyond 2019 for the GHSA, despite its renewal through 2024. Detailed tracking of financing remains a challenge.</p>

National Health Systems Capacity	
<p><b>Status:</b> Assessment is progressing steadily: 77 countries had completed Joint External Evaluation (JEE) by the end of May 2018, with 20 more scheduled. The US invested \$1 billion in IHR implementation through GHSA. National funding may be increasing but is difficult to track. WHO’s Health Emergencies Programme supported 39 countries to improve their preparedness. In addition to several regional initiatives, the World Bank committed to support at least 25 countries.</p>	<p><b>Gaps:</b> Inadequate funding remains a major barrier to increasing national capacity. Despite many JEEs conducted, few full-scale national action plans have been developed, funded, or implemented. Concerns persist that GHSA’s progress has been inadequate and will be difficult to sustain. Questions also remain on how outbreak capacity building can complement universal health coverage, and vice versa.</p>
World Health Organization	
<p><b>Status:</b> WHO continues to develop its operational capacity through its Health Emergencies Programme (WHE), whose leadership has received widespread regard. WHO is considered much better prepared to respond to outbreaks. The Director-General is engaging at high political levels, and outbreaks are a major component of the 2019-23 General Programme of Work.</p>	<p><b>Gaps:</b> WHE is seen as an operational island within a non-operational organisation. The sustainability of WHO reforms is at risk due to unstable and inadequate funding. Perennial questions remain about the relationship between headquarters and the regional and country offices, coordination with other UN agencies, and managing sensitive political relationships with outbreak-affected Member States – and will only be answered in the next major global pandemic.</p>
The Humanitarian Aid System	
<p><b>Status:</b> Protocols have been reformed and simulations conducted to improve coordination of humanitarian aid in health crises. The UN’s main humanitarian coordination body, the Inter-Agency Standing Committee, released and tested a new protocol for serious outbreaks. Several preparedness and response simulations were also conducted.</p>	<p><b>Gaps:</b> Post-Ebola reviews highlighted the importance of strengthening the humanitarian sector’s outbreak response capacity and coordination. The humanitarian system is already under strain with multiple ongoing complex emergencies that require resources that might otherwise go to reform. Managing outbreaks in conflict settings remains a major political and operational challenge for humanitarian organisations.</p>



### Research & Development of Health Technologies

**Status:** R&D has received extensive attention. The WHO's R&D Blueprint is the main source of global guidance for epidemic preparedness R&D, and includes ten prioritised pathogens, with related roadmaps and target product profiles. Vaccine development is a clear priority, with the Coalition for Epidemic Preparedness Innovations (CEPI) beginning to fund projects in 2018. A number of companies are conducting relevant R&D.

**Gaps:** Therapeutics, diagnostics and non-bio-medical interventions, such as personal protective equipment, have received less attention and financing than vaccines. Momentum has been lost, and it is unclear whether several priority-pathogen vaccine candidates will be submitted for or receive regulatory approval, whether they will be manufactured, affordable, or stockpiled, and ultimately used by directly-affected populations. These questions also hold for therapeutics, diagnostics and non-medical tools.

### Knowledge Sharing

**Status:** There is widespread agreement on the importance of knowledge sharing during a public health emergency. Initiatives at WHO and GloPID-R are working to address the many inherent challenges. A number of platforms have been designed to facilitate the free exchange of epidemiological and research data. There have also been significant efforts to improve risk-mapping and modeling for prediction and surveillance. The US National Academy of Medicine and WHO both released guidance for research during emergencies.

**Gaps:** Despite work to address knowledge sharing barriers, regulatory, legal, and ethical questions remain. There are no overarching frameworks to ensure knowledge sharing, reflected in the proliferation of pathogen-specific platforms. It is difficult to assess how widely these platforms are being used, their impact, or whether they are sufficient. Ensuring that pathogen samples (and related genomic sequencing data and benefits) are shared between researchers remains challenging, with limited information on the extent to which this is occurring.

### Trade & Travel Restrictions

**Status:** Minimising outbreak-related travel and trade restrictions unwarranted on scientific or public health grounds is critical for public health, humanitarian and economic reasons. WHO has strengthened monitoring of trade and travel restrictions. Both the World Economic Forum and Chatham House/Graduate Institute have launched efforts focusing on this problem, with active participation from the airline and tourism industries.

**Gaps:** There is no central framework or entity to govern the wide range of relevant public and private stakeholders involved in trade and travel restrictions. Further research is needed to better understand their causes and impacts, as well as greater political engagement to strengthen accountability for their negative consequences. Norms and reasonable expectations for private firms during outbreaks remain undefined.

*Overall, our analysis leads us to three priorities: First, significant investments are needed to strengthen outbreak management capacity, but thus far only a small fraction of required funding seems to have been committed at national or international levels. The large number of initiatives, the scope of funding required, and decreasing political attention have all contributed to this gap. In order to achieve adequate progress, more funding, and better tracking and coordination of those funds, are required.*

Second, it is difficult to meaningfully assess the overall level of global capacity to manage outbreaks, as doing so requires in-depth investigation of implementation efforts and specialised expertise, and no clear arrangements exist for doing so system-wide. Ideally, the new Global Pandemic Monitoring Board will be a much-needed independent global mechanism to ensure regular in-depth, system-wide tracking and assessment of efforts.

Finally, leadership, better coordination, and a clear governing framework are needed to ensure that efforts are coherent and that they sum up to a functional, adequate global system. In the absence of overarching stewardship, efforts are being made initiative by initiative and pathogen by pathogen. While the WHO can and does govern some areas, the overall system requires broader stewardship, a role we argue is best served by the UN. Without adequate leadership, momentum cannot be sustained, and the world will fall short of what is required to manage a major outbreak.

**Key Words**

outbreaks, global health, global governance, global health security, Ebola, monitoring & accountability, WHO, UN

## INTRODUCTION

There has been significant activity to strengthen global capacity to manage outbreaks of infectious disease since the West Africa Ebola crisis, and the issue has emerged as a focal area for both public and private actors. Despite the attention, there has been limited assessment of progress to date.

Over the past few decades, we have seen a cycle of urgency, then neglect, following major disease outbreaks. After each outbreak, panels and commissions make recommendations of what the world needs to do to ensure it is better prepared next time. The aftermath of the 2013-2016 Ebola epidemic saw seven major reports published reviewing what went wrong and how infectious disease outbreaks could be better managed.<sup>1-9</sup> The reviewed reports concluded that the world remained unprepared for major outbreaks of infectious disease. In January 2017, we published an analysis of those reports and identified areas of consensus on action, assessed what progress had been made, and highlighted gaps.<sup>10</sup>

Our assessment identified priority gaps in several areas. Here, we assess the current situation in each of the gap areas, including:

- Leadership and monitoring
- Financing
- National health systems capacity
- World Health Organization
- The humanitarian aid system
- Research and development of health technologies
- Knowledge sharing
- Travel and trade restrictions

The recent spread of Ebola to an urban centre in the Democratic Republic of Congo (DRC) highlights the importance of outbreak management capacity.<sup>11</sup> It is just one of many; already this year there have also been outbreaks of MERS, Dengue, Lassa Fever, Yellow fever, Nipah, and cholera.<sup>12</sup> Most of these were nationally contained. On the one hand, this points to solid response capacity. On the other, we have not yet seen a major stress test of the system for an outbreak of regional or global importance. As we get farther from the catalyst for this preparedness push, attention may wane, making monitoring even more important.

Findings for this paper were derived from a review of relevant published and unpublished reports and papers, official statements, news reports and other documents. These sources were supplemented with informal conversations with individuals with experience and expertise in relevant areas. However, given the broad scope and complex nature of the system being examined, this paper should be considered a high-level overview. While we tried to identify key activities in each area, the surge of new initiatives means that we cannot guarantee that all were covered.

## LEADERSHIP AND MONITORING

While there was significant discussion on outbreak preparedness immediately following the West Africa Ebola outbreak, the past year has seen a comparative decrease in political attention. Nevertheless, many actors demonstrated leadership to strengthen various aspects of global outbreak capacity – including governments, multilateral organisations, foundations, NGOs, companies, and researchers. However, there is no governing framework to ensure this proliferation of efforts sum up to a functional, adequate global system.

The post-Ebola reviews emphasised the importance of system-wide leadership extending beyond the health sector, but the United Nations (UN) has not stepped forward to take on this stewardship role. With a new UN Secretary General (UNSG) having taken the helm in 2017, it remains unclear what kind of leadership the UN will provide.

The World Health Organization (WHO) is well-placed to play a stewardship role in many areas, and has clearly done so with respect to country capacity assessment, research and development (R&D), and emergency response. In areas that extend beyond the health sector, such as travel and trade restrictions or providing aid in large-scale humanitarian crises, it is less obvious who should take global responsibility. Many have argued for UN headquarters to become engaged more systematically, including the 2016 final report of the UNSG's High-level Panel on the Global Response to Health Crises.<sup>5</sup>

In the absence of overarching coordination and stewardship, efforts are being made initiative by initiative and pathogen by pathogen. For example, the Ending Cholera - Road Map to 2030 was adopted by partners and WHO Member States in October 2017.<sup>13</sup> Eliminating yellow fever epidemics (EYE) was adopted by WHO's AFRO regional committee in August 2017.<sup>14</sup> The global influenza strategy was updated in September 2016.<sup>15</sup> Follow up of the Meningitis Vaccine Project Road Map document will be developed this year.<sup>16</sup> A MERS strategic overview was discussed at a multi-stakeholder meeting in September 2017.<sup>17</sup> A Zika global strategy is being developed, and may include alignment with other arbovirolosis (chikungunya, dengue).<sup>18</sup>

Monitoring and accountability are also challenging without central stewardship. That said, a number of initiatives have been launched in this area. In May 2017 the Global Health Security Agenda (GHSA) proposed an accountability mechanism to coordinate commitments made by

each country and track progress and outcomes. It would promote transparency among partners by making all commitments and outcomes publicly available and demonstrating GHSA's impact.<sup>19</sup> Data would be collected and compiled on a biannual basis by a sub-group of the GHSA Steering Group or a third-party entity, such as a foundation. The IHR Core Capacity Monitoring Framework monitors national governments' outbreak preparedness.<sup>20</sup> The Joint External Evaluation (JEE) Alliance also proposed metrics to monitor progress related to the JEE.

In its final report in mid-2017, the UNSG's Global Health Crises Task Force recommended that the SG develop and implement a new time-limited independent mechanism for reporting on the status of the world's preparedness.<sup>21</sup> The Global Preparedness Monitoring Board, created by WHO and World Bank Group, was announced during the 2018 World Health Assembly, after several years of discussions.<sup>22</sup> While it is an important step forward, key questions remain about its independence, membership, and modus operandi.

The Nuclear Threat Initiative, the Johns Hopkins Center for Health Security, and the Economist Intelligence Unit are developing a Global Health Security Index, a national-level assessment to aid systematic prioritisation of financing to fill gaps in country capability to prevent, detect, and respond to outbreaks, drawing from existing metrics, including the WHO JEE.<sup>23</sup>

The Harvard Global Health Institute (HGHI) and the US National Academy of Medicine (NAM) developed a shared monitoring framework. The framework includes quantitative indicators to track inputs, outcomes, and other indicators of epidemic management for each of four domains: strengthening public health capacity as a foundation; improving science, technology, and access; reinforcing risk analysis and incentives for action; and strengthening global mechanisms.<sup>24</sup>

A new research-oriented Global Health Security Conference will be held in Sydney, Australia, in June 2019, and aims to bring together stakeholders working in global health security to measure progress, determine gaps, and identify new opportunities to enhance health security, as well as share policy and research developments.<sup>25</sup>

## FINANCING

In order to achieve progress across the above issue areas, a significant increase in funding is necessary. An estimated additional \$4.5 billion average annual spending is needed to reach sufficient levels of emergency preparedness for health security.<sup>6</sup> Just to boost R&D, an incremental expenditure of \$1 billion per year would be required.<sup>6</sup>

The GHSA was launched in 2014 with \$45 million in funding from the U.S, followed by an additional \$1 billion commitment linked to Ebola funding. Additionally, Australia (\$100m) South Korea (\$100m), Japan \$(40m), and Canada (\$20m) have all made financial commitments in support of GHSA.<sup>26</sup> An estimated \$100m to \$200m per year will be required to continue GHSA. While the US has publicly announced its support for extending GHSA through 2024, commensurate funding has not been committed.<sup>27,28</sup> It has also been widely-reported that the US Centers for Disease Control and Prevention (CDC) will decrease their own country preparedness support by 80%.<sup>29,30</sup>

In 2016, G7 members committed to concretely assisting 76 countries and regions to develop national plans for strengthening prevention and preparedness against public health emergencies.<sup>31</sup> However, specific funding was not committed, making it difficult to track progress toward this pledge. There were no further commitments made by the G7 in 2017 or 2018, however the commitment to the International Health Regulations (IHR) and WHO's leadership in responding to public health emergencies was reinforced.<sup>32</sup>

WHO created a Contingency Fund for Emergencies (CFE) in 2015. In 2016-17, the fund received \$44.5m, leaving a \$55m gap from the initial goal.<sup>33</sup> In March, 12 member state pledged \$23m towards the 100m goal for the 2018-2019.<sup>34</sup> Since its founding, the CFE has disbursed \$36m in 46 emergency allocations to 31 countries/territories, two regional and one global response. The average amount released was \$580,000, and more than 80% of the allocations were released within 24 hours. In 2017, CFE funds enabled WHO to work with the Democratic Republic of Congo's government to contain the Ebola outbreak there, to respond to an urban pneumonic plague outbreak in Madagascar, and to successfully stem an outbreak of the Marburg virus on the Ugandan/Kenyan border.<sup>35</sup> The Fund is being depleted faster than it is being replenished.<sup>36</sup>

Gaps also persist in other WHO budget allocations. At the end of 2017 there remained a gap of 23% (\$110m out of \$485m) in WHO's core budget. The Outbreak Crisis Response (OCR) unit was

left with a 27% gap (\$293m out of \$1,073m budget).<sup>37</sup> Increasing support for the Global Outbreak Alert and Response Network (GOARN), a collaboration of institutions pooling human and technical resources for rapid identification, confirmation, and response to outbreaks, was a post Ebola recommendation.<sup>1,2,6</sup> However, when GOARN met in December 2017, it was not clear that any additional funding had been committed. WHO funding is chronically unstable, with assessed contributions providing less than a quarter of the budget and high dependency on voluntary funding, which is often tied to donors' priorities.

WHO is working to increase transparency about donor commitments at country level through the new Programme Budget Portal, which provides details of WHO's work, financing, and implementation progress.<sup>38</sup> On the portal countries specify financial details at output level, in order to comply with standards of the International Aid and Transparency Initiative (IATI).

The World Bank has several mechanisms for financing outbreak preparedness and response. Total financing is difficult to quantify as parts of many initiatives contribute to outbreak management capacity and we did not identify a unified source of information on contributions across the World Bank Group.

Following the Ebola epidemic, the Bank created the Pandemic Emergency Financing Facility (PEF) to help countries respond to major outbreaks.<sup>39</sup> An outbreak must meet specific criteria to trigger PEF financing, based on outbreak size, growth, and spread, and only after the WHO's CFE early disbursement mechanism is activated.\* The Insurance window became operational in July 2017, and a replenishable cash window will provide funding for diseases that may not meet the activation criteria for the bond.<sup>40</sup> The cash window made its first allocation in May 2018, an \$11.4m grant for the DRC's Ebola strategic response plan.<sup>41</sup> The Bank committed \$500m to PEF over the next five years.

In November 2015 the Bank expanded the eligibility criteria for accessing its Crisis Response Window (CRW), which provides resources following crises to prevent long-term development disruption, to include public health emergencies and epidemics.<sup>42</sup> The Bank's Disaster Risk Financing and Insurance Program (DRFIP) provides funding and expertise to help countries develop and implement financial protection strategies to increase resilience.<sup>43</sup> The International Development Association (IDA) and The International Bank for Reconstruction and Development (IBRD) provides bridge financing for health emergencies and other disasters and IDA offers an Immediate Response

\* The PEF covers six viruses it deems most likely to cause a pandemic: new Orthomyxoviruses, Coronaviridae, Filoviridae, Crimean Congo, Rift Valley, and Lassa fever.



Mechanism giving countries access to undisbursed balances to address urgent post crisis needs.<sup>44</sup>

The International Working Group on Financing Preparedness, supported by the World Bank and the Wellcome Trust, was created in November 2016 to propose ways in which national governments and development partners can ensure adequate and sustainable financing for outbreaks. The Working Group's May 2017 report set out 12 recommendations outlining a framework for roles and responsibilities in tackling pandemic preparedness. One recommendation suggested that the Bank include an assessment of pandemic preparedness capacity in the formula for IDA allocations, and recommended that other multilateral development banks consider introducing equivalent mechanisms to incentivise investment in preparedness.<sup>45</sup>

The philanthropic sector is also contributing. The Wellcome Trust has financed several outbreak preparedness initiatives and, with Norway and the Bill & Melinda Gates Foundation, was a driving force behind the Coalition for Epidemic Preparedness Innovations (CEPI). In addition, a group of philanthropies and private companies have formed the Ending Pandemics Collective (EPC), which was started by the Skoll Global Threats Fund, and is now convened by Ending Pandemics.\*

Overall, international financing has started to flow. However, detailed tracking of financing remains a major challenge. Georgetown University Center for Global Health Science and Security and Talus Analytics have developed a Global Health Security Funding Tracking Dashboard to map the flow of committed and disbursed international funds for outbreaks, based on an algorithm identifying which global health funding flows may contribute to this goal.<sup>46</sup> However, we did not find any aggregate estimates of how much is being invested globally in outbreak management, and data on national investments has been especially difficult to find. Without such estimates, it is impossible to track whether global financing is increasing or decreasing over time, nor the size of the financing gap.

\* EPC includes Facebook, the Future of Life Institute, the Bill & Melinda Gates Foundation, INQTEL, Intellectual Ventures, Open Philanthropy Project, the Page Family Foundation, the Parker Foundation, Resolve to Save Lives, the Rockefeller Foundation, salesforce.org, TEDMED, the Wellcome Trust, and Vulcan Philanthropies.

## NATIONAL HEALTH SYSTEMS CAPACITY

National capacity to manage outbreaks, including workforce development and training, was reiterated as a priority following Ebola. The first step in building country capacity is assessment, and increased emphasis was put on adding an external perspective to domestic capacity assessments post-Ebola. After being incubated within GHSA, WHO took the lead on implementing a “Joint External Evaluation (JEE)” process, arguably creating more widespread political acceptance. Twenty-nine countries underwent a JEE in the past year, for a total of 77 completed by the end of May 2018, with 20 additional evaluations scheduled.<sup>47</sup> Each evaluation is intended to result in a costed action plan, with many countries now in the phase of developing such plans. However, the lack of funding for conducting JEEs, or for the resulting action plans, risks discouraging countries from participating.

*Table 1: Status of Joint External Evaluations*

	<b>Completed</b>	<b>In pipeline</b>	<b>Not scheduled</b>	<b>No (%) of countries in income group with JEEs completed or scheduled</b>
Low income countries	Afghanistan, Benin, Burkina Faso, Burundi, Chad, Comoros, DRC, Eritrea, Ethiopia, Gambia, Guinea, Liberia, Madagascar, Mali, Mozambique, Rwanda, Senegal, Sierra Leone, Somalia, South Sudan, Tanzania, Togo, Uganda, Zimbabwe	DPR Korea, Malawi, Nepal, Niger,	Central African Republic, Guinea-Bissau, Haiti,	28/31 (88%)
Lower middle income countries	Armenia, Bangladesh, Bhutan, Cambodia, Cameroon, Cote d'Ivoire, Ghana, Indonesia, Kenya, Kyrgyz Republic, Lao PDR, Lesotho, Mauritania, Mongolia, Morocco, Myanmar, Nigeria, Pakistan, Sri Lanka, Sudan, Swaziland, Tunisia, Viet Nam, Zambia	Djibouti, Egypt, Micronesia, Moldova, Philippines, Timor-Leste	Bolivia, Cape Verde, Rep of Congo, El Salvador, Guatemala, Honduras, India, Kiribati, Nicaragua, Papua New Guinea, Sao Tome and Principe, Samoa, Solomon Islands, Syria, Tajikistan, Tonga, Ukraine, Uzbekistan, Vanuatu, Yemen	30/50 (60%)

Table 1: Status of Joint External Evaluations

	Completed	In pipeline	Not scheduled	No (%) of countries in income group with JEEs completed or scheduled
Upper middle Income	Albania, Belize, Botswana, Jordan, Lebanon, Maldives, Namibia, South Africa, Thailand, Turkmenistan, Georgia, Peru	Alergia, Angola, Iraq, Libya, Macedonia, Serbia	Argentina, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Brazil, China, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, Equatorial Guinea, Fiji, Gabon, Grenada, Guyana, Iran, Jamaica, Kazakhstan, Malaysia, Marshall Islands, Mauritius, Mexico, Montenegro, Palau, Panama, Paraguay, Peru, Romania, Russian Federation, St Lucia, St Vincent and the Grenadines, Suriname, Turkey, Tuvalu, Venezuela	18/56 (32%)
High income	Australia, Bahrain, Belgium, Finland, Japan, Rep Korea, Kuwait, Latvia, Liechtenstein, Oman, Qatar, Saudi Arabia, Seychelles, Singapore, Slovenia, Switzerland, UAE, USA, Portugal, United Kingdom	Brunei Darussalam, Canada, Lithuania, New Zealand	Andorra, Antigua and Barbuda, Austria, Bahamas, Barbados, Chile, Croatia, Cyprus, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Nauru, Netherlands, Norway, Poland, Portugal, Saint Kitts and Nevis, San Marino, Slovakia, Spain, Sweden, Trinidad and Tobago, Uruguay	24/58 (41%)
Not classified			Cook Islands, French Polynesia, Guam, Hong Kong SAR, Macao SAR, New Caledonia, Niue, Northern Mariana Islands, Occupied Palestinian Territory, Pitcairn Islands, Tokelau, Wallis and Futuna	0/12 (0%)
Total				100/207 (46)

Source: JEE Dashboard [Internet]. World Health Organization | Strategic Partnership Portal. [cited 2018 Jun 23]. Available from: <https://extranet.who.int/spp/jee-dashboard>

WHO developed the Strategic Partnership Portal (SPP) to establish a coordinated approach among national and international stakeholders supporting JEE missions and to develop, implement, and support global and national preparedness plans. The SPP aims to enable countries, donors, and other relevant health security stakeholders to track the IHR capacity building activities and initiatives that are being carried out at the country level.<sup>48</sup>

Once an action plan is developed, a country needs to cost out what it would take to implement the plan. There are currently several different tools to help countries calculate the cost of developing the required health capacities.<sup>49</sup> The World Bank's Health Security Financing Assessment Tool assesses current levels of expenditure, and used with the costing tools it assists countries in understanding current expenditures and estimating financing gaps.<sup>45</sup> The World Bank also convened the Health Security Financing Task Force, comprised of five Southeast Asian nations coming together to cost national health security plans.

The GHSA, with 64 participating countries, continues to be a driving force in building national health systems preparedness. While GHSA initially had a five-year mandate ending in 2018, it is now developing a strategic plan through 2024, though funding has not yet been committed for the extension.<sup>50</sup> Action Packages, each led by a member state, are country-driven focal points for discussion about each of the GHSA target areas of capacity building. The GHSA resulted in over 30 countries developing five-year roadmaps for achieving GHSA targets, as developing them was a requirement to receive US funding.

The GHSA Private Sector Roundtable was created to mobilise private industry to help countries strengthen systems for health security, engage companies across a broad array of industry sectors, and generate private sector insights and resources to address specific health and development risks and vulnerabilities.

Over the past year, the roles of both WHO and the World Bank in supporting country preparedness have significantly increased, and new global initiatives have been developed to support this work.

Since being mandated in May 2016, the WHO's new Health Emergencies Programme (WHE) has engaged in country preparedness in the areas of risk assessment, epidemic prevention and control, IHR assessment and capacities strengthening, and health systems strengthening. WHO's 2018-2019 biennium budget for country health emergency preparedness and the International Health Regulations totals nearly \$150 million.<sup>51</sup> In 2017, WHE supported health emergency responses in 44 countries and worked with 39 countries to improve preparedness.<sup>52</sup> WHE has prioritised support to fragile states, where many outbreaks occur but which have the least capacity.

The World Bank has also become involved in building national and regional capacity.<sup>53</sup> The IDA, which provides loans and grants to the poorest countries, committed in July 2017 to support at least 25 countries to develop pandemic preparedness plans and strengthen governance mechanisms for their implementation.<sup>54</sup> The Bank also engages in regional initiatives such as the Regional Disease Surveillance and Enhancement (REDISSE) Project for West Africa, the East Africa Public Health Laboratory Network, and a collaboration with Australia to promote health security in East Asia.<sup>53</sup> The Bank provides routine financing through IDA and IBRD, in the form of loans, credits, grants, and trust funds such as the Global Financing Facility to build both human and veterinary health systems and improve public health capacities under the umbrella of achieving universal health coverage and universal health security.

The above-mentioned Bank-supported International Working Group on Financing Preparedness recommended that national governments incorporate the private sector into their strategy for reinforcing preparedness, through a combination of awareness-building, direct involvement in preparedness and response planning, and regulation. In particular, where private companies contribute to the risks of disease outbreak by the nature of their business, national governments should introduce regulations requiring them to invest in risk mitigation and preparedness.<sup>45</sup>

The Africa Centers for Disease Control (Africa CDC) officially launched in January 2017 with an Emergency Operations Center in Ethiopia and five Regional Collaborating Centers. It works with Member States, the WHO, and other partners to strengthen public health in the areas of surveillance, information systems, laboratory systems, emergency preparedness and response, and public health research. In mid-2017 Africa CDC responded to the Ebola outbreak in Democratic Republic of Congo (DRC), and in November, it launched a framework to fight antibiotic resistant infections.<sup>55</sup>

Resolve to Prevent Epidemics, a new initiative led by former US CDC Director Tom Frieden, aims to catalyze technical assistance and funding to help countries turn plans for health capacity development into funded projects.<sup>56</sup>

The majority of emerging and reemerging infections are zoonotic or vector borne.<sup>57</sup> WHO is working with the Food and Agriculture Organization (FAO) and the World Organisation for Animal Health (OIE) in a tripartite One Health collaboration to address public health threats at the human-animal-ecosystems interface, and build national capacity to reduce those risks.<sup>58</sup> The US CDC also conducts One Health Zoonotic Disease Prioritization Workshops, which seek to aid countries in developing multisectoral partnerships, prioritising zoonoses of greatest national concern,

creating coordination mechanisms, and focusing the use of limited resources.<sup>59</sup> The Network for Evaluation of One Health is developing an evaluation protocol for One Health activities to further the evidence base.<sup>60</sup>

Following the West Africa Ebola outbreak, there was widespread recognition that community-led behaviour change was a major factor in containing transmission. Several new initiatives focus on ensuring that communities are partnering closely with implementing organisations and governments in responding to outbreaks. The Communication and Community Engagement Initiative began in early 2017, with a secretariat hosted by UNICEF, to address the need for a more systematic and coordinated approach to communications and community engagement with affected peoples.<sup>61</sup> UNICEF and the Institute for Development Studies at the University of Sussex also established a global partnership to carry out research on effective community engagement and risk communication needs.<sup>21</sup> In addition, the WHO R&D Blueprint includes guidance on Good Community Engagement Practices for conducting clinical research in emergencies.<sup>62</sup>

A lingering concern regards reconciling efforts to increase outbreak capacity with efforts to achieve Universal Health Coverage (UHC). Some are concerned that they compete for attention and funds, while others insist they can be mutually reinforcing. In December, the Universal Health Coverage Forum met in Tokyo, with the goal of stimulating global and country-level progress towards UHC.<sup>63</sup> A joint declaration released during the Forum stated that in pursuing UHC, members commit to targeted investments to prevent, detect and respond to disease outbreaks and other emergencies including surveillance systems.<sup>64</sup> More research is needed to better understand whether each agenda is being implemented in a manner complementary to the other, and how this can be improved.

**Panel 1: Building outbreak management capacity in Liberia**

Liberia applied lessons learned from the Ebola response to increase emergency preparedness and outbreak infrastructure. The Ministry of Health created a new department and appointed a Deputy Minister to lead efforts in developing a robust health emergency risk management system and lead implementation of the 2015-2021 National Investment Plan for Building a Resilient Health System. Liberia also established a new National Public Health Institute of Liberia (NPHIL). NPHIL's focus on building national laboratory and diagnostics capacity resulted in increasing the number of priority diseases for which they can test and reducing turnaround time for testing from three weeks to 24-48 hours. NPHIL also trains technicians, researchers, and epidemiologists. Its Field Epidemiology Training Program (FETP) trains surveillance officers, who are then deployed to each district and county. The Epi Division has already managed 50 events, including a meningitis outbreak and a suspected yellow fever outbreak. Isolation facilities and triage structures have been built to replace the temporary structures constructed during the Ebola response, and a new public health complex which will increase lab capacity and facilitate research on infectious diseases like Ebola, Measles, Yellow fever, and Lassa.

Human resources for health remains the outstanding gap for Liberia. Insufficient personnel has prematurely capped the development of some departments. In the event of another major outbreak, Liberia would still require assistance from outside health workers. They lack sufficient human resources in epidemiology, environmental health, anthropology, and laboratory technicians to handle a major emergency. This gap also impacts efforts to revitalize the overall health system. Moving forward, Liberia's top priorities are building staff capacity and securing sustainable funding for health. Their goal is to improve outbreak prevention, detection, and response, so as to prevent another crisis like the 2014/2015 Ebola Outbreak.

Source: Dr. Tolbert Nyenswah, National Public Health Institute of Liberia Director

## WORLD HEALTH ORGANIZATION

Significant attention has centred on the WHO and the reforms it implemented post-Ebola. The WHE was established in 2016, aiming “to build the capacity of Member States to manage health emergency risks and, when national capacities are overwhelmed, to lead and coordinate the international health response to contain outbreaks and to provide effective relief and recovery to affected populations”. The WHE screens 3,000 signals per month, following up on 300, and investigating around 30 events per month.<sup>52</sup> WHE conducts risk assessments on a subset of those, which are shared with key operational partners including GOARN. In its annual report, WHO stated that WHE’s response to public health events improved, including better coordination in health emergencies and faster deployment of WHO experts.<sup>65</sup> WHO is continuing to focus on its operational capacity in emergencies and to build the WHE, whose leadership has received widespread regard.

Since taking office in 2017, Director-General Dr. Tedros Adhanom Ghebreyesus has identified outbreak preparedness and response as a priority. In WHO’s thirteenth general programme of work 2019–2023, unanimously endorsed by the Executive board in January and approved by the World Health Assembly in May, one of the three strategic priorities articulated is health emergencies.<sup>66</sup> Dr. Tedros has stated an intent to transform the WHO, focusing on impact and accountability, and overhauling core business processes.<sup>67</sup>

Following these developments, many consider the WHO much better prepared to respond to health emergencies. There is concern, however, regarding the sustainability of these efforts due to unstable and inadequate funding for both outbreaks and WHO more broadly. Perennial questions remain about the working relationship between headquarters and the regional and country offices, and coordination with other UN agencies. A major criticism of WHO during the Ebola outbreak was that its business processes related to human resources and procurement were not sufficiently nimble to allow for rapid response to a fast-moving outbreak.<sup>1,68</sup> WHE is still seen as an operational island within a non-operational organisation.

WHO also plays a critical role as an arbiter of the severity of outbreaks globally. For this reason, the political skills, and ability of the Director-General to manage political pressure from its Member States are crucial. Given the recent leadership transition and establishment of the WHE, many believe the jury is still out on whether WHO’s progress to date is adequate to effectively manage a response to a major global outbreak.



## THE HUMANITARIAN AID SYSTEM

When outbreaks overwhelm the capacities of health actors or develop into complex emergencies, the broader humanitarian aid system becomes critical. Post-Ebola reviews highlighted the importance of strengthening the humanitarian sector's outbreak response capacity and coordination. The international aid system is already under heavy strain, however, with multiple ongoing complex emergencies that require resources that might otherwise go to reform.

Though the development of the Cluster System was a reaction to a previous call for increased coordination,<sup>69</sup> a recommendation for improved coordination and communication emerged once again following the Ebola response.<sup>1-4,6-8</sup> In April 2017, WHO issued the second edition of an Emergency Response Framework to try to improve processes for coordinating information on health threats.<sup>70</sup> With this same goal in mind, WHO is also working with the UN Operation and Crisis Centre to improve reporting on health threats internally within the UN system and with the UN Department of Public Information to improve coordination of external communications on health crises.

The Inter-Agency Standing Committee (IASC), the UN's main coordination body for humanitarian aid, responded to the recommendation to rely more on existing structures and protocols during a response, rather than trying to establish novel systems. The IASC developed a new protocol on Level 3 Activation Procedures for Infectious Disease Events, which was endorsed by its members in December 2016.<sup>71</sup> The protocol directs the immediate deployment of surge capacity and activation of appropriate field level leadership and coordination arrangements, as well establishing a link between the responsibilities of the WHO under the IHR and the capacities and emergency response tools of the IASC. Protocol deployment was simulated by IASC and UN leadership in late 2017.<sup>72</sup>

A number of preparedness and response simulations have been conducted. In January 2017, a pandemic simulation involving 30 private sector CEOs was organised by the World Bank and World Economic Forum (WEF).<sup>21</sup> The next month, WHO published a Simulation Exercise Manual to provide guidance on planning, conducting, and evaluating simulation exercises for outbreaks and public health emergency preparedness and response.<sup>73</sup> In May, ministers and representatives from international organisations simulated their response to a possible global disease outbreak at the G20 meeting.<sup>74</sup> A Simulation Exercise on Pandemic Preparedness was conducted with

Ministers of Finance from selected IDA funded countries during the World Bank/IMF Annual Meetings in October 2016.<sup>75</sup>

At the WHO Executive Board Meeting in January 2018, the WHO DG highlighted an idea that surfaced following Ebola - the creation of a global “health reserve army” to mobilise new capacities worldwide to support outbreak-affected countries.<sup>76</sup> There is a push to increase the capacity of the emergency workforce and better coordinate their deployment,<sup>77</sup> including through GOARN and the Emergency Medical Teams (trained and certified individuals, ready to be deployed anywhere in the world within 72 hours after sudden onset disaster is detected).<sup>78</sup>

Delivering aid in conflict settings remains a major deficit in humanitarian capabilities. The famine and long-running cholera epidemic in Yemen demonstrate the limitations of the humanitarian sector in conflict zones.<sup>79,80</sup> The UN system is likely to face severe challenges operating in conflict zones because of its intergovernmental nature, particularly when a member state is party to the conflict. This political challenge, which can limit access and undermine impartiality, remains a major barrier despite the focus on strengthening the operational capacity of WHO or UN agencies. There are a limited number of actors with capacity to respond in such settings.

## RESEARCH AND DEVELOPMENT OF HEALTH TECHNOLOGIES

R&D of technologies for outbreaks has received extensive attention. The WHO's R&D Blueprint is the main source of global guidance for epidemic preparedness R&D and for the rapid activation of R&D activities during epidemics.<sup>81</sup> The Blueprint includes a list of 10 priority diseases,<sup>\*</sup> with related roadmaps of action and target product profiles. The Blueprint seeks to improve coordination and foster an enabling environment, accelerate R&D processes, and develop new norms and standards tailored to the epidemic context. In the event of an outbreak, Blueprint activities will shift from R&D preparedness to an emergency R&D response plan. The list of Blueprint priority diseases underwent a second annual review in February 2018, reaffirming the initial list and adding Disease X, which represents the knowledge that a serious international epidemic could be caused by a pathogen that is currently unknown.<sup>82</sup>

Under the Blueprint, a Global Coordination Mechanism (GCM) for R&D preparedness held its first formal meeting in London in March 2017.<sup>83</sup> The GCM seeks to build a framework to address global R&D challenges during epidemics, while also providing a discussion and sharing platform, nurturing collaborations and addressing gaps, without duplication of efforts. WHO has also developed an R&D Blueprint Mapping Tool to visualise partner networks and activities in epidemic R&D preparedness, to be released in 2018.<sup>84</sup>

The Blueprint's first test came with the Zika epidemic. The Blueprint-guided response began with a survey of existing Zika research and product development and prioritisation of R&D activities for diagnostics, vaccines, and vector control measures.<sup>85</sup> WHO published target product profiles for Zika virus diagnostic tests<sup>86</sup> and vaccines<sup>87</sup> in mid-2016 and the Emergency Use Assessment and Listing (EUAL) procedure established to accelerate new product assessment during the Ebola response was opened to Zika diagnostics candidates.<sup>88</sup>

Other actors are also contributing. To ensure effective research during epidemic response the Global Research Collaboration for Infectious Disease Preparedness (GloPID-R), initiated by the European Union three years ago, works with research funders to facilitate an effective research response within 48 hours of an infectious disease outbreak. It aims to set a research agenda, share information, and address scientific, legal, ethical and financial challenges.<sup>89</sup>

\* Priorities for accelerated research and development were identified as Crimean-Congo haemorrhagic fever, Ebola virus disease and Marburg virus disease, Lassa fever, MERS-CoV and SARS, Nipah and henipaviral diseases, Rift Valley fever, Zika, and Disease X, which represents the knowledge that a serious international epidemic could be caused by a pathogen currently unknown to cause human disease.

## Vaccines

Post-Ebola, vaccine development has emerged as a clear priority, for both Ebola and other pathogens with outbreak potential. In the DRC Ebola outbreak, an investigational vaccine was used in the early stages of a response for the first time. Gavi supported the delivery of 7,560 vaccine doses donated by Merck, to high-risk health workers and in a ring vaccination strategy.<sup>90–92</sup> There are several Ebola vaccines in development,<sup>\*</sup> which have been shown to be safe and well tolerated after Phase I clinical trials.<sup>93</sup> Phase II and III trials were initiated during the west African epidemic but ended before Phase III trials could be completed.<sup>94</sup> Three leading candidates are in various stages of development,<sup>\*\*</sup> with stockpile commitments from Gavi for at least one.<sup>93,95–100</sup> Russia and China have each licensed an Ebola vaccine, though little data is available on either.<sup>101</sup>

The Ebola vaccine development efforts were a rare achievement, with multiple trials launched within months. It is unlikely that vaccines for other pathogens could be developed so quickly. Without the prospect of profits, finding a private sector partner to fund expensive trials required for licensing is difficult. Sanofi Pasteur pulled out of Zika vaccine work in September 2017, due to complications in development as well as evaporating market prospects and limited USG funding.<sup>102</sup> Sanofi Pasteur and the US Army came under criticism by members of Congress and NGOs for pursuing an exclusive license, which may have also contributed to their abandonment of the programme.<sup>103</sup> USG funding went to Takeda's Zika vaccine candidate, which was determined to be closer to clinical trials.<sup>102</sup> Adequate vaccine stockpiles also remain a challenge, though in September 2017 the US Biomedical Advanced Research and Development Authority awarded \$84M towards development and procurement of the Merck and Janssen Ebola vaccines.<sup>104</sup>

Another significant development on the vaccine front, the Coalition for Epidemic Preparedness Innovations (CEPI) was launched<sup>\*\*\*</sup> and is initially targeting the MERS-CoV, Lassa, and Nipah viruses.<sup>105,106</sup> CEPI signed its first partnership agreement with Vienna based Themis Bioscience in early March 2018, to develop vaccines against Lassa Fever and MERS.<sup>107</sup> While many are

\* The Partnership for Research on Ebola Vaccination (PREVAC) is conducting an ongoing Phase II trial comparing three experimental Ebola vaccination strategies with placebo regimens. It was launched in late March 2017 in Liberia and Guinea and plans expansion to Sierra Leone, with a target of enrolling 5,500 participants.

\*\* Initially developed by the Public Health Agency of Canada (PHAC), Merck's V920 Ebola vaccine (for the Zaire strain), was tested in the Guinea ring vaccination, cluster-randomised trial (Ebola Ça Suffit!) in 2015, with promising results, including evidence of protection after a single immunisation. Merck and Gavi reached an agreement to establish an emergency stockpile of 300,000 doses. The Vaccine Research Center (VRC) of the National Institute of Allergy and Infectious Diseases in collaboration with Okairos (now a division of GlaxoSmithKline) also developed a vaccine for Ebola (Zaire strain). VRC will conduct further research on candidates for Marburg and Ebola (Sudan strain) later this year. The Oxford Vaccine Group and Johnson & Johnson's Janssen Vaccines announced in March that their candidate induced a durable immune response in 100 percent of healthy volunteers one year following vaccination. The WHO's Strategic Advisory Group of Experts (SAGE) on Immunisation Working Group reviewed all the vaccines and made recommendations for their use in September 2015.

\*\*\* CEPI is funded by the Wellcome Trust, the Bill & Melinda Gates Foundation, the European Commission, and the governments of Norway, Japan, and Germany. Belgium, Canada, and Australia also recently made funding commitments.

enthusiastic about the rapid pace with which CEPI was developed and launched, concerns have been raised about what will be required to keep major pharmaceutical companies engaged, and about CEPI's selection of priority diseases. Some doubts have been raised regarding the feasibility of creating platforms usable across multiple vaccines, particularly as Zika vaccine development did not build off the dengue vaccine. While CEPI did not list Ebola or related viruses as initial targets for vaccine development it did convene a meeting in 2017 on the issue of how to gain regulatory approval for filovirus vaccines.<sup>108</sup>

### **Diagnostics & Therapeutics**

Diagnostics and therapeutics seem to have received less attention and funding than vaccines. Despite this, research has continued. For example, more than a dozen diagnostic tools that can detect Ebola virus in a matter of hours now exist.<sup>81</sup> A new blood test using a simple paper strip and costing less than \$1 can cheaply and quickly distinguish between the Zika and dengue viruses.<sup>109</sup> Investments in therapeutics are also being made, including by many public research funders, academic research centres and private pharmaceutical firms.<sup>81</sup>

In June 2017, with startup funding from Germany, CEPI and the Foundation for Innovative New Diagnostics (FIND) formed a partnership to start CEPIdx, to strengthen global diagnostic preparedness by addressing the key issues around the development and uptake of critical diagnostics.<sup>110</sup> In May, the founders published a proposed framework for diagnostic preparedness and response, framed around outbreak detection, research and development, manufacturing and distribution, and implementation of new diagnostic tools.<sup>111</sup> It seeks a unified vision for diagnostics development and identifies 14 factors key to speeding up diagnostic responses.

### **Development of non-clinical outbreak response technologies**

During the Ebola outbreak, there was a recognition that there was a need for R&D on other non-clinical tools needed to support the fight against emerging infectious diseases. Competitions were held for innovative tools to help in the response, including the development of better "PPE" (personal protective equipment) and rapidly deployable bio-containment units. While prototypes for each of these products were developed, they are not yet available, and there is no process in place to ensure new research is translated into protocols that will be consistently used.<sup>112-114</sup>

## KNOWLEDGE (DATA) SHARING

Sharing knowledge and data on outbreak-prone pathogens in a timely and transparent manner remains challenging. In addition to a lack of incentives and inadequate infrastructure, there are complex regulatory, ethical, and legal questions. Despite the challenges, there is widespread agreement that in the context of a public health emergency, there is an imperative to make available any information that might contribute to combatting the crisis.

In September 2015, the WHO held a consultation on Data and Results Sharing During Public Health Emergencies, which identified challenges to data sharing, and potential solutions.<sup>115</sup> Challenges include data protection, confidentiality of potentially re-identifiable data, individual countries' data protection legislation, concerns about consent, the tension between rapid sharing and accuracy, political and cultural issues, reciprocity concerns, and poor systems for knowledge curation. Solutions offered included regulatory frameworks, better knowledge curation, formal data sharing platforms, rewards, and standardizing agreements.

Together, research organisations, journals, and donors also published a statement to call for all research data gathered during the Zika virus outbreak, and future public health emergencies, to be made available as rapidly and openly as possible.<sup>116</sup> Journals agreed to make all content concerning the emergency available open access, and ensured that any data openly shared ahead of submission would not pre-empt its publication. Funders agreed to require researchers undertaking work relevant to public health emergencies to set up mechanisms for sharing quality-assured interim and final data as rapidly and widely as possible.

GloPID-R established the Data Sharing Working Group in March 2016, chaired by Wellcome Trust, to develop a system for data sharing during public health emergencies.<sup>117</sup> To help remove barriers to data sharing they are developing principles for data sharing, a Public Health Emergency Decision Tree, and case studies to document data-sharing practices in past emergencies.

Chatham House has developed an online guide to facilitate data sharing, which aims to create a conducive environment for data sharing and facilitate ethical sharing practices.<sup>118</sup>

### **Data sharing platforms**

While there are no overarching frameworks for knowledge sharing across pathogens that could potentially cause large scale public health threats, there has been a proliferation of different platforms designed to facilitate the free exchange of epidemiological and research data. The Infectious Diseases Data Observatory (IDDO), an international research network based at the University of Oxford, has online data sharing platforms for Ebola, malaria, and visceral leishmaniasis.<sup>119</sup> The WHO hosts Zika Open, a space within the Bulletin of the World Health Organization, where experts can share their data, which is freely available for unrestricted use.<sup>120</sup> FluID is a global influenza epidemiological data sharing platform.<sup>121</sup> Wellcome Trust, Sanger Institute and Imperial College London developed Microreact, an epidemic visualisation and tracking platform that has been used to monitor outbreaks of Ebola, Zika and antibiotic-resistant microbes.<sup>122</sup> The Nuffield Department of Obstetrics & Gynaecology produced an online, digital information sharing platform for Zika.<sup>123</sup> CDC and Palantir Technologies developed the System for Enteric Disease Response, Investigation, and Coordination, an online platform developed to facilitate collaborative multistate outbreak investigations of enteric disease.<sup>124</sup> It is difficult to assess, however, how widely these platforms are being used, or what their impact has been.

### **Sample sharing**

Ensuring that pathogen samples (and related genomic sequencing data) are shared between laboratories remains challenging, with limited information publicly available regarding the extent to which this is or is not occurring. Brazil delayed sharing Zika samples, partly due to national law, which may have hindered international efforts to combat the virus.<sup>125</sup> When the Pandemic Influenza Preparedness (PIP) framework was reviewed in late 2016 a decision was made that PIP would not be extended to other pathogens. While no overarching framework exists for sample-sharing beyond influenza, WHO has developed a Material Transfer Agreement capacity building tool to facilitate pathogen- and benefit-sharing between research entities and countries.<sup>126</sup>

### **Clinical trials**

The WHO R&D Blueprint includes a workstream on designs for clinical trials in emergencies. It has developed tools including a guidance document on major study designs to be used during emergencies, an interactive decision tree to help researchers explore design methodology options, and a modelling platform to simulate different trial designs under disease outbreak scenarios.<sup>81</sup>

The US NAM conducted an assessment of the clinical trials conducted during the Ebola response to assess the value of those trials. They concluded that the therapeutic trials were not as

successful as they could have been, but the vaccine trials were more fruitful. The committee found that the randomised controlled trial was an ethical and appropriate design to use, and in most circumstances, should be used, even during epidemics. They recommended that clinical research be embedded within the local healthcare system, and that during an epidemic an independent rapid research response workgroup should convene, to prioritise products for trial, assess trial designs, and monitor and evaluate the trials.<sup>127</sup>

Strengthening national clinical research capacity is a key part of epidemic preparedness. The World Bank and CEPI created the International Vaccines Task Force in October 2017 to strengthen research capacity in low-income countries, including appropriate physical infrastructure, trained health research workforce, functional ethics committees, regulatory capacity, and expertise in social sciences.<sup>128</sup> In May 2018, the Task Force issued its final report, addressing how to develop the political support, financing, and coordination required to build national research capacity.<sup>129</sup>

### **Surveillance**

Although there are a number of independent initiatives in the area of surveillance, a maturation of the global event-based surveillance system is key, combined with strengthened baseline country-wide surveillance in all countries.

Connecting Organizations for Global Disease Surveillance (CORDS) has been in existence for eight years, and is comprised of six international networks, working to reduce and prevent the spread of infectious diseases by exchanging information between surveillance systems globally.<sup>130</sup> It aims to improve surveillance capacity, build sustainable surveillance networks, promote innovation, and advance One Health.

In 2015 the Bill & Melinda Gates Foundation committed support for the Child Health and Mortality Prevention Surveillance Network (CHAMPS), to collect and share data on under five morbidity and mortality from six sites in Africa and South Asia, with the aim of preventing childhood mortality and helping prepare for the next epidemic.<sup>131</sup>

Growing out of the Skoll Global Threats Fund, Ending Pandemics is a new initiative working to detect, verify, and report outbreaks faster around the world. They seek to apply innovation that already exists to improve surveillance.<sup>132</sup>



Several new surveillance tools are bringing together different sources of data. DiSARM, being developed by the University of California, San Francisco's Global Health Group, is a spatial intelligence tool, to enable disease prediction and control programme to deliver more effective field campaigns.<sup>133</sup> Building off of Dengue Track, eBarometer, being developed by The Synergist in partnership with Harvard Medical School and Boston Children's Hospital, bundles data from a variety of public and private sources, including crowd surveillance, for outbreak management.<sup>134</sup> EpiHack brings together health and related professionals at workshops to create, adapt, and improve existing or prototype technologies in order to improve disease surveillance.<sup>135</sup> The Doctor Me app in Thailand uses digital volunteerism to identify potential outbreaks by incorporating a participatory disease detection mechanism into its existing web and mobile platforms to capture data for faster disease detection.<sup>136</sup> Metabiota seeks to identify and track pathogens, and to contextualise the risk they pose based on socioeconomic, political, environmental and other factors.<sup>137</sup>

Two initiatives are surveilling zoonotic viruses. To contain pandemics, scientists are investigating viruses that might spread from wildlife to humans. The PREDICT project, led by the One Health Institute at the School of Veterinary Medicine at the University of California, Davis, seeks to identify viruses with potential for zoonotic outbreaks before they become a pandemic. A project of USAID's Emerging Pandemic Threats programme, PREDICT works with over 30 countries in Asia and Africa.<sup>138</sup> More recently, the Global Virome Project was created to detect and sequence the DNA of viruses present in wildlife, in order to pre-empt emerging pandemic threats by identifying unknown viruses around the world that are likely to infect humans.<sup>139</sup>

### **Risk Mapping and Modeling**

There has been progress in approaches to risk-mapping and modeling for prediction. The Models of Infectious Disease Agent Study (MIDAS) is an interagency/private sector group conducting advancing predictive modeling for infectious disease threats. MIDAS is a collaboration of research and informatics groups developing computational models of the interactions between infectious agents and their hosts, disease spread, prediction systems and response strategies.<sup>140</sup> The Institute for Health Metrics and Evaluation conducted a study assessing subnational pandemic potential for four viral haemorrhagic fevers in Africa, to aid in identifying priorities for outbreak mitigation and prevention.<sup>141</sup> The World Economic Forum is developing a Corporate Infectious Disease Risk Dashboard to enable companies to visualise estimates of expected costs to their business associated with infectious disease outbreaks.<sup>142</sup>

## TRAVEL AND TRADE RESTRICTIONS

Following the Ebola outbreak, numerous reports cited the need to prevent travel and trade restrictions that are not warranted on scientific or public health grounds. Such restrictions exacerbate the economic impact of outbreaks, make it harder for aid organisations to support affected regions, and disincentivise outbreak reporting.

The WHO has strengthened monitoring of trade and travel restrictions. The UNSG's Task Force proposed posting travel and trade measures and their rationale on a WHO website, to promote greater transparency and accountability.<sup>21</sup> In November 2017, a Chatham House/Graduate Institute paper proposed a set of indicators and areas to monitor regarding travel and tourism.<sup>143</sup> It concluded that in order to develop a comprehensive, systematic monitoring framework, new sources of data on private stakeholder reactions would need to be developed, and the method for collecting data on government reactions would need to be strengthened.

The World Economic Forum is working to bring the private sector into preparedness efforts. Their Epidemics Readiness Accelerator includes a Travel and Trade Workstream, which explores the driving forces behind and impact of travel restrictions during outbreaks, and works to improve decision-making, coordination, and communications within and between both the public and private sectors, relating to travel advisories and border measures. The above-mentioned WEF simulation tested private and public sector reactions to an epidemic, with a focus on travel.

However, overall progress in this area is insufficient. There is no central framework or entity to govern the wide range of relevant public and private stakeholders involved in trade and travel restrictions. Reasonable norms and expectations for private firms during outbreaks remain undefined. Further research is needed to better understand their causes and impacts, and greater political engagement is needed to strengthen accountability for the negative consequences of unwarranted trade and travel interruptions.

## CONCLUSIONS

Significant progress in strengthening global capacity to manage outbreaks has, without question, been made. The past several years have been characterised by the implementation of many of the key policy changes and decisions made in the immediate post-Ebola era. The wealth of initiatives and efforts is encouraging, but also raises questions about ensuring adequate financing for the multiplicity of projects, as well as governance challenges with respect to coherence and accountability. It also highlights the need for a more sensitive barometer of global capacity to deal with outbreaks, which requires more in-depth, system-wide tracking of efforts across diverse issue areas than currently exists.

We conclude that attention is needed in three priority areas:

**Funding** - Significant investments are needed to strengthen outbreak management capacity, but thus far only a small fraction of required funding seems to have been committed at national or international levels. The large number of initiatives, the scope of funding required, and decreasing political attention have all contributed to this gap. In order to achieve adequate progress, more funding, and better tracking and coordination of those funds, are required.

**Monitoring** - It is difficult to meaningfully assess the overall level of global capacity to manage outbreaks, as doing so requires in-depth investigation of implementation efforts and specialised expertise, and no clear arrangements exist for doing so system-wide. Ideally, the new Global Pandemic Monitoring Board will be a much-needed independent global mechanism to ensure regular in-depth, system-wide tracking and assessment of efforts.

**Leadership** – Leadership and a clear governing framework are needed to ensure that efforts are coherent and that they sum up to a functional, adequate global system. In the absence of overarching stewardship, efforts are being made initiative by initiative and pathogen by pathogen. While the WHO can and does govern some areas, the overall system requires broader stewardship, as the actors and issues extend beyond the health sector. We believe this role is best played by the UN.

It is unclear how much better prepared the global system is today for a major outbreak than it was a few years ago. The evidence suggests that efforts have been considerable, but have not progressed far enough, fast enough, or with enough financing. Without adequate leadership, momentum cannot be sustained, and the world will fall short of what is required to manage a major outbreak.

## ENDNOTES

- 1) World Health Organization. Report of the Ebola Interim Assessment Panel A68/25. 2015. [http://apps.who.int/gb/ebwha/pdf\\_files/WHA68/A68\\_25-en.pdf](http://apps.who.int/gb/ebwha/pdf_files/WHA68/A68_25-en.pdf)
- 2) Moon S, Sridhar D, Pate MA, et al. Will Ebola change the game? Ten essential reforms before the next pandemic. The report of the Harvard-LSHTM Independent Panel on the Global Response to Ebola. *Lancet* 2015;356:2204-21. doi:10.1016/S0140-6736(15)00946-0 pmid:26615326.
- 3) World Health Organization. Advisory Group on Reform of WHO's Work in Outbreaks and Emergencies; first report. 2015. [http://www.who.int/about/who\\_reform/emergency-capacities/advisory-group/first-report.pdf?ua=1](http://www.who.int/about/who_reform/emergency-capacities/advisory-group/first-report.pdf?ua=1)
- 4) World Health Organization. Second report of the Advisory Group on Reform of WHO's Work in Outbreaks and Emergencies. 2016. [http://www.who.int/about/who\\_reform/emergency-capacities/advisory-group/second-report.pdf?ua=1](http://www.who.int/about/who_reform/emergency-capacities/advisory-group/second-report.pdf?ua=1)
- 5) High-Level Panel on the Global Response to Health Crises. Protecting humanity from future health crises. 2016. Report No.: A/70/723. [http://www.un.org/News/dh/infocus/HLP/2016-02-05\\_Final\\_Report\\_Global\\_Response\\_to\\_Health\\_Crises.pdf](http://www.un.org/News/dh/infocus/HLP/2016-02-05_Final_Report_Global_Response_to_Health_Crises.pdf)
- 6) Commission on a Global Health Risk Framework for the Future; National Academy of Medicine Secretariat. The Neglected Dimension of Global Security: A Framework to Counter Infectious Disease Crises. National Academies Press, 2016.
- 7) Checchi F, Waldman RJ, Roberts LF, et al. World Health Organization and emergency health: if not now, when? *BMJ* 2016;356:i469. doi:10.1136/bmj.i469 pmid:26821569.
- 8) World Health Organization. Implementation of the International Health Regulations (2005). Report of the Review Committee on the Role of the International Health Regulations (2005) in the Ebola outbreak and response A69/21. 2016. [http://apps.who.int/gb/ebwha/pdf\\_files/WHA69/A69\\_21-en.pdf?ua=1](http://apps.who.int/gb/ebwha/pdf_files/WHA69/A69_21-en.pdf?ua=1)
- 9) United Nations General Assembly. Strengthening the global health architecture: implementation of the recommendations of the High-level Panel on the Global Response to Health Crises.; 2016. [http://www.un.org/ga/search/view\\_doc.asp?symbol=A/70/824](http://www.un.org/ga/search/view_doc.asp?symbol=A/70/824).
- 10) Moon, S., Leigh, J., Woskie, L., Checchi, F., Dzau, V., Fallah, M., ... & Katz, R. (2017). Post-Ebola reforms: ample analysis, inadequate action. *Bmj*, 356, j280. Available: <http://www.bmj.com/content/356/bmj.j280>
- 11) Emergencies preparedness, response | 2017 [Internet]. WHO. [cited 2018 Jan 16]. Available from: <http://www.who.int/csr/don/archive/year/2017/en/>
- 12) High-Level Panel on the Global Response to Health Crises. Protecting humanity from future health crises. 2016. Report No.: A/70/723. [http://www.un.org/News/dh/infocus/HLP/2016-02-05\\_Final\\_Report\\_Global\\_Response\\_to\\_Health\\_Crises.pdf](http://www.un.org/News/dh/infocus/HLP/2016-02-05_Final_Report_Global_Response_to_Health_Crises.pdf)
- 13) Global Task Force on Cholera Control. Ending Cholera | A Global Roadmap to 2030 [Internet]. 2017 Oct. Available from: <http://www.who.int/cholera/publications/global-roadmap.pdf>
- 14) Global Strategy to Eliminate Yellow fever Epidemics (EYE) [Internet]. World Health Organization; 2016 Sep. Available from: [http://www.who.int/immunization/sage/meetings/2016/october/2\\_EYE\\_Strategy.pdf](http://www.who.int/immunization/sage/meetings/2016/october/2_EYE_Strategy.pdf)
- 15) Pandemic Influenza Risk Management | A WHO guide to inform & harmonize national & international pandemic preparedness and response [Internet]. World Health Organization; 2017 May. Available from: <http://apps.who.int/iris/bitstream/10665/259893/1/WHO-WHE-IHM-GIP-2017.1-eng.pdf?ua=1>
- 16) Meningitis Vaccine Project: Deadly epidemic gives rise to groundbreaking partnership [Internet]. PATH. [cited 2018 Feb 19]. Available from: <https://www.path.org/menafrivac/about-mvp.php>
- 17) Regional Committee for the Eastern Mediterranean. Progress report on emerging and re-emerging diseases including dengue and dengue haemorrhagic fever [Internet]. World Health Organization; 2016 Sep. Report No.: EM/RC63/INF.DOC 2 Rev.2. Available from: [http://applications.emro.who.int/docs/RC\\_technical\\_papers\\_2016\\_inf\\_doc\\_2\\_19010\\_EN.pdf?ua=1&ua=1](http://applications.emro.who.int/docs/RC_technical_papers_2016_inf_doc_2_19010_EN.pdf?ua=1&ua=1)
- 18) Zika Strategic Response Plan [Internet]. World Health Organization; 2016 Jul. Report No.: WHO/ZIKV/SRF/16.3. Available from: <http://www.who.int/emergencies/zika-virus/strategic-response-plan/en/>
- 19) GHSA. GHSA Steering Group Meeting "Take Action: ACE for GHSA" [Internet]. 2017. Available from: <https://www.ghsagenda.org/docs/default-source/default-document-library/21-may-2017-steering-group-meeting-agenda-and-concept-note.pdf>
- 20) WHO. Joint External Evaluation Tool: International Health Regulations. IHR(2015) Monitoring and Evaluation Framework. 2016. Available from: [http://apps.who.int/iris/bitstream/10665/204368/1/9789241510172\\_eng.pdf](http://apps.who.int/iris/bitstream/10665/204368/1/9789241510172_eng.pdf)

- 21) Nuzzo J. Johns Hopkins Center for Health Security Teams with NTI and the Economist Intelligence Unit to Develop a Global Health Security Index [Internet]. The Bifurcated Needle. 2017 [cited 2018 Feb 10]. Available from: <http://www.bifurcatedneedle.com/new-blog/2017/3/6/johns-hopkins-center-for-health-security-teams-with-nti-and-the-economist-intelligence-unit-to-develop-a-global-health-security-index>
- 22) Harvard Global Health Institute. 2018. Global Monitoring of Epidemic and Pandemic Preparedness: A Shared Framework. Harvard University, Cambridge, MA. Available from: <https://globalhealth.harvard.edu/>
- 23) Welcome | Global Health Security 2019 [Internet]. Global Health Security 2019. [cited 2018 Feb 9]. Available from: <http://ghs2019.com/welcome.php>
- 24) Global Health Crises Task Force Final Report [Internet]. Global Health Crises Task Force, United Nations; 2017 Jun. Available from: <http://www.un.org/en/pdfs/Final%20Report.Global%20Health%20Crises%20Task%20Force.pdf>
- 25) Nuzzo JB, Cicero AJ, Inglesby TV. The importance of Continued US Investment to Sustain Momentum Toward Global Health Security. JAMA. 2017 Dec 26;318(24):2403–503.
- 26) Tillerson R W. Remarks at the Grand Challenges Annual Meeting [Internet]. U.S. Department of State. 2017. Available from: <http://www.state.gov/secretary/remarks/2017/10/274635.htm>
- 27) Banin E. Healthier World, Safer America: a US Government roadmap for international action a to prevent the next pandemic [Internet]. PATH; 2017 Dec. Available from: [https://www.path.org/publications/files/APP\\_GH\\_Security\\_rpt\\_rev.pdf](https://www.path.org/publications/files/APP_GH_Security_rpt_rev.pdf)
- 28) McKay B. CDC to Scale Back Work in Dozens of Foreign Countries Amid Funding Worries. Wall Street Journal [Internet]. 2018 Jan 19 [cited 2018 Feb 10]; Available from: [https://www.wsj.com/articles/cdc-to-scale-back-work-in-dozens-of-foreign-countries-amid-funding-worries-](https://www.wsj.com/articles/cdc-to-scale-back-work-in-dozens-of-foreign-countries-amid-funding-worries-1516344400)
- 29) Sun LH. CDC to cut by 80 percent efforts to prevent global disease outbreak. Washington Post [Internet]. 2018 Feb 1 [cited 2018 Feb 10]; Available from: <https://www.washingtonpost.com/news/to-your-health/wp/2018/02/01/cdc-to-cut-by-80-percent-efforts-to-prevent-global-disease-outbreak/>
- 30) G7 Ise-Shima Vision for Global Health. 2016. Available from: <http://www.mofa.go.jp/files/000160273.pdf>
- 31) G7 Milan Ministers' Communiqué. 2017. Available from: [http://www.g7italy.it/sites/default/files/documents/FINAL\\_G7\\_Health\\_Communiq%C3%A8\\_Milan\\_2017\\_0.pdf](http://www.g7italy.it/sites/default/files/documents/FINAL_G7_Health_Communiq%C3%A8_Milan_2017_0.pdf)
- 32) WHO. Contingency Fund for Emergencies. Enabling Quick Action to Save Lives. 2017. Available from: [http://www.who.int/about/who\\_reform/emergency-capacities/contingency-fund/CFE-what-is-2January2018-ver8.pdf](http://www.who.int/about/who_reform/emergency-capacities/contingency-fund/CFE-what-is-2January2018-ver8.pdf)
- 33) Jenny Lei Ravelo. 18 months in, how is WHO's health emergencies program working? [Internet]. Devex. 2018 [cited 2018 Feb 1]. Available from: <https://www.devex.com/news/sponsored/18-months-in-how-is-who-s-health-emergencies-program-working-91956>
- 34) Health Emergencies Programme. Update on the WHO Health Emergencies Programme. 2017 Dec 4; World Health Organization.
- 35) Programme Budget Web Portal [Internet]. World Health Organization. [cited 2018 Feb 10]. Available from: <http://open.who.int/>
- 36) Bank DF Human Development, and Treasury Vice-Presidencies. Pandemic emergency financing facility : global pandemic response through a financial intermediary fund [Internet]. The World Bank; 2016 May [cited 2016 Jun 19] p. 1–33. Report No.: 104838. Available from: <http://documents.worldbank.org/curated/en/2016/05/26238695/pandemic-emergency-financing-facility-global-pandemic-response-through-financial-intermediary-fund>
- 37) Pandemic Emergency Financing Facility (PEF) Operational Brief for Eligible Countries [Internet]. Pandemic Emergency Financing Facility; 2017 Nov. Available from: <http://pubdocs.worldbank.org/en/574211510673362977/PEF-Operational-Brief-Nov-2017.pdf>
- 38) Crisis Response Window [Internet]. International Development Association. 2016 [cited 2018 Feb 19]. Available from: <http://ida.worldbank.org/financing/crisis-response-window>
- 39) Disaster Risk Financing and Insurance (DRFI) Program [Internet]. The World Bank. 2018 [cited 2018 Feb 19]. Available from: <http://www.worldbank.org/en/programs/disaster-risk-financing-and-insurance-program>
- 40) International Working Group on Financing Preparedness. From Panic and Neglect to Investing in Health Security: Financing Preparedness at a National Level. The World Bank; 2017 May. Available from: <http://documents.worldbank.org/curated/en/979591495652724770/pdf/115271-REVISED-PUBLIC-IWG-Report-Conference-Edition-8-10-2017-low-res.pdf>
- 41) Global Health Security Funding Tracking Dashboard [Internet]. Center for Global Health Science and Security. [cited 2018 Jan 17]. Available from: [https://ghss.georgetown.edu/ghs\\_tracking](https://ghss.georgetown.edu/ghs_tracking)
- 42) JEE Dashboard [Internet]. World Health Organization | Strategic Partnership Portal. [cited 2018 Jan 17]. Available from: <https://extranet.who.int/spp/jee-dashboard>
- 43) About Strategic Partnership Portal (SPP) [Internet]. World Health Organization | Strategic Partnership Portal. [cited 2018 Feb 10]. Available from: <https://extranet.who.int/spp/about-strategic-partnership-portal>

- 44) Welcome to the IHR Costing Tool [Internet]. IHR Costing Tool. [cited 2018 Feb 9]. Available from: <http://ghscosting.org/>
- 45) International Working Group on Financing Preparedness. From Panic and Neglect to Investing in Health Security: Financing Preparedness at a National Level [Internet]. The World Bank; 2017 May. Available from: <http://documents.worldbank.org/curated/en/979591495652724770/pdf/115271-REVISED-PUBLIC-IWG-Report-Conference-Edition-8-10-2017-low-res.pdf>
- 46) The 4th GHSA High Level Ministerial Meeting. The Kampala Declaration on the Global Health Security Agenda [Internet]. Global Health Security Agenda; 2017. Available from: [https://www.ghsagenda.org/docs/default-source/default-document-library/kampala-declaration-2017\\_web.pdf?sfvrsn=4](https://www.ghsagenda.org/docs/default-source/default-document-library/kampala-declaration-2017_web.pdf?sfvrsn=4)
- 47) Proposed programme budget 2018–2019 [Internet]. World Health Organization; 2017 Apr. Document No.: A70/7. Available from: [http://apps.who.int/gb/ebwha/pdf\\_files/WHA70/A70\\_7-en.pdf](http://apps.who.int/gb/ebwha/pdf_files/WHA70/A70_7-en.pdf)
- 48) Key results for WHO's work on emergencies in 2017 [Internet]. World Health Organization. [cited 2018 Jan 17]. Available from: <http://www.who.int/emergencies/achievements/2017-in-figures/en/>
- 49) Osewe PL. Options for financing pandemic preparedness. Bull World Health Organ. 2017 Dec 1;95(12):794–794A. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5710087/>
- 50) Bank TW. Report from the Executive Directors of the International Development Association to the Board of Governors : Additions to IDA Resources - Eighteenth Replenishment [Internet]. The World Bank; 2017 Jan [cited 2018 Jan 17] p. 1–171. Report No.: 112728. Available from: <http://documents.worldbank.org/curated/en/348661486654455091/Report-from-the-Executive-Directors-of-the-International-Development-Association-to-the-Board-of-Governors-Additions-to-IDA-Resources-Eighteenth-Replenishment>
- 51) Africa Centers for Disease Control and Prevention. African countries launch framework to tackle the threat of antibiotic resistant infections [Press release]. 7 November 2017. Available from <https://au.int/en/pressreleases/20171107/african-countries-launch-framework-tackle-threat-antibiotic-resistant>
- 52) Preventing Epidemics [Internet]. Resolve to Save Lives. [cited 2018 Feb 19]. Available from: <https://www.resolvetosavelives.org/preventing-epidemics/>
- 53) One Health Initiative - One World One Medicine One Health [Internet]. One Health Initiative. [cited 2018 Feb 10]. Available from: <http://www.onehealthinitiative.com/map.php>
- 54) The FAO-OIE-WHO Collaboration. Sharing responsibilities and coordinating global activities to address health risks at the animal-human-ecosystems interfaces | A Tripartite Concept Note [Internet]. 2010 Apr. Available from: [http://www.who.int/foodsafety/zooses/final\\_concept\\_note\\_Hanoi.pdf?ua=1](http://www.who.int/foodsafety/zooses/final_concept_note_Hanoi.pdf?ua=1)
- 55) One Health Zoonotic Disease Prioritization Workshop | One Health | CDC [Internet]. Centers for Disease Control and Prevention. 2018 [cited 2018 Feb 10]. Available from: <https://www.cdc.gov/onehealth/global-activities/prioritization-workshop.html>
- 56) Network for Evaluation of One Health [Internet]. Network for Evaluation of One Health. [cited 2018 Feb 22]. Available from: <http://neoh.onehealthglobal.net/>
- 57) Smart Pod [Internet]. Baylor College of Medicine. [cited 2018 Jan 18]. Available from: <https://www.bcm.edu/global-initiatives/innovation-center/emergency-smart-pod>
- 58) The Communication & Community Engagement Initiative: Towards a collective service for more effective humanitarian responses [Internet]. ReliefWeb. 2017 [cited 2018 Jan 18]. Available from: <https://reliefweb.int/report/world/communication-community-engagement-initiative-towards-collective-service-more-effective>
- 59) Global Health Crises Task Force Final Report [Internet]. Global Health Crises Task Force, United Nations; 2017 Jun. Available from: <http://www.un.org/en/pdfs/Final%20Report.Global%20Health%20Crises%20Task%20Force.pdf>
- 60) Universal Health Coverage Forum 2017. Program Book [Internet]. 2017. Available from: [http://universalhealthcoverageday.org/wp-content/uploads/2017/11/UHC-Forum\\_program-book\\_agenda-inserted.pdf](http://universalhealthcoverageday.org/wp-content/uploads/2017/11/UHC-Forum_program-book_agenda-inserted.pdf)
- 61) Tokyo Declaration on Universal Health Coverage: All Together to Accelerate Progress towards UHC. In The World Bank; 2017 [cited 2018 Feb 10]. Available from: <http://www.worldbank.org/en/news/statement/2017/12/14/uhc-forum-tokyo-declaration>
- 62) WHO Health Emergencies Programme in the African Region: Annual Report 2016. Geneva: World Health Organization; 2017. Licence: CC BY-NC-SA 3.0 IGO. Available from: <https://reliefweb.int/report/world/annual-report-2016-who-health-emergencies-programme-african-region>
- 63) Draft thirteenth general programme of work 2019–2023 | Promote health, keep the world safe, serve the vulnerable [Internet]. World Health Organization; 2018 Jan. Report No.: EB142/3. Available from: [http://apps.who.int/gb/ebwha/pdf\\_files/EB142/B142\\_3-en.pdf?ua=1](http://apps.who.int/gb/ebwha/pdf_files/EB142/B142_3-en.pdf?ua=1)
- 64) Adam Kamradt-Scott. WHO's to blame? The World Health Organization and the 2014 Ebola outbreak in West Africa. Third World Quarterly [Internet]. 2016 Jan 4;37(3). Available from: <http://www.tandfonline.com/doi/full/10.1080/01436597.2015.1112232>

- 65) OCHA Annual Report 2006 [Internet]. United Nations Office for the Coordination of Humanitarian Affairs; 2007. Available from: [http://interactive.unocha.org/publication/2006\\_annualreport/index.html](http://interactive.unocha.org/publication/2006_annualreport/index.html)
- 66) Emergency Response Framework - 2nd Edition [Internet]. World Health Organization; 2017. Available from: <http://apps.who.int/iris/bitstream/10665/258604/1/9789241512299-eng.pdf?ua=1>
- 67) Level 3 (L3) Activation Procedures for Infectious Disease Events [Internet]. Inter-Agency Standing Committee; 2016. Available from: [https://interagencystandingcommittee.org/system/files/final\\_-iasc\\_system-wide\\_level\\_3\\_activation\\_for\\_infectious\\_disease\\_events\\_-\\_iasc\\_principals.doc](https://interagencystandingcommittee.org/system/files/final_-iasc_system-wide_level_3_activation_for_infectious_disease_events_-_iasc_principals.doc)
- 68) IASC Integrated L3 Health Emergency Exercise (H2E) 2017 - Participant Briefing Note [Internet]. Inter-Agency Standing Committee; 2017. Available from: [https://interagencystandingcommittee.org/system/files/iasc\\_h2e\\_participant\\_briefing\\_note\\_2.pdf](https://interagencystandingcommittee.org/system/files/iasc_h2e_participant_briefing_note_2.pdf)
- 69) WHO Simulation Exercise Manual [Internet]. World Health Organization; 2017 Feb. Report No.: WHO/WHE/CPI/2017.10. Available from: <http://www.who.int/ihr/publications/WHO-WHE-CPI-2017.10/en/>
- 70) Berlin Declaration of the G20 Health Ministers: Together Today for a Healthy Tomorrow [Internet]. 2017. Available from: <http://www.g20.utoronto.ca/2017/170520-health-en.html>
- 71) Osewe P. Pandemic simulations: Preparing for the catastrophe we hope will never happen [Internet]. Investing in Health. 2016 [cited 2018 Jan 18]. Available from: <http://blogs.worldbank.org/health/pandemic-simulations-preparing-catastrophe-we-hope-will-never-happen>
- 72) Tedros Adhanom Ghebreyesus. WHO | WHO Director-General addresses the Executive Board [Internet]. WHO Executive Board; 2018 Jan 22 [cited 2018 Feb 11]; Geneva, Switzerland. Available from: <http://www.who.int/dg/speeches/2018/142-executive-board/en/>
- 73) Ian Norton, Johan von Schreeb, Peter Aitken, Patrick Herard, Camila Lajolo. Classification and Minimum Standards for Foreign Medical Teams in Sudden Onset Disasters [Internet]. Geneva: World Health Organization; 2013. Available from: [http://www.who.int/hac/global\\_health\\_cluster/fmt\\_guidelines\\_september2013.pdf?ua=1](http://www.who.int/hac/global_health_cluster/fmt_guidelines_september2013.pdf?ua=1)
- 74) David Heymann. Development of a Plan for a Stronger Global Health Emergency Workforce [Internet]. Friends of the Resolution, Second Meeting; 2015 Apr 9. Available from: [http://www.who.int/about/who\\_reform/emergency-capacities/Global-health-emergency-workforce.pdf](http://www.who.int/about/who_reform/emergency-capacities/Global-health-emergency-workforce.pdf)
- 75) Elizabeth Dickinson, Amy Lieberman. With limited aid, Yemen cholera "getting worse every day" [Internet]. 2017 [cited 2017 Jan 17]. Available from: <https://www.devex.com/news/with-limited-aid-yemen-cholera-getting-worse-every-day-90598>
- 76) Section UNNS. UN News - Wrapping up visit to Yemen, UN aid chief stresses need for all parties to facilitate humanitarian work [Internet]. UN News Service Section. 2017 [cited 2018 Jan 18]. Available from: <http://www.un.org/apps/news/story.asp?NewsID=57984#.WmAHYpOpIQI>
- 77) WHO. An R&D Blueprint for Action to Prevent Epidemics. Plan of Action [Internet]. 2016 [cited 2018 Jan 18]. Available from: [http://www.who.int/blueprint/about/r\\_d\\_blueprint\\_plan\\_of\\_action.pdf](http://www.who.int/blueprint/about/r_d_blueprint_plan_of_action.pdf)
- 78) WHO | List of Blueprint priority diseases [Internet]. World Health Organization. [cited 2018 Feb 11]. Available from: <http://www.who.int/blueprint/priority-diseases/en/>
- 79) WHO | Global Coordination Mechanism [Internet]. WHO. [cited 2018 Jan 18]. Available from: [http://www.who.int/blueprint/what/improving-coordination/global\\_coordination\\_mechanism/en/](http://www.who.int/blueprint/what/improving-coordination/global_coordination_mechanism/en/)
- 80) WHO R&D Blueprint Mapping Tool [Internet]. World Health Organization. [cited 2018 Jan 18].
- 81) WHO | WHO involvement in Zika R&D [Internet]. WHO. 2016 [cited 2018 Jan 18]. Available from: [http://www.who.int/blueprint/priority-diseases/key-action/r\\_d\\_zika\\_involvement/en/](http://www.who.int/blueprint/priority-diseases/key-action/r_d_zika_involvement/en/)
- 82) Target Product Profiles for better diagnostic tests for Zika Virus Infection. World Health Organization; 2017. Available from: <http://www.who.int/blueprint/what/research-development/zika-tp.pdf?ua=1>
- 83) WHO/UNICEF Zika Virus (ZIKV) Vaccine Target Product Profile (TPP): Vaccine to protect against congenital Zika syndrome for use during an emergency [Internet]. World Health Organization; 2017. Available from: [http://www.who.int/immunization/research/development/WHO\\_UNICEF\\_Zikavac\\_TPP\\_Feb2017.pdf?ua=1](http://www.who.int/immunization/research/development/WHO_UNICEF_Zikavac_TPP_Feb2017.pdf?ua=1)
- 84) WHO | Zika virus disease (IVDs) emergency use assessment and listing (EUAL) status after PHEIC termination [Internet]. WHO. 2016 [cited 2018 Jan 18]. Available from: [http://www.who.int/diagnostics\\_laboratory/eual-zika-virus/zika/en/](http://www.who.int/diagnostics_laboratory/eual-zika-virus/zika/en/)
- 85) Find out about our work – GloPID-R [Internet]. Global Research Collaboration for Infectious Disease Preparedness. [cited 2018 Jan 18]. Available from: <https://www.glopid-r.org/find-out-about-our-work/>
- 86) Pavot V. Ebola virus vaccines: Where do we stand? *Clinical Immunology*. 2016 Dec 1;173:44–9.
- 87) Kennedy SB, Bolay F, Kieh M, Grandits G, Badio M, Ballou R, et al. Phase 2 Placebo-Controlled Trial of Two Vaccines to Prevent Ebola in Liberia. *N Engl J Med*. 2017 12;377(15):1438–47.

- 88) Henaó-Restrepo AM, Camacho A, Longini IM, Watson CH, Edmunds WJ, Egger M, et al. Efficacy and effectiveness of an rVSV-vectored vaccine in preventing Ebola virus disease: final results from the Guinea ring vaccination, open-label, cluster-randomised trial (Ebola Ça Suffit!). *The Lancet*. 2017 Feb 4;389(10068):505–18.
- 89) Coller B-AG, Blue J, Das R, Dubey S, Finelli L, Gupta S, et al. Clinical development of a recombinant Ebola vaccine in the midst of an unprecedented epidemic. *Vaccine*. 2017 Aug 16;35(35 Pt A):4465–9.
- 90) Check Hayden E. Unusual deal ensures Ebola vaccine supply. *Nature News* [Internet]. 2016 Jan 20 [cited 2018 Jan 18]; Available from: <http://www.nature.com/news/unusual-deal-ensures-ebola-vaccine-supply-1.19186>
- 91) Ebola Vaccines [Internet]. National Institute of Allergy and Infectious Disease. [cited 2018 Feb 8]. Available from: <https://www.niaid.nih.gov/diseases-conditions/ebola-vaccines>
- 92) Winslow RL, Milligan ID, Voysey M, Luhn K, Shukarev G, Douoguih M, et al. Immune Responses to Novel Adenovirus Type 26 and Modified Vaccinia Virus Ankara–Vectored Ebola Vaccines at 1 Year. *JAMA*. 2017 Mar 14;317(10):1075–7.
- 93) Strategic Advisory Group of Experts (SAGE) on Immunization Working Group. Report of the SAGE Working Group on Ebola Vaccines and Vaccination with provisional recommendations for vaccination. World Health Organization; 2015 Sep.
- 94) Helen Branswell. As foreign powers approve Ebola vaccines, U.S. drug makers lag in development pipeline [Internet]. *STAT*. 2017. Available from: <https://www.statnews.com/2017/12/08/ebola-vaccine-development/>
- 95) Helen Branswell. Race for a Zika vaccine slows, a setback for efforts to head off outbreaks [Internet]. *STAT*. 2017 [cited 2017 Dec 28]. Available from: <https://www.statnews.com/2017/09/13/zika-vaccine-sanofi-challenges/>
- 96) Angus Liu. Regret it or not, the Zika vaccine Sanofi walked away from shows early promise | FiercePharma [Internet]. 2017 [cited 2018 Jan 18]. Available from: [/vaccines/regret-it-or-not-zika-vaccine-sanofi-walked-away-from-shows-early-promise](http://www.fiercepharma.com/news/regret-it-or-not-the-zika-vaccine-sanofi-walked-away-from-shows-early-promise)
- 97) Priority Diseases [Internet]. CEPI. [cited 2018 Jan 18]. Available from: <http://cepi.net/resources#Priority-diseases>
- 98) Partners [Internet]. CEPI. [cited 2018 Jan 18]. Available from: <http://cepi.net/partners>
- 99) CEPI – Ebola vaccines regulatory science meeting [Internet]. Washington, DC: Coalition for Epidemic Preparedness Innovations; 2017 Mar. Available from: [20meeting\\_FINAL](https://www.cepi.net/2017/03/20/meeting-final)
- 100) Andrew Joseph. Cheap, fast test for Zika and dengue could cost just \$1 [Internet]. *STAT*. 2017 [cited 2017 Dec 28]. Available from: <https://www.statnews.com/2017/09/27/zika-dengue-test-one-dollar/>; Bosch I, Puig H de, Hiley M, Carré-Camps M, Perdomo-Celis F, Narváez CF, et al. Rapid antigen tests for dengue virus serotypes and Zika virus in patient serum. *Science Translational Medicine*. 2017 Sep 27;9(409):eaan1589.
- 101) CEPI dx [Internet]. FIND. [cited 2018 Jan 18]. Available from: <https://www.findx.org/cepidx/>
- 102) Perkins MD, Dye C, Balasegaram M, Bréchet C, Mombouli J-V, Røttingen J-A, et al. Diagnostic preparedness for infectious disease outbreaks. *The Lancet*. 2017 Nov 11;390(10108):2211–4.
- 103) Glancey M, Osei P, Patterson WA, Petney M, Scavo L, Ruparella C, et al. Design Improvements for Personal Protective Equipment Used in Ebola and Other Epidemic Outbreaks. *Global Health: Science and Practice*. 2017 Jun 27;5(2):325–8.
- 104) Phil Sneiderman. 2015. Johns Hopkins, DuPont join forces to produce improved Ebola protection suit [Internet]. *The Hub*. 2015 [cited 2018 Jan 18]. Available from: <https://hub.jhu.edu/2015/09/28/hopkins-dupont-ebola-garment-partnership/>
- 105) Steph Moore. Improving the Use of Personal Protective Equipment to Prevent Spread of Pathogens | Center for Health Care Human Factors [Internet]. [cited 2018 Jan 18]. Available from: [https://www.hopkinsmedicine.org/armstrong\\_institute/centers/human\\_factors\\_engineering/projects/personal\\_protective\\_equipment.html](https://www.hopkinsmedicine.org/armstrong_institute/centers/human_factors_engineering/projects/personal_protective_equipment.html)
- 106) Catherine Hankins. Good participatory practice guidelines for trials of emerging (and re-emerging) pathogens that are likely to cause severe outbreaks in the near future and for which few or no medical countermeasures exist - Outcome document of the consultative process [Internet]. World Health Organization; 2016. Available from: <http://www.who.int/blueprint/what/norms-standards/GPP-EPP-December2016.pdf?ua=1>
- 107) Ben Goldacre, Sian Harrison, Kamal R. Mahtani, Carl Heneghan. WHO consultation on Data and Results Sharing During Public Health Emergencies [Internet]. Oxford, United Kingdom: Centre for Evidence-Based Medicine; 2015 Sep. Available from: [http://www.who.int/medicines/ebola-treatment/background\\_briefing\\_on\\_data\\_results\\_sharing\\_during\\_phes.pdf](http://www.who.int/medicines/ebola-treatment/background_briefing_on_data_results_sharing_during_phes.pdf)
- 108) Statement on data sharing in public health emergencies [Internet]. Wellcome. [cited 2018 Jan 18]. Available from: <https://wellcome.ac.uk/what-we-do/our-work/statement-data-sharing-public-health-emergencies>
- 109) Data Sharing [Internet]. Global Research Collaboration for Infectious Disease Preparedness. [cited 2018 Jan 18]. Available from: <https://www.glopid-r.org/find-out-about-our-work/data-sharing-working-group/>
- 110) A Guide to Sharing the Data and Benefits of Public Health Surveillance [Internet]. Chatham House. 2018 [cited 2018 Feb 19]. Available from: <https://datasharing.chathamhouse.org/>



- 111) Center for Tropical Medicine and Global Health. Infectious Disease Data Observatory [Internet]. Available from: <https://www.tropicalmedicine.ox.ac.uk/iddo-data-sharing>
- 112) WHO. Zika Open [Internet]. Bulletin of the World Health Organization. 2016. [cited 2018 Jan 18]. Available from: [http://www.who.int/bulletin/online\\_first/zika\\_open/en/](http://www.who.int/bulletin/online_first/zika_open/en/)
- 113) WHO. FluID - a global influenza epidemiological data sharing platform [Internet]. Influenza. 2010. [cited 2018 Jan 18]. Available from: [http://www.who.int/influenza/surveillance\\_monitoring/fluid/en/](http://www.who.int/influenza/surveillance_monitoring/fluid/en/)
- 114) Argimón S, Abudahab K, Goater RJE, Fedosejev A, Bhai J, Glasner C, et al. Microreact: visualizing and sharing data for genomic epidemiology and phylogeography. *Microbial Genomics* [Internet]. 2016 Nov 30;2(11). Available from: <http://www.microbiologyresearch.org/content/journal/mgen/10.1099/mgen.0.000093>
- 115) Zika Online Data-sharing Platform [Internet]. Nuffield Department of Women's and Reproductive Health Obstetrics and Gynaecology. [cited 2018 Jan 18]. Available from: <https://www.obs-gyn.ox.ac.uk/research/zika-online-data-sharing-platform>
- 116) CDC. SEDRIC: System for Enteric Disease Response, Investigation, and Coordination [Internet]. Center for Disease Control and Prevention. [cited 2018 Jan 18]. Available from: <https://www.cdc.gov/foodsafety/outbreaks/investigating-outbreaks/sedric.html>
- 117) Few Zika samples are being shared by Brazil [Internet]. STAT. 2016 [cited 2018 Jan 6]. Available from: <https://www.statnews.com/2016/02/03/zika-samples-brazil/>.
- 118) WHO R&D Blueprint. Building capacity for material transfer agreements in public health emergencies [Internet]. Geneva, Switzerland: World Health Organization; 2016 Dec. Available from: <http://www.who.int/blueprint/what/norms-standards/MTA-meeting-report.pdf>
- 119) The National Academies of Medicine. Integrating Clinical Research into Epidemic Response: The Ebola experience [Internet]. 2017 Apr [cited 2018 Jan 18]. Available from: <http://nationalacademies.org/hmd/~/media/Files/Report%20Files/2017/epidemicclinicaltrials-report-highlights.pdf>
- 120) Marie-Paule Kieny, Richard Sezibera, Mukesh Chawla. Strengthening national clinical research capacities is key to epidemic preparedness and saving lives [Internet]. Investing in Health. 2018 [cited 2018 Feb 11]. Available from: <http://blogs.worldbank.org/health/strengthening-national-clinical-research-capacities-key-epidemic-preparedness-and-saving-lives>
- 121) Welcome to CORDS [Internet]. Connecting Organizations for Regional Disease Surveillance. [cited 2018 Feb 19]. Available from: <https://www.cordsnetwork.org/about-cords/>
- 122) Bill & Melinda Gates Foundation. Disease Surveillance Network in Africa and Asia [Internet]. Bill & Melinda Gates Foundation. [cited 2018 Jan 18] Available from: <https://www.gatesfoundation.org/Media-Center/Press-Releases/2015/05/Child-Health-and-Mortality-Prevention-Surveillance-Network>
- 123) Skoll. Pandemics [Internet]. Skoll Global Threats Fund. [cited 2018 Jan 18]. Available from: <http://www.skollglobalthreats.org/global-threats/pandemics/>
- 124) DiSARM [Internet]. DiSARM. 2017 [cited 2018 Feb 11]. Available from: <http://www.disarm.io/>
- 125) Global Observatory for eHealth. Global diffusion of eHealth: Making universal health coverage achievable [Internet]. World Health Organization; 2016. Available from: <http://apps.who.int/iris/bitstream/10665/252529/1/9789241511780-eng.pdf?ua=1>
- 126) Epihack. What is EpiHackTM [Internet]. [cited 2018 Jan 18]. Available from: <https://epihack.org/what-is-epihack>
- 127) Susumpow P, Pansuwan P, Sajda N, Crawley A. Participatory disease detection through digital volunteerism: how the doctorme application aims to capture data for faster disease detection in Thailand. In 2014. p. 663–6.
- 128) Home | Metabiota [Internet]. Metabiota. 2017 [cited 2018 Feb 26]. Available from: <http://metabiota.com/>
- 129) PREDICT. Reducing Pandemic Risk, Promoting Global Health [Internet]. USAID; Available from: [http://www.vetmed.ucdavis.edu/ohi/local\\_resources/pdfs/predict-global-flyer.pdf](http://www.vetmed.ucdavis.edu/ohi/local_resources/pdfs/predict-global-flyer.pdf)
- 130) Global Virome Project. About the Global Virome Project [Internet]. Global Virome Project. [cited 2018 Jan 18]. Available from: <http://www.globalviromeproject.org/about-1/>
- 131) MIDAS. Models of Infectious Disease Agent Study (MIDAS) - National Institute of General Medical Sciences [Internet]. National Institute of General Medical Sciences. [cited 2018 Jan 18]. Available from: <https://www.nigms.nih.gov/Research/specificareas/MIDAS/Pages/default.aspx>
- 132) Pigott DM, Deshpande A, Letourneau I, Morozoff C, Reiner RC, Kraemer MUG, et al. Local, national, and regional viral haemorrhagic fever pandemic potential in Africa: a multistage analysis. *The Lancet*. 2017 Dec 16;390(10113):2662–72.
- 133) Infectious Disease Outbreaks and Business Risk [Internet]. World Economic Forum [cited 2018 Jan 18]. Available from: <https://www.weforum.org/projects/infectious-disease-outbreaks-and-business-risk/>





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