

1 **Recommendations for the Evaluation and Oversight of**
2 **Proposed Gain-of-Function Research**

3 **A Draft Report of the NSABB Working Group**

4
5 **Version: May 6, 2016**
6
7
8

9 **Preface for NSABB Meeting on May 24, 2016**

10 This draft report was developed by the NSABB working group tasked with evaluating the risks and
11 benefits associated with gain-of-function studies and developing draft recommendations on a
12 conceptual approach for evaluating proposed gain-of-function studies. The first version of this
13 document was discussed at the NSABB meeting on January 7 & 8, 2016 and again at the symposium
14 hosted by the National Academies on March 10 & 11, 2016. This version represents an updated draft of
15 that initial working paper. Significant changes in this revised version are found in Section 5 (Findings)
16 and Section 6 (Recommendations). This document is still pre-decisional and intended as a deliberative
17 document to be discussed and potentially finalized at the meeting of the full NSABB on May 24, 2016.
18 This is document is not a formal NSABB work product and should not be considered to be official NSABB
19 findings or recommendations to the U.S. government. This document does not represent official policy
20 of the U.S. government.
21

22 **Contents**

23 Executive Summary..... 3

24 1. Introduction 6

25 2. NSABB Charge 8

26 3. NSABB Deliberative Approach 10

27 4. Analysis 13

28 4.1. Analysis and Interpretation of the Risk and Benefit Assessment 13

29 4.2. Consideration of Ethical Values 18

30 4.3. Decision-Making Strategies and Frameworks for Evaluating and Managing Risks and

31 Developing Policy..... 21

32 4.4. Examination of the Current Policy Landscape 24

33 5. Findings of the NSABB Working Group 36

34 6. Recommendations of the NSABB Working Group 42

35 7. Appendices..... 54

36 Appendix A. Description of NSABB Deliberations..... 54

37 Appendix B. Summary of Federal Policies for Biosecurity and Biosecurity Oversight Analyzed by NSABB

38 Working Group..... 59

39 Appendix C. Identifying GOFROC: Examples of Studies that Would and Would Not be Considered

40 GOFROC..... 61

41 Appendix D. Summaries of Stakeholder Perspectives 63

42 Appendix E. Consultations, Comments, and Sources Considered During NSABB Deliberations 70

43 Appendix F. National Science Advisory Board for Biosecurity Roster 81

44 Appendix G. National Science Advisory Board for Biosecurity Charter 86

45
46
47

48 Executive Summary

49 Research involving pathogens is essential to global health and security. Such research provides insight
50 into the fundamental nature of human-pathogen interactions, enables the assessment of the pandemic
51 potential of emerging infectious agents, and informs public health and preparedness efforts, including
52 the development of medical countermeasures. Several Federal policies are in place to help ensure that
53 pathogen research is conducted safely and in ways to minimize the risks of laboratory accidents and
54 security risks. Recently, in the wake of a number of biosafety incidents at Federal facilities, concerns
55 have been raised about certain “gain-of-function” (GOF) studies with the potential to generate
56 pathogens with pandemic potential. The concerns center on whether a pathogen with enhanced
57 transmissibility and/or virulence could be accidentally or intentionally released from a laboratory,
58 potentially exposing surrounding populations and possibly causing a wider pandemic.
59

60 The U.S. Government (USG), as part of its continued focus on biosafety and biosecurity, has undertaken
61 a deliberative process to carefully examine the risks and benefits associated with certain GOF studies.
62 The deliberative process involves the National Science Advisory Board for Biosecurity (NSABB), which
63 has been tasked with making recommendations to the USG on this topic, and the National Academy of
64 Sciences (NAS), which was tasked to convene two public symposia to generate broad discussion on the
65 relevant issues. To further inform NSABB deliberations, the National Institutes of Health (NIH)
66 commissioned Gryphon Scientific to perform an independent assessment of the risks and benefits
67 associated with GOF studies and a separate ethical analysis of the issues related to funding and
68 conducting such studies.
69

70 The NSABB was charged with advising on the design of the risk and benefit assessment (RBA) for GOF
71 studies and with providing recommendations to the USG on a conceptual approach for evaluating
72 proposed GOF studies. In May 2015 the NSABB issued its *Framework for Guiding the Conduct of Risk
73 and Benefit Assessments of Gain-of-Function Research*, which guided NIH in overseeing the contractor
74 conducting the risk and benefit assessments. In May 2016, informed by the results of the RBA as well as
75 its analysis of the current policy landscape, consideration of relevant ethical issues, and consultations
76 with domestic and international stakeholders, the NSABB working group will present this draft report for
77 consideration and finalization by the full NSABB.
78

79 The NSABB working group has developed 7 major findings:
80

81 **Finding 1.** There are many types of GOF studies and not all of them have the same level of risks.
82 Only a small subset of GOF research—GOF research of concern (GOFROC)—entail risks that are
83 potentially significant enough to warrant additional oversight.

84 **Finding 2.** The U.S. government has several policies in place for identifying and managing risks
85 associated with life sciences research. There are several points throughout the research life cycle
86 where, if the policies are implemented effectively, risks can be managed and oversight of GOF
87 research of concern could be implemented.

88 **Finding 3.** Oversight policies vary in scope and applicability, and do not cover all potential GOFROC,
89 therefore, current oversight is not sufficient for all GOF research of concern.

90 **Finding 4.** An adaptive policy approach is a desirable way to ensure that oversight and risk
91 mitigation measures remain commensurate with the risks associated with the research and the
92 benefits of the research are being fully realized.

93 **Finding 5.** There are life sciences research studies, including possibly some GOF research of concern,
94 that should not be conducted because the potential risks associated with the study are not justified
95 by the potential benefits. Decisions about whether specific GOFROC should be permitted will entail
96 an assessment of the potential risks and anticipated benefits associated with the individual
97 experiment in question. The scientific merit of a study is a central consideration during the review
98 of proposed studies but other considerations, including legal, ethical, public health, and societal
99 values are also important and need to be taken into account.

100 **Finding 6.** Managing risks associated with GOF research of concern, like all life sciences research,
101 requires both Federal-level and institutional oversight, awareness and compliance, and a
102 commitment by all stakeholders to safety and security.

103 **Finding 7.** Funding and conducting GOF research of concern involves many issues that are
104 international in nature.

105 The NSABB working group has developed 7 draft recommendations to the U.S. government:

106
107 **Recommendation 1.** Research proposals involving GOF research of concern entail significant
108 potential risks and should receive an additional, multidisciplinary review, prior to determining
109 whether they are acceptable for funding. If funded, such projects should be subject to ongoing
110 oversight at the Federal and institutional levels.

111 As part of this recommendation, the NSABB working group has proposed a conceptual approach for
112 guiding funding decisions about GOFROC. First, the working group identified the attributes of
113 GOFROC, which is research that could generate a pathogen that is: 1) highly transmissible and likely
114 capable of wide and uncontrollable spread in human populations; and 2) highly virulent and likely to
115 cause significant morbidity and/or mortality in humans. Next, the working group identified a set of
116 principles that should guide funding decisions for GOFROC. Only research that is determined to be
117 in line with these principles should be funded. Additional risk mitigation measures may be required
118 for certain research studies to be deemed acceptable for funding.

119 **Recommendation 2.** An external advisory body that is designed for transparency and public
120 engagement should be utilized as part of the U.S. government's ongoing evaluation of oversight
121 policies for GOF research of concern.

122 **Recommendation 3.** The U.S. government should pursue an adaptive policy approach to help
123 ensure that oversight remains commensurate with the risks associated with the GOF research of
124 concern.

125 **Recommendation 3.1.** The U.S. government should consider developing a system to collect and
126 analyze data about laboratory safety incidents to inform GOF research of concern policy
127 development over time.

128 **Recommendation 4.** In general, oversight mechanisms for GOF research of concern should be
129 incorporated into existing policy frameworks when possible.

130 **Recommendation 5.** The U.S. government should consider ways to ensure that all GOF research of
131 concern conducted within the U.S. or by U.S. companies be subject to oversight, regardless of
132 funding source.

133 **Recommendation 6.** The U.S. government should undertake broad efforts to strengthen laboratory
134 biosafety and biosecurity and, as part of these efforts, seek to raise awareness about the specific
135 issues associated with GOF research of concern.

136 **Recommendation 7.** The U.S. government should engage the international community in a dialogue
137 about the oversight and responsible conduct of GOF research of concern.

138

139

140

141 **1. Introduction**

142 A robust life sciences research enterprise is necessary to counter the continually evolving threats to
143 public health and national security posed by endemic and emerging pathogens, as well as malicious
144 biological threats. By helping to define the nature of human-pathogen interactions, life sciences
145 research promotes public health and national security not only by enhancing our understanding of
146 pathogen biology and disease pathogenesis, but also by informing biosurveillance and medical
147 countermeasure development. Such research can also aid in the assessment of the pandemic potential
148 of emerging infectious agents, thereby underpinning health policy decisions and preparedness and
149 response efforts.

150 While the ultimate goal of life sciences research involving pathogens is the protection and promotion of
151 public health, there are inherent associated biosafety and biosecurity risks. Potential risks might arise
152 from laboratory accidents or security breaches that result in laboratory acquired infections or the
153 accidental or deliberate release of a pathogen from containment. Life sciences research has “dual use”
154 potential. That is, legitimate research may generate information, products or technologies that could be
155 misused to threaten public health or national security. To mitigate such dual use concerns, as well as
156 potential biosafety and biosecurity risks, research involving pathogens is subject to multiple layers of
157 Federal and institutional oversight.

158 **The Gain-of-Function Debate and the USG Response**

159 Experimental techniques and approaches that modify the genome of microorganisms are routinely
160 employed in pathogen research to ascertain the roles of genes and their functional products. Such
161 studies are fundamental to the field of microbial genetics and facilitate correlation of genetic and
162 phenotypic characteristics – a critical step in deciphering the complex nature of host-pathogen
163 interactions that underlie transmission, infection, and pathogenesis. Such genetic manipulations can
164 result in either diminished (loss-of-function) or enhanced (gain-of-function) biological phenotypes.

165 Studies that result in the generation of pathogens with enhanced, or gain-of-function (GOF), phenotypes
166 are conducted for a number of valid scientific purposes. Such studies provide information that adds to
167 the scientific knowledge base and can inform biosurveillance, medical countermeasure development,
168 and public policy decision-making related to public health and preparedness. The vast majority of such
169 GOF studies do not raise significant safety or security concerns. However, certain GOF studies involving
170 pathogens have raised significant concerns about whether a laboratory-generated pathogen with
171 pandemic potential could be accidentally or intentionally released, resulting in significant consequences
172 to public, or perhaps, global health. Concerns have also been raised about whether certain GOF studies
173 could generate information that could enable individuals with malevolent intent to generate a pathogen
174 with pandemic potential (see Box 1).

175 The controversy over certain GOF studies arose
176 after two groups demonstrated that highly
177 pathogenic avian influenza H5N1 viruses with a
178 small number of engineered mutations became
179 transmissible between mammals by respiratory
180 droplets.^{1,2} In 2012, in response to the
181 controversy associated with publishing the
182 manuscripts describing these findings, the
183 influenza community initiated a voluntary
184 suspension of certain GOF studies involving
185 highly pathogenic avian influenza H5N1 viruses.
186 During that time, policymakers considered
187 whether certain GOF studies should be
188 conducted using Federal funds, and if so, how
189 those studies could be safely conducted. The
190 Centers for Disease Control and Prevention
191 (CDC) and the National Institutes of Health
192 (NIH) issued new biosafety guidelines for
193 working with highly pathogenic avian influenza
194 strains.^{3,4} The U.S. Department of Health and
195 Human Services (HHS) developed a framework
196 for guiding its funding decisions about GOF
197 projects that may generate H5N1 or H7N9
198 avian influenza viruses that are transmissible
199 between mammals by respiratory droplets.⁵

200 Concerns regarding laboratory safety and
201 biosecurity associated with GOF studies were
202 renewed following a number of biosafety
203 incidents at U.S. Federal laboratories during
204 the summer of 2014. The incidents did not
205 involve GOF studies *per se* but raised broader
206 concerns about laboratory safety and security
207 as it applies to pathogen research.

208 As one component of comprehensive efforts to review and enhance laboratory biosafety and
209 biosecurity, the U.S. government (USG) embarked on a deliberative process to re-evaluate the risks and
210 benefits of certain GOF research with a goal of developing policy governing the funding and conduct of

Box 1. Gain-of-Function Research

Recently, the phrase “gain-of-function research” has become synonymous with certain studies that enhance the ability of pathogens to cause disease. However, gain-of-function studies, as well as loss-of-function studies, are common in molecular and microbiology and form the foundation of microbial genetics. Changes to the genome of an organism, whether naturally occurring or directed through experimental manipulations in the laboratory, can result in altered phenotypes as biological functions are lost or gained.

Investigators routinely conduct loss- and gain-of-function experiments to understand the complex nature of host-pathogen interactions that underlie transmission, infection, and pathogenesis.

The term “gain-of-function” is generally used to refer to changes resulting in the acquisition of new, or an enhancement of existing, biological phenotypes. This report further defines “gain-of-function research of concern” to describe the subset of studies that have been the subject of recent debate regarding potential biosafety and biosecurity implications -- that is, gain-of-function studies with the potential to generate pathogens with pandemic potential in humans by exhibiting high transmissibility and high virulence. See Section 6 for a more rigorous description of GOF research of concern (GOFROC).

¹ Imai et al. Experimental adaptation of an influenza H5 HA confers respiratory droplet transmission to a reassortant H5 HA/H1N1 virus in ferrets. *Nature* 486, 21 June 2012

² Herfst et al. Airborne Transmission of Influenza A/H5N1 Virus Between Ferrets. *Science* 336, 22 June 2012

³ Gangadharan D, Smith J, and Weyant R. Biosafety Recommendations for Work with Influenza Viruses Containing a Hemagglutinin from the A/goose/Guangdong/1/96 Lineage, Morbidity and Mortality Weekly Report 62(RR06); 1-7. <http://www.cdc.gov/mmwr/preview/mmwrhtml/rr6206a1.htm>

⁴ NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules. <http://osp.od.nih.gov/office-biotechnology-activities/biosafety/nih-guidelines>

⁵ Framework for Guiding Funding Decisions about Research Proposals with the Potential for Generating Highly Pathogenic Avian Influenza H5N1 Viruses that are Transmissible among Mammals by Respiratory Droplets, February 21, 2013. <http://www.phe.gov/s3/dualuse/Documents/funding-hpai-h5n1.pdf>

211 such research.⁶ The deliberative process involves the National Science Advisory Board for Biosecurity
212 (NSABB), which serves as the official Federal advisory body for providing advice in this area, and the
213 National Academy of Sciences (NAS), which is to foster broader scientific and public discussions on the
214 topics. To inform NSABB deliberations, NIH commissioned formal risk and benefit assessments (RBA) of
215 GOF research involving pathogens with pandemic potential and an analysis of ethical issues surrounding
216 the conduct of such studies. Stakeholder input is also essential to the process and has been received
217 throughout the deliberative process.

218 The deliberative process is accompanied by a pause in the provision of new federal funds for certain
219 GOF research involving influenza, Middle East Respiratory Syndrome (MERS) or Severe Acute
220 Respiratory Syndrome (SARS) viruses—pathogens determined to have pandemic potential. Specifically:

221 *New USG funding will not be released for gain-of-function research projects that may be*
222 *reasonably anticipated to confer attributes to influenza, MERS, or SARS viruses such that the*
223 *virus would have enhanced pathogenicity and/or transmissibility in mammals via the*
224 *respiratory route. This restriction would not apply to characterization or testing of naturally*
225 *occurring influenza, MERS, and SARS viruses, unless the tests are reasonably anticipated to*
226 *increase transmissibility and/or pathogenicity.⁷*

227 In parallel, the USG has encouraged the research community (both those who receive USG funding and
228 those who do not) to join in adopting a voluntary pause on any ongoing research that involves the types
229 of studies that are subject to the funding restriction above.

230 NSABB recommendations will inform the USG as it develops policy about whether certain types of GOF
231 studies on pathogens with pandemic potential should be supported and, if so, how such research
232 proposals should be evaluated to inform funding and oversight decisions. It is expected that the
233 temporary funding pause will be lifted and/or replaced by a decision or policy that addresses GOF
234 research involving the generation of pathogens with pandemic potential.

235 **2. NSABB Charge**

236 On October 22, 2014, as part of the USG's deliberative process for GOF studies, the NSABB was issued its
237 charge to:

- 238 1. Advise on the design, development, and conduct of risk and benefit assessments for GOF
239 studies, and
- 240 2. Provide recommendations to the U.S. government on a conceptual approach to the evaluation
241 of proposed GOF studies

242 In developing its recommendations the NSABB was asked to consider: the results of the risk and benefit
243 assessments; the discussions hosted by the National Academies; the spectrum of potential risks and

⁶ U.S. Government Gain-of-Function Deliberative Process and Research Funding Pause on Selected Gain-of-Function Research Involving Influenza, MERS, and SARS Viruses, U.S. Government, October 17, 2014.

<http://www.phe.gov/s3/dualuse/documents/gain-of-function.pdf>

⁷ Ibid.

244 benefits associated with GOF studies; and any alternative methods that may be employed to yield
245 similar scientific insights or benefits, while reducing potential risks.

246 Since gain-of-function studies encompass a broad spectrum of pathogens and experimental
247 manipulations, the NSABB discussed its charge and sought to identify the appropriate scope of its
248 deliberations. Since the experiments that initiated the controversy involved the generation of
249 pathogens that were concerning from a human health perspective, NSABB deliberations and
250 recommendations focus on pathogens that pose risks to human populations. NSABB recommendations
251 also focus on guiding U.S. government funding decisions but the Board also considered issues associated
252 with non-Federally funded research and international research.

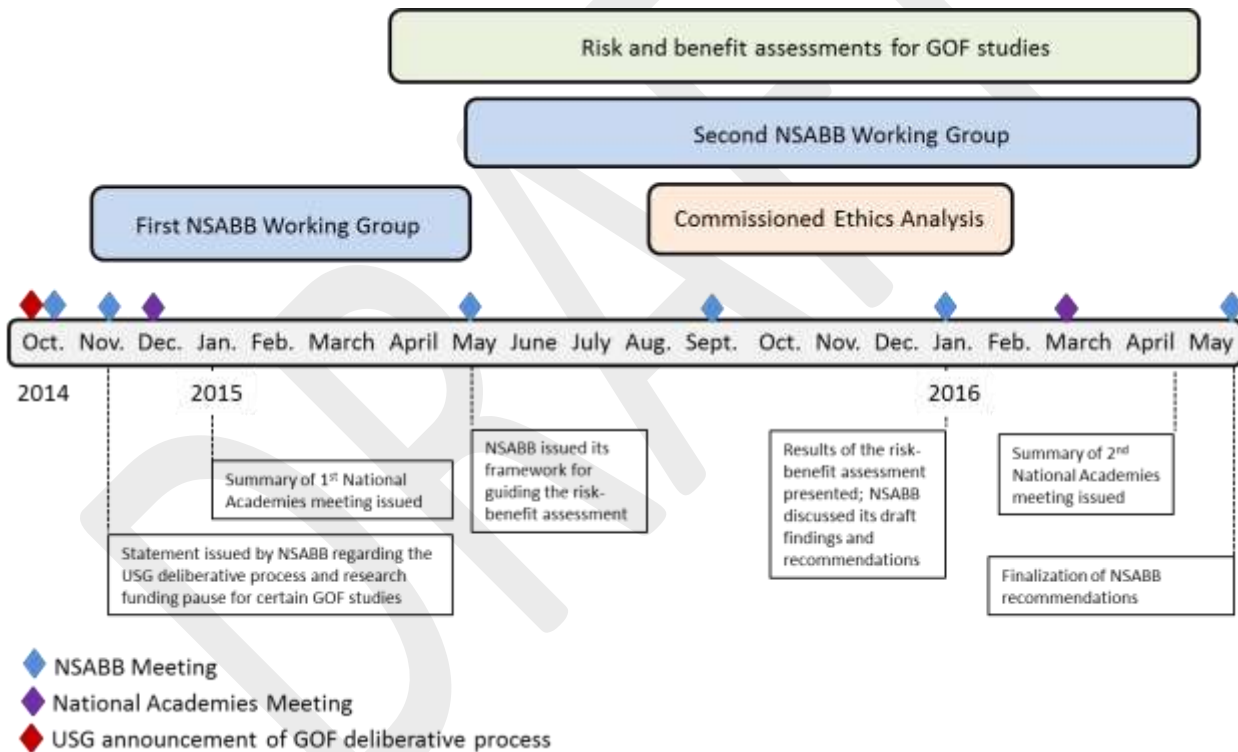
DRAFT

253 3. NSABB Deliberative Approach

254 The deliberative process (Figure 1) initiated by the USG to evaluate the risks and benefits of GOF studies
255 involves the NSABB and the National Academies. To address its charge, NSABB formed two working
256 groups to develop draft recommendations, which were discussed by the full Board⁸. The National
257 Academies convened public forums to generate broad discussions and receive additional stakeholder
258 input. The first forum was held early in the deliberative process and a second was held in March 2016;
259 both were designed to inform NSABB deliberations.

260
261 To inform the deliberative process further, NIH commissioned two additional analyses: 1) qualitative
262 and quantitative risk and benefit assessments, conducted by Gryphon Scientific, and 2) a review of the
263 ethical considerations associated with the GOF issue and an analysis of relevant ethical decision-making
264 frameworks, conducted by Dr. Michael Selgelid.

265



266

267

268 **Figure 1. Timeline and major events of the GOF deliberative process.**

269

270 The NIH Office of Science Policy, which administers the NSABB, managed the overall deliberative
271 process. NIH oversaw the work of its contractors, Gryphon Scientific and Dr. Michael Selgelid, and
272 interfaced between the NSABB and contracted entities.

⁸ Information about these meetings and activities, including agendas, summaries, and archived videocasts, can be found on the NSABB website at: <http://osp.od.nih.gov/office-biotechnology-activities/biosecurity/nsabb/nsabb-meetings-and-conferences/past-meetings>

273
274 See Appendices for more information. Appendix A provides a detailed description of the NSABB's
275 deliberative approach. Appendix B summarizes the current U.S. policy landscape for the oversight of
276 pathogen research. Appendix C describes examples of studies that would or would not be considered
277 GOF research of concern. Appendix D provides an overview of stakeholder views that were presented
278 and considered by NSABB. Appendix E lists the experts and sources consulted by NSABB, including those
279 who submitted public comments. Appendix F and G list the NSABB roster and charter.
280

281 **Guiding Principles for NSABB Deliberations**

282 The NSABB developed the principles below to guide its deliberations and underpin its analysis of the risk
283 and benefit assessments.

- 284
- 285 1. The NSABB deliberations should focus on defining the GOF problem then include broad
286 consideration of possible solutions. A range of approaches and decision-making frameworks will be
287 considered, and the NSABB will take into account these various approaches when developing its
288 recommendations.
 - 289 2. NSABB will consider the potential risks and benefits of a broad range of GOF studies involving
290 influenza, SARS, and MERS viruses in order to identify those that may raise significant concerns that
291 should be addressed. However, the NSABB will aim to develop recommendations that are grounded
292 in broadly-applicable concepts and principles that could, if necessary, apply to GOF studies involving
293 other pathogens that may require evaluation in the future.
 - 294 3. Similarly, NSABB will consider the risks and benefits associated with alternative research approaches
295 to GOF research to understand whether or not these may substitute for or complement GOF
296 studies.
 - 297 4. NSABB recommendations will be informed by data and information about potential risks and
298 benefits as well as values that will guide the evaluation and comparison of these risks and benefits.
299 Ethical, societal, and legal considerations will also contribute to the development of
300 recommendations and these inputs should be explicitly identified, discussed, and prioritized.
 - 301 5. NSABB recognizes that not all analyses relevant to its task are quantitative and that uncertainties
302 inherent in any quantitative analysis may remain. NSABB will seek to document important areas of
303 uncertainty in any data or analysis when necessary.
 - 304 6. NSABB should publicly debate its draft recommendations and describe in its report any dissenting
305 views that may vary substantially from the Board's recommendations.
 - 306 7. NSABB should consider current USG policies and guidelines, determine whether they adequately
307 address risks associated with GOF research (in light of potential benefits), and make
308 recommendations that are consistent with that determination. Current policies may be adequate or

309 require only minor changes; alternatively, significant enhancements may be needed. The adequacy
310 of current policy to cover GOF studies may vary by pathogen. Recognizing the paramount
311 importance of ensuring safety, security, and public health, policies should also minimize the burdens
312 placed upon the conduct of science.

313 8. NSABB recommendations will inform the development of U.S. government policy, which will apply
314 to research funded, conducted, or overseen by the U.S. government either domestically or
315 internationally. NSABB will be mindful in its deliberations of the likelihood that the Board's
316 recommendations and U.S. policy decisions will also influence other governments and non-USG
317 funders of life sciences research.

318 9. The NSABB will also consider whether there are certain studies that should not be conducted under
319 any circumstances, and if so, articulate the critical characteristics of such studies.

320 10. Maintaining public trust and confidence in life sciences research is critical and must be taken into
321 account as recommendations are formulated.

322

323

324

325 4. Analysis

326 In developing recommendations on a conceptual approach for evaluating GOF proposals, NSABB
327 examined three major areas: the current policy landscape for overseeing research involving pathogens,
328 ethical issues associated with funding and conducting GOF studies, and the results of Gryphon's risk and
329 benefit assessments. In addition, the NSABB considered broad stakeholder perspectives through
330 presentations from domestic and international experts at Working Group and full NSABB meetings,
331 expert consultations, individual NSABB member participation in and ideas and views from the National
332 Academies workshops and proceedings, analysis of published articles, and comments from attendees at
333 NSABB meetings or public comments submitted to the Board.

334 4.1. Analysis and Interpretation of the Risk and Benefit Assessment

335 The NSABB working group has reviewed the risk and benefit assessments (RBA) conducted by Gryphon
336 Scientific, which were designed to evaluate the risks and benefits of GOF research in a manner that
337 encompassed both benign and worrisome aspects of a broader range of GOF studies than those that
338 have raised concern. The RBA analyzed biosafety and biosecurity risks as well as possible benefits.
339 Overall, the RBA include a commendable amount of sophisticated work and analysis, is generally well-
340 done, and largely achieves the goals it was intended to address. Gryphon's draft RBA report was made
341 publically available in December 2015 and key results were presented and discussed at NSABB and NAS
342 meetings. The final report is available on Gryphon's website.⁹

343 **Strengths of the Risk and Benefit Assessments**

344 The RBA has significant strengths. It is a thorough and extensive analysis of the risks and benefits of
345 GOF work in the context of the guidance provided in the NSABB *Framework for Conducting Risk and*
346 *Benefits Assessments of Gain-of-Function Research* (May 2015)¹⁰. It takes into account the principles
347 articulated in the framework and includes the agents, categories of possible risks, types of possible
348 benefits, and possibly concerning scenarios and phenotypes that were laid out in the *Framework*. A few
349 items from the *Framework* were eliminated from consideration at the meeting of the NSABB where the
350 framework was voted on¹¹, so that the most probable issues of concern could be thoroughly addressed
351 within the available time and resources.

352 The biosafety risk assessment does a credible job of defining the relative risks associated with potential
353 laboratory accidents involving GOF manipulations of pathogens with enhanced characteristics as
354 compared to wild-type pathogens. This analysis is performed in a semi-quantitative way; it uses

⁹ Risk and Benefit Analysis of Gain-of-Function Research, Final Draft Report. Gryphon Scientific, December, 2015.
<http://osp.od.nih.gov/sites/default/files/Risk%20and%20Benefit%20Analysis%20of%20Gain%20of%20Function%20Research%20-%20Draft%20Final%20Report.pdf>

¹⁰ Framework for Conducting Risk and Benefits Assessments of Gain-of-Function Research, May 2015.
http://osp.od.nih.gov/sites/default/files/resources/NSABB_Framework_for_Risk_and_Benefit_Assessments_of_GOF_Research-APPROVED.pdf

¹¹ National Science Advisory Board for Biosecurity Meeting, May 5, 2015. <http://osp.od.nih.gov/office-biotechnology-activities/event/2015-05-05-120000-2015-05-05-200000/national-science-advisory-board-biosecurity-nsabb-meeting>

355 appropriate, established, peer-reviewed methods to the extent available. The parametric approach
356 employed is powerful and allows consideration of many situations of interest.

357 The report effectively illustrates that the harmful events being modeled are low probability (see Figures
358 6.2 and 6.4 in Gryphon’s report). Only a small fraction of laboratory accidents would result in a loss of
359 containment; of those, only a small fraction would result in a laboratory acquired infection, and of
360 those, only a fraction would spread throughout the surrounding community (or to the global
361 population). The working group recognizes the challenge of analyzing low-probability, high-
362 consequence events for which little data exists and appreciates attempts to make this point clear in the
363 RBA.

364 The biosecurity risk assessment is primarily qualitative, and highlights analysis of previous malevolent
365 events and evasions of security systems, likely capabilities and motivations of various possible actors,
366 and an evaluation of the systems in place to prevent biosecurity breaches. Information was obtained
367 from a survey of literature and discussions with biosecurity, intelligence, and law enforcement
368 professionals. It is an extensive gathering of a wide range of information that has not been presented
369 before in one place.

370 The information risk assessment (an element of the biosecurity risk assessment) is a qualitative analysis
371 of risks that may result from the misuse of information derived from certain GOF studies that might be
372 published in the future. It identifies information that might be attractive to malicious actors and
373 compares it to other sources of information they might find attractive.

374 The benefits assessment uses a novel approach to assess benefits of GOF studies, a difficult task with
375 little prior methodology to draw upon. The results are not quantitative, and attempts to quantify would
376 have been appreciated. However, as is, the assessment may be the best that can be done with the
377 available information and analytic tools. The benefits assessment thoroughly analyzed the possible
378 benefits of alternatives to GOF studies and identified areas where GOF research appears to provide
379 unique benefits (i.e., benefits that are not attainable without the use of GOF), either currently or in the
380 near future.

381 The RBA contains a number of other useful analyses as well, including background and contextual
382 information on the biology of influenza and coronavirus, historical analysis of naturally-occurring
383 seasonal and pandemic influenza and coronavirus outbreaks, an examination of the potential
384 proliferation of GOF research, and analysis of the potential loss of public trust in science that could
385 result if a laboratory incident involving GOF research were to occur. Significantly, the historical analysis
386 notes that each year, influenza infects 5 – 10% of the world’s population, resulting in significant
387 morbidity and mortality (up to 500,000 deaths per year). This description of naturally-occurring
388 influenza (and coronavirus) infections helps to establish the extant risks associated with these infectious
389 diseases to which the risks associated with GOF studies might be compared.

390 Overall, the RBA is comprehensive, objective, reasonable, and generally extensively documented.

391

392 **Limitations of the Risk and Benefit Assessments**

393 The RBA also has some weaknesses and limitations that should be noted. First, the RBA was limited to
394 the types of labs traditionally funded by the Federal government, which may not be representative of
395 other settings where GOF research may be conducted. Every attempt was made to base the analyses in
396 the RBA on scientific information and data. Nevertheless, data on the properties of the various
397 pathogens being examined, events such as laboratory accidents or security breaches, or possible future
398 acts of terrorism are limited in some cases and unavailable in principle in others. Therefore,
399 assumptions and estimations were necessary. For this reason, the biosafety risk assessment is not fully
400 quantitative, primarily because absolute, quantitative baselines for the risk of work with wild-type
401 pathogens could not be estimated with any certainty. Thus, the data presented are primarily
402 comparative, and provide relative, not absolute values, for the risks associated with laboratory accidents
403 involving GOF studies. Gryphon compared the risks associated with potential lab accidents involving a
404 GOF strain with the risks associated with the same accident involving a wild-type strain. This
405 comparative approach is adequate for some instances but inadequate for others. For instance, an
406 increased risk associated with a GOF study that is relatively large (5-10-fold or greater) may appear
407 significant, but if this increase is in comparison to a very small risk baseline, the overall risk associated
408 with the GOF study may not be significant or concerning. Similarly, small increases in risk over a higher
409 risk baseline, in fact, may be concerning. Additionally, differences in risk that are relatively small (~2-
410 fold) are difficult to interpret because such changes may fall within the limits of uncertainty for the
411 analysis. Attempts to include some absolute baseline estimates of risk (an admittedly difficult task)
412 were included in Section 6.8 of Gryphon's report. However, the lack of comprehensive estimates of
413 baseline risk make interpreting the biosafety risks a challenge.

414 Given the comparative approach undertaken for the biosafety risk assessment, the implications of the
415 results of this analysis depend a great deal on the wild-type comparator strains that were selected for
416 the analysis. For instance, for pandemic influenza Gryphon initially selected the 1918 influenza strain as
417 the comparator. Gryphon regarded this strain as embodying the maximum risk for influenza, yet a level
418 of risk that is also deemed as acceptable given that research with this strain is permitted. However,
419 using 1918 influenza as the comparator for the analysis compares GOF risks to a relatively high level of
420 baseline risk, making the changes in risk associated with GOF manipulations comparatively small.
421 Utilizing different comparator strains alters the relative risks associated with GOF manipulations; using a
422 high-risk baseline strain may obscure significant risks associated with GOF studies whereas using a low-
423 risk baseline strain may inflate the potential risks associated with GOF studies.

424 Little data exists about the probabilities of the accidents that initiate the chain of events that may lead
425 to a pandemic and therefore, the quantitative probability of these accidents could not be incorporated
426 into the biosafety risk assessment. The modeling of secondary spread of a pathogen through
427 populations once it is released from a laboratory allows for some estimation of the consequences of an
428 event but without a better understanding of the likelihood that an accident would result in loss of
429 containment or a laboratory acquired infection, it is difficult to make judgments about the overall risk.
430 Gryphon's analysis accounts for this by presenting relative, actuarial risk. However, this approach results
431 in the challenges associated with comparing relative risks described above. There are large

432 uncertainties in most of the input parameters that are the basis for the biosafety risk calculations.
433 Uncertainties about inferring absolute risk from these relative risks exist and should be kept in mind as
434 any conclusions are reached.

435 The biosecurity risk assessment attempts to examine how GOF studies add to the risk of malevolent
436 acts. Portions of the biosecurity risk assessment focus on GOF studies but others describe the type of
437 threats that could occur against any high-containment laboratory. The semi-quantitative portion of the
438 biosecurity risk assessment estimates probabilities for escape and secondary spread and escape from
439 local control for various pathogens and event types. However, this analysis (see section 7.4 and Table
440 7.7 in Gryphon's report) assumes that 1 or 10 individuals are initially infected as a result of a malicious
441 act with no indication of how likely such an event would be, since there is no way to make such an
442 estimate.

443 While exhaustively documented, the RBA is not always transparent about data reliability. In particular,
444 interviews were used to gather much critical information, and this was not always well documented in a
445 way that reflects how robust the resulting information may be. For peer-reviewed publications, this is
446 less of a concern.

447 While evaluation of the benefits of alternatives to GOF studies was extensive, evaluation of risks of
448 alternative approaches was not as thorough. In addition, risks and benefits have not been presented in
449 comparable terms, making it a challenge to determine whether certain risks are justified by potential
450 benefits. Significantly, the benefit assessment is not quantitative and there is no probability analysis or
451 attempt to estimate the likelihood that a certain benefit would be realized or what its impact might be.

452 **Key Results of the Risk and Benefit Assessments**

453 While NSABB has examined all of the analyses in the RBA, some results are important to highlight. In
454 general, the RBA examined risks and benefits associated with the major GOF phenotypes with the
455 intention of identifying types of studies that would be most and least concerning, based particularly on
456 their risk profile.

457 With regard to biosafety risks, only some potential GOF phenotypes represent substantially increased
458 (5- to 10-fold or more) risks over the starting strain. Two-fold changes most likely fall within the
459 uncertainty of the data, and while small differences might be important if it could be shown that they
460 are significant, this demonstration is probably difficult. For coronaviruses, GOF studies that would
461 create strains with increased transmissibility among mammals may entail significant risks if they also
462 increase human transmission. The risks, were this combination to occur, would include increased
463 probability of an outbreak escaping local control and increased likelihood of global consequences. In
464 addition, experiments that enhance coronavirus growth in culture would likely increase the possibility of
465 laboratory acquired infections.

466 For seasonal influenza, the GOF-generated phenotypes entailing the greatest risks include enhanced
467 transmission in mammals (assuming this increases transmission in humans), enhanced virulence, and
468 evasion of immunity. Enhanced pathogenicity might significantly increase the global consequences of

469 an outbreak. For pandemic influenza, no GOF-generated phenotypes led to greatly increased risk, but
470 that is based on using 1918 influenza as the comparator; because the risk associated with the wild-type
471 1918 strain is already so great it is difficult to increase risk substantially. If less transmissible and/or less
472 virulent wild-type strains were used as the basis of comparison, the risks of GOF studies with pandemic
473 strains might appear higher. For avian influenza, the GOF experiments that lead to enhanced
474 transmissibility in mammals (and presumably humans) would likely lead to an increased probability of
475 local and widespread outbreaks, as well as increased global consequences. More subtle aspects of these
476 very general conclusions may be found in the biosafety risk section of the Executive Summary of
477 Gryphon's RBA report.

478 In general, GOF studies that were not considered by the working group to entail significant risks were
479 those that would: adapt human pathogens to mammals to generate animal models; enhance the growth
480 of attenuated vaccine strains; and antigenic drift or immune evasion studies that are commonly used to
481 guide vaccine selection.

482 The biosecurity risk assessment shows that the most probable threats involve insiders who have direct
483 access to dangerous pathogens or outsiders who collaborate with or subvert insiders. If currently
484 mandated biosecurity systems are effective, outsiders have little chance of causing harm on their own.
485 The RBA report also concludes that the risks associated with information from future GOF studies with
486 influenza, SARS and MERS appear small; this is because most of the information of interest is already
487 published, or non-GOF information relating to pathogens that are more attractive agents of harm is
488 readily available. However, future scientific advancements could alter this assessment.

489 Most GOF studies provide benefits in the form of new scientific knowledge, and some of these benefits
490 are unique (i.e., unable to be achieved by alternative, non-GOF approaches). While some GOF studies
491 are likely to provide unique near-term benefits, these are associated with specific agents and
492 phenotypes. With regard to more applied benefits, such as countermeasure development and
493 biosurveillance, the most clear-cut situation is experiments that increase growth of seasonal influenza
494 vaccine candidates in culture; these studies provide unique benefits to current production of seasonal
495 influenza vaccines, and likely will in the future. Another reasonably clear unique benefit is derived from
496 experiments that enhance mammalian pathogenicity for coronavirus as a means of developing animal
497 models for studying disease and developing countermeasures. GOF studies that yield phenotypes that
498 provide unique benefits to countermeasure development include enhanced pathogenicity, evasion of
499 vaccines, and evasion of therapeutics. For several other potential benefits with seasonal influenza,
500 either the potential benefit is long term, or alternative approaches may yield the same or similar
501 benefits. Interestingly, few unique benefits pertaining to GOF studies involving pandemic influenza
502 were identified. There are several types of GOF studies that entail generating avian influenza strains
503 with phenotypes that may be valuable for surveillance and preparedness efforts, although other
504 advances are needed to fully realize such benefits. This point is controversial, with strong proponents
505 and critics. Additionally, a variety of benefits were identified that may also be provided to some extent
506 by alternative approaches. It should be noted that no attempt was made to provide a probability
507 assessment based on historical data for potential benefits; hence no direct comparison of risk to benefit
508 for a proposed research project is possible.

509 **4.2. Consideration of Ethical Values**

510 The risk and benefit assessments provide information about the potential risks and benefits associated
511 with conducting GOF research. However, determinations about whether such studies should be
512 undertaken will involve value judgments when weighing the risks and benefits. The NSABB identified a
513 number of values (that are applicable to the decisions about whether to fund certain GOF studies and
514 how to oversee them. Sources of these values include the Belmont Report,¹² the literature on public
515 health ethics,¹³ and the literature on oversight of emerging technologies,¹⁴ as well as the literature
516 specifically debating appropriate approaches to overseeing DURC and GOF research that has raised
517 concern.^{15,16,17,18,19} The commissioned ethics analysis conducted by Dr. Michael Selgelid also describes
518 additional decision-making frameworks and values to be considered.²⁰

519 **Substantive values**

520 The following values are important to consider when determining whether to fund a research proposal
521 involving GOF studies that might entail significant risks.

522 **Non-maleficence:** not causing harm. There are inherent risks associated with research involving
523 pathogens that could result in harm that might include: losing lives; causing disease; damage to the
524 economy, national or international security, or agriculture; or loss of public trust in science or
525 governance structures. Approaches aimed at preventing harm and mitigating potential risks should
526 be considered and applied to the design, conduct, and communication of research involving
527 pathogens in GOF studies.

528 **Beneficence:** promoting beneficial outcomes while preventing harmful outcomes; appropriately
529 balancing benefits and risks; formulating policy that maximizes public benefit while minimizing
530 public harm. Benefits might include: saving lives, preventing disease, improving public health;
531 enhancing the economy, national and international security, or public trust in science and

¹² The Belmont Report. Office of the Secretary, U.S. Department of Health and Human Services. Ethical Principles and Guidelines for the Protection of Human Subjects Research. The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, April 18, 1979. <http://www.hhs.gov/ohrp/humansubjects/guidance/belmont.html>

¹³ Kass NE. An Ethics Framework for Public Health. *American Journal of Public Health*. 2001;91(11):1776-1782. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1446875/>

¹⁴ New Directions. The Ethics of Synthetic Biology and Emerging Technologies. Presidential Commission for the Study of Bioethical Issues, December 2010. http://bioethics.gov/sites/default/files/PCSBI-Synthetic-Biology-Report-12.16.10_0.pdf

¹⁵ Resnik DB. H5N1 Avian flu research and the ethics of knowledge. *Hastings Center Report* 2013; 43, 2: 22-33.

¹⁶ Kelle A. Beyond patchwork precaution in the dual-use governance of synthetic biology. *Sci Eng Ethics*. 2013 Sep;19(3):1121-39.

¹⁷ Kuhlau F, Höglund AT, Evers K, Eriksson S. A precautionary principle for dual use research in the life sciences. *Bioethics*. 2011 Jan;25(1):1-8.

¹⁸ Biotechnology Research in the Age of Terrorism. The National Academies, 2004. <http://www.nap.edu/catalog/10827/biotechnology-research-in-an-age-of-terrorism>

¹⁹ Proposed Framework for the Oversight of Dual Use Life Sciences Research: Strategies for Minimizing the Potential Misuse of Research Information. National Science Advisory Board for Biosecurity, June, 2007. <http://osp.od.nih.gov/sites/default/files/resources/Framework%20for%20transmittal%20duplex%209-10-07.pdf>

²⁰ Selgelid, Michael. Gain-of-Function Research: Ethical Analysis. December 7, 2015. http://osp.od.nih.gov/sites/default/files/GOF%20White%20Paper%20by%20Michael%20Selgelid_0.pdf

532 governance structures. When the ultimate goals of the research are to improve public health, public
533 health ethics would ask how effective the research is likely to be in achieving those goals, what are
534 the known or potential burdens of the research, can those burdens be minimized, whether there are
535 alternative approaches that are less risky or burdensome, and how can the potential benefits and
536 burdens of the research be fairly balanced. The work of the Presidential Commission for the Study
537 of Bioethical Issues suggests that those formulating and implementing government policy on
538 scientific research and emerging technologies have a duty of public beneficence – a duty “to
539 promote individual activities and institutional practices...that have great potential to improve the
540 public’s well-being,” while being “vigilant about risks and harms, [and] standing ready to revise
541 policies that pursue potential benefits with insufficient caution.”²¹ Both risks and benefits have
542 associated probabilities, magnitudes, and uncertainties. In some instances, it may be justifiable to
543 pursue benefits despite the potential risks; in others, the potential benefits may be foregone due to
544 possible risks.

545 **Social justice:** distributing potential benefits and harms fairly (distributive justice) and selecting
546 participants in research fairly, as well as those who may potentially be exposed to risk. There are
547 many different approaches to social justice, such as egalitarianism, utilitarianism, and
548 libertarianism,²² to name but a few. Decisions about whether to fund research that entails some risk
549 should consider how the risks and benefits associated with conducting that research will be
550 distributed, with an effort to distribute risks and benefits as fairly as possible. When considering
551 pandemic potential, fair distribution of risks and benefits must be considered on a global scale.
552 Those who will potentially be exposed to risk, through participation in research or other avenues of
553 exposure, should be selected equitably.

554 **Respect for persons:** allowing competent individuals to make informed choices, and ensuring that
555 the representatives of individuals lacking capacity to choose can make choices in keeping with the
556 wishes, values, or interests of those represented. Autonomy generally requires informing human
557 research participants, laboratory workers, and the public about the risks of research and eliciting
558 their free and uncoerced decision about whether to subject themselves to those risks. In the case of
559 the public, mechanisms for representative decision-making and publicly accountable governance
560 may be needed, as getting consent directly from the members of the public may be impracticable.

561 **Scientific freedom:** avoiding unnecessary interference with scientific research, debate, or
562 publication. Scientific freedom includes an entitlement to avoid interference unless necessary
563 (negative freedom), but not the affirmative right to receive funding or other forms of support for a
564 particular project (positive freedom). Scientific freedom is compatible with norms and regulation to
565 promote the responsible conduct of research and protect participants in research and the public. As
566 a corollary to the principle of scientific or intellectual freedom, the Presidential Commission

²¹ New Directions. The Ethics of Synthetic Biology and Emerging Technologies. Presidential Commission for the Study of Bioethical Issues, December 2010. http://bioethics.gov/sites/default/files/PCSBI-Synthetic-Biology-Report-12.16.10_0.pdf

²² Nozick R. Anarchy, State, and Utopia. New York: Basic Books, 1974.

567 endorses a principle of regulatory parsimony, requiring “only as much oversight as is truly necessary
568 to ensure justice, fairness, security, and safety while pursuing the public good.”²³

569 **Responsible stewardship:** acting in a way that shows concern for children, future generations, and
570 the environment. The Presidential Commission emphasizes that this is both a domestic and global
571 responsibility that requires “prudent vigilance, establishing processes for assessing likely benefits
572 along with assessing safety and security risks both before and after projects are undertaken.”²⁴

573 **Procedural Values**

574 The following values apply to the process of decision-making about GOF research and are important to
575 consider when establishing mechanisms to review and/or approve the funding of research proposals
576 involving gain-of-function studies that may entail significant risks.

577 **Public participation & democratic deliberation:** making decisions with participation from the public,
578 utilizing respectful debate and inclusive deliberation. Life sciences research is largely a publicly-
579 supported endeavor; therefore, those who allocate funds and conduct life sciences have a
580 responsibility to be good stewards of public funds and to respond to the interests and concerns of
581 the public. Many, if not all, members of society have a stake in the life sciences enterprise and will
582 be affected directly or indirectly by the benefits and risks stemming from such research. This
583 stakeholder community has diverse values and tolerances for risk, which are important to consider
584 when making decisions about funding and overseeing life sciences research. Some forms of public
585 participation include: oversight by the legislative or executive branches of government, public
586 membership and input on government science advisory committees, other mechanisms of public
587 governance, surveys of public opinion on science policy issues, research models such as community-
588 based participatory research, and efforts by scientists and government officials to share information
589 with the public and better understand the public’s interests and concerns. The Presidential
590 Commission urges the importance of democratic deliberation, as “[a]n inclusive process of
591 deliberation, informed by relevant facts and sensitive to ethical concerns, promotes an atmosphere
592 for debate and decision making that looks for common ground wherever possible and seeks to
593 cultivate mutual respect where irreconcilable differences remain.”²⁵

594 **Accountability:** taking responsibility for one’s actions and being prepared to justify or explain them
595 to others. It is important that decisions to fund research are justifiable to the public and others.
596 Decisions should be justified in terms of substantive and procedural values.

597 **Transparency:** sharing with the public the information and assumptions used to make decisions,
598 including uncertainties, controversies, and limitations of analyses. Transparency is an important

²³ New Directions. The Ethics of Synthetic Biology and Emerging Technologies. Presidential Commission for the Study of Bioethical Issues, December 2010. http://bioethics.gov/sites/default/files/PCSBI-Synthetic-Biology-Report-12.16.10_0.pdf, p5.

²⁴ Ibid., p5.

²⁵ Ibid., p5.

599 part of accountability and public participation. It allows review and reconsideration of policy over
600 time as new facts emerge and analysis evolves.

601 **4.3. Decision-Making Strategies and Frameworks for Evaluating and Managing Risks** 602 **and Developing Policy**

603 The NSABB working group identified a number of approaches or frameworks that may be used to guide
604 the making of complex decisions with ethical implications, particularly in the face of uncertainty. These
605 may also be used in developing policies such as that for managing GOF research. Different strategies
606 reflect different attitudes toward risk-taking. Some may be more appropriate in some situations than
607 others. The NSABB working group examined a number of such strategies as it attempted to determine
608 the best option as relates to GOF research that has raised concerns. These options are not mutually
609 exclusive, and elements from more than one may be used together to develop a path forward. The
610 following are decision-making frameworks that were considered.

611 **Maximax:** This involves choosing the option with the best possible outcome. Maximax is a
612 relatively simple strategy that focuses on choosing the option with the best possible outcomes While
613 maximax may be appropriate for making some types of personal choices (e.g. playing games with
614 nothing of value to lose), it may not be appropriate for making science and technology policy
615 decisions because most people would want to take appropriate steps to prevent or mitigate risks
616 regardless of benefits. For GOF studies, use of maximax would involve identifying research with the
617 best possible benefits, generally regardless of risks.

618 **Maximin:** This involves choosing the option with best outcome among the worst possible
619 outcomes. Maximin is a risk-averse approach because it aims to avoid the worst possible outcomes.
620 Maximin is another relatively simple approach, but may present difficulties in making science and
621 technology policy decisions, because it would recommend not developing a new technology if this
622 decision could lead to the worst possible outcome. Since all technologies (and scientific ideas) can
623 conceivably lead to good and bad outcomes, strict adherence to maximin would imply a very
624 cautious approach to science and technology development. For GOF studies, use of maximin would
625 involve identifying studies with risks, and choosing the least risky regardless of benefits.

626 **Expected Utility Theory:** This involves choosing the option that maximizes expected utility, where
627 expected utility for a possible outcome = probability x utility. Expected utility theory involves a
628 quantitative balancing of risks and benefits and is inherently a more complex process. Cost-benefit
629 analysis in economics is a form of expected utility theory. A problem with expected utility theory is
630 that sufficient evidence may not always be available to confidently estimate the probabilities
631 involved in the utility calculus. When this is the case, other approaches may be appropriate. For
632 GOF studies, use of expected utility theory would require determining quantitatively the likelihood
633 of risks and benefits and calculating the resulting utility.

634 **Precautionary approach:** This approach involves taking reasonable measures to prevent, minimize,
635 or mitigate risks that are significant and plausible. A measure is “reasonable” if it: 1) appropriately

636 balances the values at stake in the risk management; 2) is proportional to nature of the risk (i.e.
637 greater risks require stronger measures); and 3) is likely to be effective. A risk is “plausible” if there
638 is some scientific evidence that it could occur even if the probability of the risk cannot be
639 confidently estimated. There are many versions of the precautionary principle, including ones that
640 are more or less risk-averse.^{26,27} A precautionary approach, in general, would limit an activity unless
641 the environment, health, or security, are clearly protected. This approach can recognize a potential
642 problem early and prevent harm from occurring but may lead to regulatory burdens or
643 unnecessarily limit activities. This approach might restrict potential GOF research unless the studies
644 are demonstrated to be safe.

645 **Permissive approach:** This approach, in general, would allow an activity unless the environment,
646 health, or security, are clearly compromised. This approach may reduce unnecessary regulatory
647 burdens but can result in after-the-fact reaction to harms. This approach might allow certain GOF
648 studies to proceed until they are demonstrated to entail significant risk.

649 **Planned adaptation or risk-based approach:** This approach provides a systematic way to deal with
650 managing risks in the face of uncertainty. It involves: 1) preparation to identify the risks and
651 regulatory gaps, including getting input from a broad range of perspectives; 2) putting measures in
652 place to control risk based on the best information available at the time; 3) systematically gathering
653 data and observing effects of policies; and 4) updating and revising policy as needed. An example of
654 an adaptive approach is the life cycle approach taken by the Food and Drug Administration when
655 making decisions about whether to approve drugs, when that includes post-market surveillance.²⁸
656 For GOF studies, this approach might entail allowing GOF studies of potential concern—or certain
657 GOF studies—to proceed under defined conditions, then evaluating the risk-benefit landscape
658 periodically to determine whether the GOF studies that are permitted should continue, be
659 expanded, or be restricted.

660 **Threshold approach:** This approach would entail identifying a risk threshold beyond which, certain
661 studies are given special attention or subject to additional scrutiny or oversight and might preclude
662 certain studies. Implementation would involve defining or describing the studies that would require
663 additional oversight as well as a description of what that oversight would entail. This approach
664 would allow for the identification of studies of concern but might need to be reevaluated if the risk
665 landscape changes and the threshold that was identified is no longer appropriate. For GOFROC, this
666 would entail identifying the characteristics of studies involving significant risks that may not be
667 adequately managed and then stipulating further oversight or determining that they should not be
668 conducted.

²⁶ Resnik DB. *Environmental Health Ethics*, New York: Oxford University Press, 2013.

²⁷ Munthe C. *The Price of Precaution and the Ethics of Risks*. Dordrecht: Springer, 2011.

²⁸ FDA determinations about whether a new drug is safe and effective are complex, address uncertainty, and involve ongoing monitoring to assess risks and benefits and take appropriate post-marketing actions as necessary. See: *Structured Approach to Benefit-Risk Assessment in Drug Regulatory Decision-Making*, 2013

<http://www.fda.gov/downloads/ForIndustry/UserFees/PrescriptionDrugUserFee/UCM329758.pdf>

669 **Point-source approach:** This approach would involve controlling where certain studies are
670 conducted and under what conditions. This approach would centralize certain research activities,
671 restricting them to designated locations or facilities. For GOFROC this might involve requiring that
672 certain studies only be conducted in facilities with certain biocontainment conditions, biosafety
673 practices, and security measures.

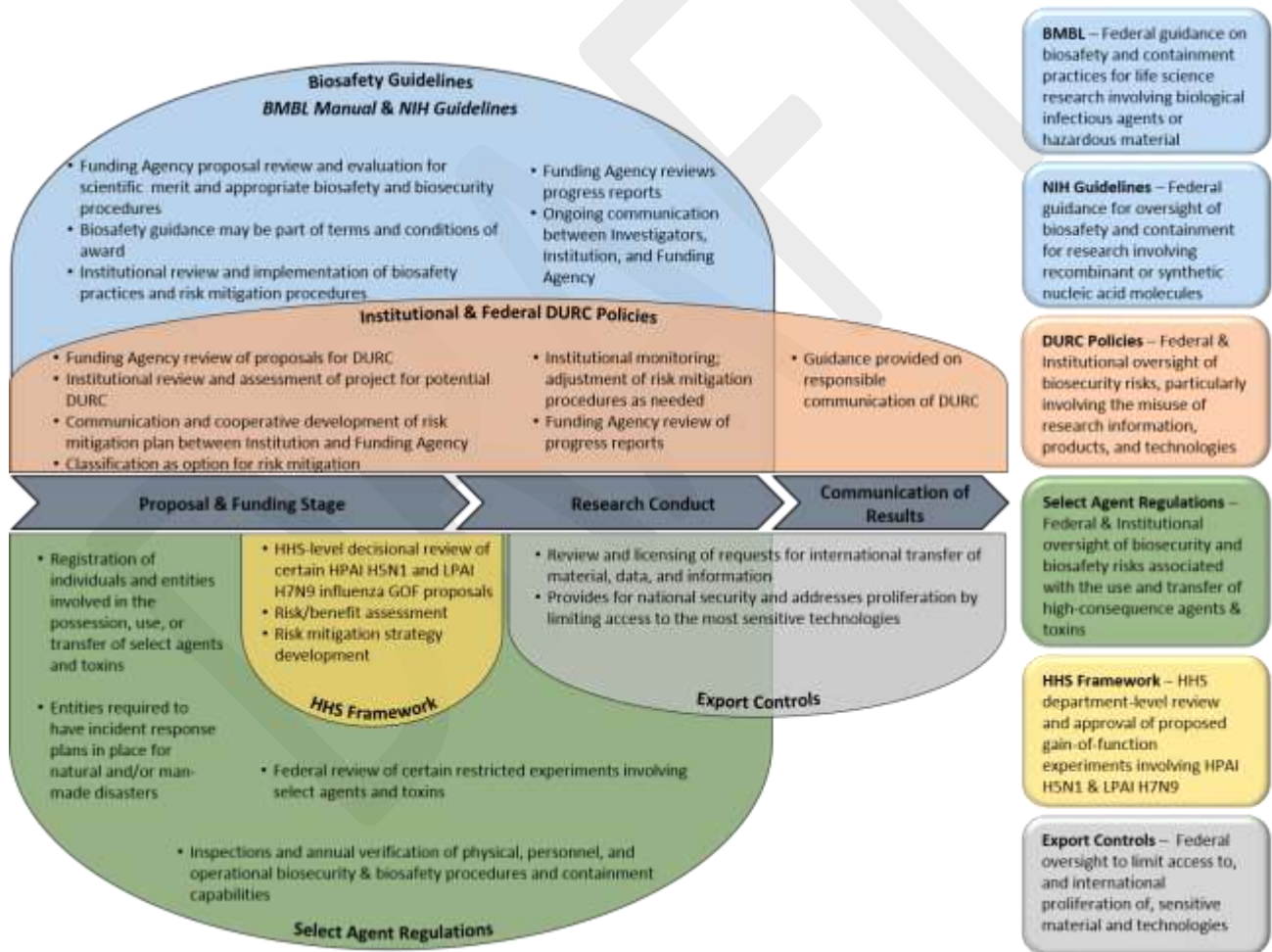
674 The NSABB working group used ideas from a number of frameworks to inform its findings and
675 deliberations (Sections 5 and 6). The criteria for identifying GOF research of concern (see
676 Recommendation 1) reflect a threshold approach. The principles for guiding funding decisions for GOF
677 research of concern include elements from several of the decision frameworks above. For instance, an
678 explicit call for a risk-benefit analysis (Recommendation 1, Guiding Principle 3) reflects expected utility
679 theory; however, a strict quantitative calculation is probably not possible. The principles to guide
680 funding decisions that call for risk mitigation and a restriction to laboratories with a demonstrated
681 capacity to safely carry out the studies (Recommendation 1, Guiding Principles 4 and 5) incorporate
682 elements of point-source and precautionary approaches. An adaptive approach was considered
683 particularly attractive and appropriate for policies aimed at providing oversight of GOF research (see
684 Recommendation 3).

685

686

687 **4.4. Examination of the Current Policy Landscape**
688

689 Many Federal agencies fund life sciences research in furtherance of their specific missions. In general,
690 research supported by the USG is founded on the principle of scientific merit and goals of the funding
691 agency. Multiple complementary layers of oversight are in place to manage laboratory and other risks
692 associated with Federally-funded life sciences research. These policies are intended to provide oversight
693 at various points throughout the research life cycle, from research conception to its publication and
694 translation into practice. These policies include a foundation of occupational health and medicine (for
695 laboratory and clinical workers), laboratory biosafety practices, and policies that address biosecurity
696 risks. Below is a description of the oversight policies in place for Federally-funded life sciences research
697 involving pathogens, with discussion of whether and how such policies apply to GOF studies. This
698 analysis is illustrated in Figures 2 and 3 and summarized in Appendix B.
699



700
701
702 **Figure 2. U.S. government oversight of life sciences research involving pathogens.** Oversight policies apply at different stages
703 and occur at different levels throughout the research life cycle. See text and Appendix B for descriptions of each policy. These
704 policies have different applicability and scope conditions and therefore do not apply to all life sciences (or GOF) research
705 projects.

706 **Scientific Merit Review**

707
708 Departments and agencies within the U.S. government fund diverse portfolios of life sciences research.
709 Funding decisions are based on the scientific merit of a given proposal and the ability of a project to
710 advance the agency's strategic mission. The U.S. government funds life sciences research through a
711 variety of mechanisms including grants, contracts, and cooperative agreements. Each funding agency
712 has its own processes for evaluating research proposals and awarding funds but, in general, proposals
713 are subject to rigorous scientific review by Federal agency staff and often, scientific peers. NIH grant
714 proposals, for example, undergo two levels of review. The first evaluation is by a panel of scientific peer
715 reviewers who score proposals based on scientific merit and other criteria. The second round of review
716 includes discussion of meritorious proposals at public meetings of advisory councils, specific to
717 individual funding institutes and centers within NIH, to determine how proposals fit within their broader
718 strategic objectives.

719
720 **Biosafety Oversight**

721
722 Oversight of pathogen research focuses first on ensuring the safe handling of biological agents through
723 appropriate biosafety practices and containment measures, which are addressed by the *Biosafety in*
724 *Microbiological and Biomedical Laboratories (BMBL)*²⁹, the *NIH Guidelines for Research Involving*
725 *Recombinant or Synthetic Nucleic Acid Molecules (NIH Guidelines)*³⁰, and other documents. The BMBL
726 and the *NIH Guidelines* provide for Federal and institutional biosafety oversight and guidance involving
727 biosafety practices and containment features that are based on risk assessments for specific
728 projects. Such determinations are typically made at the institutional level and are guided by Federal
729 guidelines and policies, which are updated as necessary to provide additional guidance for research
730 involving emerging pathogens or technologies. Biosafety is achieved by conducting research under
731 appropriate physical and biological containment levels and employing practices that help to ensure a
732 safe working laboratory environment.

733
734 The BMBL is a CDC-NIH guidance document that is generally considered the authoritative reference for
735 laboratory biosafety. The BMBL provides summary statements for many bacterial, fungal, parasitic,
736 rickettsial, viral, and other agents. These statements describe the characteristics of the pathogen, its
737 natural mode of infection, potential occupational hazards with the agent, and recommendations for
738 laboratory safety and containment. It also describes the fundamentals of biological containment, which
739 includes descriptions of proper microbiological practices, safety equipment, and facility safeguards that
740 protect laboratory workers, the environment, and the public from exposure to infectious
741 microorganisms that are handled and stored in the laboratory. It describes the process of biological risk

²⁹ Biosafety in Microbiological and Biomedical Laboratories (BMBL), 5th Edition.
<http://www.cdc.gov/biosafety/publications/bmbl5/>

³⁰ The NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules (NIH Guidelines), November 2013. http://osp.od.nih.gov/sites/default/files/NIH_Guidelines.html

742 assessment, which enables the appropriate selection of microbiological practices, safety equipment, and
743 facility safeguards that can prevent laboratory-associated infections. It also describes occupational
744 health, immunoprophylaxis, and principles for laboratory biosecurity. The BMBL is updated periodically
745 to refine guidance based on new knowledge and experiences and to address contemporary issues that
746 present new risks that confront laboratory workers and the public health.

747
748 **Analysis:** The BMBL does not address GOF studies *per se* but does include summary statements and
749 biocontainment guidance for research involving various influenza strains (including contemporary
750 and non-contemporary human, high and low pathogenic avian, swine, the 1918 influenza strain, and
751 reassortant viruses) and SARS-CoV. MERS-CoV had not emerged at the time of the last BMBL
752 update, but interim laboratory biosafety guidance was issued by CDC.³¹

753
754 The BMBL is not a regulatory document. U.S. funding agencies may require it be followed as a term
755 and condition of awards but, in general, compliance with the BMBL is voluntary. In addition, the
756 BMBL provides general biosafety guidance but does not describe detailed procedures or
757 experiment-specific containment protocols.

758
759 The *NIH Guidelines* specify the practices for safely constructing and handling: recombinant nucleic acid
760 molecules; synthetic nucleic acid molecules, including those that are chemically or otherwise modified
761 but can base pair with naturally occurring nucleic acid molecules; and cells, organisms, and viruses
762 containing such molecules. The *NIH Guidelines* apply to basic and clinical research involving
763 recombinant or synthetic nucleic acid molecules conducted at or sponsored by institutions that receive
764 NIH funding for any such research. Compliance with the *NIH Guidelines* is typically required as a term
765 and condition of award of funding. Other Federal agencies may also require compliance with the *NIH*
766 *Guidelines*.

767
768 The *NIH Guidelines* focus on the concepts of risk assessment, risk group classification of agents based on
769 their ability to cause disease in humans and the availability of medical countermeasures, physical and
770 biological containment levels, practices, personal protective equipment, and occupational health. To
771 help ensure the safe conduct of this research, the *NIH Guidelines* specifies roles and responsibilities of
772 investigators and institutions. Institutions subject to the *NIH Guidelines* must establish Institutional
773 Biosafety Committees (IBCs) composed of members with appropriate expertise, to review and approve
774 such research. IBCs provide local oversight and ensure compliance with the *NIH Guidelines*. Certain
775 higher risk experiments require review by the Recombinant DNA Advisory Committee (RAC)³² and
776 specific approval by the NIH Director as Major Actions. These experiments involve the deliberate
777 transfer of a drug resistance trait to microorganisms that are not known to acquire the trait naturally, if

³¹ Interim Laboratory Biosafety Guidelines for Handling and Processing Specimens Associated with Middle East Respiratory Syndrome Coronavirus (MERS-CoV) – Version 2. <http://www.cdc.gov/coronavirus/mers/guidelines-lab-biosafety.html> [last updated June 18, 2015]

³² The Recombinant DNA Advisory Committee (RAC) is a federal advisory committee that provides recommendations to the NIH Director related to basic and clinical research involving recombinant or synthetic nucleic acid molecules. See: <http://osp.od.nih.gov/office-biotechnology-activities/biomedical-technology-assessment/hgt/rac>

778 such acquisition could compromise the ability to control disease agents in humans, veterinary medicine
779 or agriculture.

780
781 In order to continue to provide appropriate guidance for emerging pathogens or experimental
782 approaches, the *NIH Guidelines* are updated periodically. The *NIH Guidelines* have been amended to
783 include additional guidance for work with Risk Group 3 influenza viruses (1918 H1N1, H2N2, highly
784 pathogenic avian influenza (HPAI) H5N1), to specify enhancements to biosafety level 3 containment,
785 practices, and to incorporate occupational health requirements. In 2012, the *NIH Guidelines* were
786 amended again to require further enhancements to facilities, biosafety equipment and practices,
787 including occupational health practices, for research involving HPAI H5N1 strains transmissible among
788 mammals by respiratory droplets.

789
790 **Analysis:** The *NIH Guidelines* provide guidance on risk assessment and appropriate containment and
791 practices for conducting research involving recombinant or synthetic nucleic acids, which would
792 apply to most government-funded GOF research. Some IBCs also review and approve non-
793 recombinant pathogen research; however, not all institutions require their IBCs to do so. While the
794 *NIH Guidelines* are often used as a model of biosafety guidance by the broader scientific community,
795 compliance is required only by institutions receiving funding from the NIH for research involving
796 recombinant or synthetic nucleic acid molecules. Therefore, some GOF studies may not be subject
797 to the *NIH Guidelines* depending on whether the institution where the research is being conducted
798 is subject to the *NIH Guidelines*.

799
800 **The Federal Select Agent Program**

801
802 Subtitle A and B of the Public Health Security and Bioterrorism Preparedness and Response Act of 2002
803 requires the U.S. Departments of Health and Human Services (HHS) and Agriculture (USDA) to establish
804 and regulate a list of select agents, biological agents and toxins that have the potential to pose a severe
805 threat to public health and safety or animal or plant health or animal or plant products. The Select
806 Agent Program (SAP) is administered jointly by the HHS Centers for Disease Control and Prevention and
807 USDA Animal and Plant Inspection Service. The SAP oversees the possession, use and transfer of
808 biological select agents and toxins. The Select Agents and Toxins List is reviewed and updated biennially.
809 Under the select agents regulations, individuals and institutions that possess, use, or transfer any select
810 agent are required to be registered, follow appropriate biosafety procedures, and undergo periodic
811 inspections. Individuals must be registered with the SAP to have access to select agents or toxins, which
812 requires that they undergo a security risk assessment performed by the Federal Bureau of Investigation
813 (FBI). There are legal penalties for failing to comply with the select agent regulations.

814
815 In addition to the agents and toxins on the list, the select agent regulations apply to some genetic
816 elements, including nucleic acids that are immediate precursors to infectious forms of any select agent
817 viruses (i.e., complete positive strand RNA viral genomes), as well as some nucleic acids that encode
818 select toxins. Select agent regulations also apply to genetically modified select agents and toxins.

819 Restricted experiments are described in the regulations and involve the deliberate transfer of or
820 selection for a drug resistance trait to select agents that are not known to acquire the trait naturally. If
821 the acquisition of resistance is to a first-line drug that could compromise the use of the drug to control
822 disease agents in humans, veterinary medicine, or agriculture, the restricted experiment requires special
823 review and approval by the SAP. Some attenuated strains of select agents may be excluded from the
824 regulations based upon a determination that the attenuated strain or modified toxin does not pose a
825 severe threat to public, plant, or animal health or safety. The Intragovernmental Select Agent and Toxin
826 Technical Advisory Committee serves as an advisory group to the SAP. In the wake of the recent
827 laboratory incidents at Federal facilities involving select agents, two advisory committees have issued
828 recommendations for ways to strengthen the Select Agent Program.^{33 34} Plans to implement these
829 recommendations are also in place.³⁵

830
831 **Analysis:** GOF studies are subject to oversight by the SAP if they involve pathogens on the select
832 agent list. Researchers and institutions performing such studies must receive favorable security risk
833 assessments by the FBI, register with the SAP, receive training on the proper procedures and
834 practices for handling such agents, and abide by other aspects of the regulations. SARS-CoV, HPAI
835 H5N1 influenza, and 1918 influenza viruses are select agents. Restricted experiments that would
836 entail conferring antiviral resistance to these viruses would require additional review and approval
837 prior to being conducted. However, MERS-CoV is not a select agent. GOF experiments involving
838 MERS, and other agents not included on the select agent list, would not be subject to oversight by
839 the SAP (though they could be subject to Federal and institutional biosafety oversight). The SAP is
840 underpinned by a regulatory requirement that applies to non-USG funded (i.e., private sector
841 funded) pathogen research as well.

842

843 **Federal and Institutional Oversight of Life Science Dual Use Research of Concern**

844

845 The U.S. government has issued two Federal policies for the oversight of life sciences DURC. These
846 policies focus oversight on research involving 15 high-consequence pathogens and toxins³⁶ that involve
847 seven categories of experimental activity, which are projects that can be reasonably anticipated to:

848

- 849 1. Enhance the harmful consequences of the agent or toxin;
- 850 2. Disrupt immunity or the effectiveness of an immunization against the agent or toxin without
851 clinical or agricultural justification;
- 852 3. Confer to the agent or toxin resistance to clinically or agriculturally useful prophylactic or
853 therapeutic interventions against that agent or toxin or facilitates their ability to evade
854 detection methodologies;

³³ Report of the Federal Experts Security Advisory Panel, U.S. Government, December 2014.

³⁴ Fast Track Action Committee Report: Recommendations on the Select Agent Regulations Based on Broad Stakeholder Engagement, U.S. Government, October 2015.

³⁵ Lisa Monaco and John Holdren White House Memorandum, October 29, 2015, Next Steps to Enhance Biosafety and Biosecurity in the United States. https://www.whitehouse.gov/sites/default/files/docs/10-2015_biosafety_and_biosecurity_memo.pdf

³⁶ The agents within the scope of the USG DURC policies are the 13 Tier 1 select agents plus HPAI H5N1 and 1918 influenza virus.

- 855 4. Increase the stability, transmissibility, or the ability to disseminate the agent or toxin;
856 5. Alter the host range or tropism of the agent or toxin;
857 6. Enhance the susceptibility of a host population to the agent or toxin; or
858 7. Generate or reconstitute an eradicated or extinct agent or toxin listed above.
859

860 Projects involving any of the 15 agents and that could be anticipated to involve any of these seven
861 experimental effects are then determined to be DURC if they then meet the definition of DURC listed in
862 the policy.³⁷
863

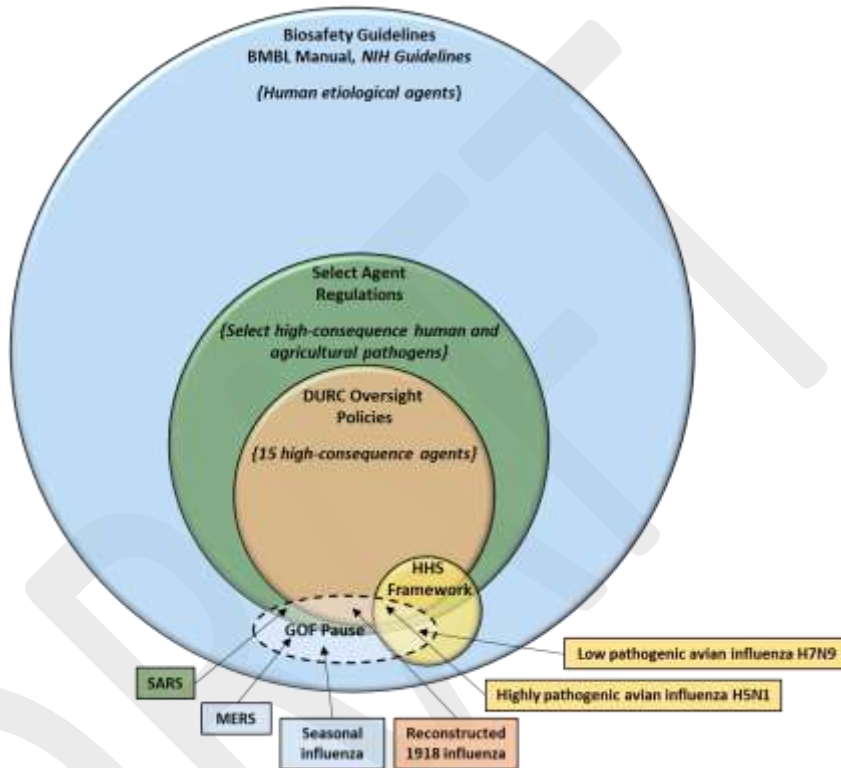
864 The DURC policies outline a coordinated approach to oversight involving the Federal funding agencies
865 and institutions that conduct such research. The policy for Federal oversight, issued in March 2012,
866 requires Federal agencies to review proposed and ongoing research projects to identify any that
867 constitute DURC.³⁸ The policy for institutional oversight, issued in September 2014, articulates
868 responsibilities of research institutions in identifying and managing DURC. Research institutions are to
869 establish an Institutional Review Entity (IRE) to review research subject to the policy to determine
870 whether any such research involves any of the seven experimental effects, and if so, whether the
871 research constitutes DURC. IREs may review projects not specifically covered under the DURC policies
872 but such additional reviews are voluntary.
873

874 When DURC is identified—either by a funding agency or a research institution—the funder and
875 institution are to work collaboratively to develop a risk mitigation plan to help ensure that the research
876 is conducted and communicated in a responsible manner. DURC risk mitigation plans are approved by
877 the Federal funding agency and are reviewed on an annual basis by the funder and the institution.
878 Specific risk mitigation measures may be incorporated into a term of award. Risk mitigation may involve
879 modifying the design or conduct of the research in order to address the same scientific question in a
880 manner that poses fewer biosafety or biosecurity risks. Other measures may involve applying enhanced
881 biosafety or biosecurity measures, evaluating the effectiveness of extant medical countermeasures prior
882 to proceeding with particular studies, or establishing a more frequent schedule of DURC reviews to
883 more closely monitor the research as it evolves. It is also expected that a communication plan is
884 established to ensure that DURC is communicated in a responsible manner. Federal funding agencies
885 can provide advice and guidance on responsible communication, but recommendations on how to
886 communicate research typically are not binding; ultimately, investigators and journal editors decide on
887 how to communicate the research.
888

³⁷ The definition of dual use research of concern listed in the USG Policy for Oversight of Life Science DURC (USG, March 2012) and the USG Policy for Institutional Oversight of Life Sciences DURC (USG, September 2014) is “Life sciences research that, based on current understanding, can be reasonably anticipated to provide knowledge, information, products, or technologies that could be directly misapplied to pose a significant threat with broad potential consequences to public health and safety, agricultural crops and other plants, animals, the environment, materiel, or national security.”

³⁸ The policy for Federal DURC oversight requires Federal funding agencies to compile biannual inventories of projects identified as being subject to DURC oversight. As part of this process, Federal agencies have been identifying projects involving MERS and LPAI H7N9 influenza and proactively managing risks associated with those projects, as necessary.

889 **Analysis:** Some of the seven experimental effects within the scope of the DURC policies could be
890 considered GOF studies. However, GOF projects that involve these effects are only subject to DURC
891 oversight if the study involves one of the 15 agents listed in the policy. Only two influenza viruses
892 are within the scope of these policies; SARS and MERS coronaviruses are not. The DURC policies are
893 also inherently subjective. While the list-based approach clearly delineates projects that are subject
894 to oversight, the definition of DURC, and to a lesser extent, the seven experimental effects, all
895 require significant judgment and interpretation.
896



897
898
899 **Figure 3. Comparison of the scope of different policies for the oversight of life sciences research involving pathogens.**
900 Oversight policies apply to research involving specified agents or procedures. GOF studies involving pathogens or
901 manipulations covered under a given policy would be subject to oversight described by that policy.
902
903

904 **Federal-Level Review of Certain Gain-of-Function Studies**

905
906 The only U.S. Federal policy that specifically addresses GOF studies is the *Framework for Guiding U.S.*
907 *Department of Health and Human Services Funding Decisions about Research Proposals with the*
908 *Potential for Generating Highly Pathogenic Avian Influenza H5N1 Viruses that are Transmissible among*
909 *Mammals by Respiratory Droplets (HHS Framework)*, issued by the U.S. Department of Health and

910 Human Services in February, 2013. Under the *HHS Framework*^{39,40} certain proposals with the potential
911 for generating highly pathogenic avian influenza H5N1 viruses that are transmissible among mammals
912 by respiratory droplets receive special review and approval before being funded by HHS. This policy was
913 subsequently expanded to include review of similar proposals involving low pathogenic avian influenza
914 H7N9 virus.⁴¹

915
916 Funding agencies within HHS (including NIH, CDC, and FDA) review relevant proposals for risks and
917 benefits, and refer relevant studies to a Department-level review group, the HHS HPAI H5N1 Gain-of-
918 Function Review Group, for advice prior to funding the proposal. The review group includes a wide
919 range of interdisciplinary expertise from across HHS and the Federal government, if necessary. HHS
920 reviews GOF research proposals that are subject to the *HHS Framework* and makes recommendations to
921 HHS funding agencies about whether the study is acceptable for funding and whether additional
922 measures may be needed to mitigate risks. HHS considers a number of factors including the following
923 criteria, which must be met in order for a GOF study to be acceptable to receive HHS funding:

- 924 1. The virus anticipated to be generated could be produced through a natural evolutionary
925 process;
- 926 2. The research addresses a scientific question with high significance to public health;
- 927 3. There are no feasible alternative methods to address the same scientific question in a manner
928 that poses less risk than does the proposed approach;
- 929 4. Biosafety risks to laboratory workers and the public can be sufficiently mitigated and managed;
- 930 5. Biosecurity risks can be sufficiently mitigated and managed;
- 931 6. The research information is anticipated to be broadly shared in order to realize its potential
932 benefits to global health; and
- 933 7. The research will be supported through funding mechanisms that facilitate appropriate
934 oversight of the conduct and communication of the research

935
936 **Analysis:** The *HHS Framework* requires an explicit consideration of the risks and benefits associated
937 with certain GOF studies prior to making a funding decision. This allows HHS to identify potential
938 risks up front and make recommendations about risk mitigation—including consideration of
939 alternative approaches or modifying the experimental design—at the outset. This review process
940 also involves broader expertise including, ethical, legal, security, intelligence, and more. The criteria
941 that must be met in order to receive funding are subject to judgment and interpretation. The scope
942 of the *HHS Framework* is quite narrow and currently covers only projects involving two influenza
943 viruses and that involve one specific experimental outcome (mammalian transmission by respiratory
944 droplets); other GOF studies do not receive this pre-funding review.
945

³⁹ *A Framework for Guiding U.S. Department of Health and Human Services Funding Decisions about Research Proposals with the Potential for Generating Highly Pathogenic Avian Influenza H5N1 Viruses that are Transmissible among Mammals by Respiratory Droplets*, U.S. Department of Health and Human Services, February, 2013.
<http://www.phe.gov/s3/dualuse/Documents/funding-hpai-h5n1.pdf>

⁴⁰ Patterson, AP, et. al. A Framework for Decisions about Research with HPAI H5N1 Viruses. *Science*. 2013 Mar 1: 339(6123): 1036-1037.

⁴¹ Jaffe H., et. al. Extra Oversight for H7N9 Experiments. *Science*. 2013 August 16: 341(6147):713-714.

946 Reviews under this framework are conducted by a group internal to the USG. Reviewing GOF
947 studies in a confidential setting allows for the examination of potentially sensitive scientific,
948 proprietary, and personal information, and allows discussions that may be sensitive from a national
949 security or public health preparedness perspective. However, such reviews do not achieve the level
950 of transparency desired by some stakeholders and also make it difficult to independently assess the
951 effectiveness of the review process. Finally, the *HHS Framework* was in place for less than two years
952 when the October 2014 funding pause was enacted and only a handful of GOF projects have been
953 reviewed to date, making it difficult to fully evaluate this policy's strengths and limitations.

954
955 In response to the funding pause⁴², the National Institute for Allergy and Infectious Diseases (NIAID),
956 within the NIH, developed a process for considering on a case-by-case basis studies that might be
957 subject to the GOF pause. Reviews by NIAID include a detailed consideration of the science, including a
958 specific examination of the viral strains in question and specific experiments being proposed. NIAID
959 begins by consulting the investigators and an internal NIAID group determines whether the projects are
960 subject to the pause. When identifying projects subject to the funding pause, NIAID has used a fairly
961 broad interpretation of the language set forth in the pause statement and paused, at least initially, more
962 projects than were ultimately determined to meet the scope of the pause policy. NIAID also sought
963 exceptions (using a mechanism provided for in the USG's moratorium statement) for projects that were
964 deemed critical to public health or national security. In determining whether an exception to the pause
965 might be warranted, NIAID considers the intent of the research, the availability of countermeasures,
966 potential alternative approaches, the risks of not conducting the research, and the available
967 mechanisms for ongoing oversight. Exceptions may only granted by the NIH Director.

968
969 **Analysis:** NIAID's process for identifying GOF projects that are subject to the funding pause is
970 rigorous and serves as an example of Federal-level identification and review of GOF studies of
971 potential concern. It includes extensive scientific review and is performed by individuals with
972 experience reviewing projects for DURC potential. It does not involve the same expertise that is
973 provided under *HHS Framework* reviews such as national security, ethics, or legal. Given the limited
974 number of projects that have been examined by NIAID it is difficult to fully evaluate how effective
975 this approach is.

976

977 Sharing and Communicating Scientific Findings and Research Products

978 The majority of life sciences research is conducted in academic settings and the results are
979 communicated openly in scientific journals and public forums. For a small subset of research with
980 national security implications, there are policies in place to restrict access to scientific information or
981 products. Under National Security Decision Directive (NSDD) 189, dissemination of fundamental
982 research is to remain unrestricted to the maximum extent possible and in instances where restriction is

⁴² U.S. Government Gain-of-Function Deliberative Process and Research Funding Pause on Selected Gain-of-Function Research Involving Influenza, MERS, and SARS Viruses, U.S. Government, October 17, 2014. <http://www.phe.gov/s3/dualuse/documents/gain-of-function.pdf>

983 necessary for national security, classification is to be the appropriate mechanism for restricting
984 access.⁴³ Life sciences research that requires classification is classified at its outset and conducted in
985 designated facilities that are equipped with the infrastructure and personnel with appropriate level
986 national security clearances to perform the research. Retroactively classifying research that was
987 conducted in an unclassified setting is immensely challenging and may be unfeasible.

988 Export controls are Federal regulations that restrict exports that have national security or foreign policy
989 implications. Certain materials and information related to biological agents and genetic elements,
990 vaccines, equipment, and related technologies are covered by export control regulations. Furthermore,
991 the transfer of controlled information to a foreign national within the United States is considered to be
992 an export to that foreign national's country. The regulations are complex but, in general, they specify
993 which items, when shipped to which destinations, will require export licenses. Life sciences research
994 that is openly published is not subject to export controls, but information that is withheld from
995 publication by the investigator or research institution based on security concerns may become subject
996 to export control regulations, and an export license may be required before that information can be
997 shared with foreign nationals. Most biological research activities that are subject to export controls fall
998 under the Department of Commerce's Export Administration Regulations, which control items that have
999 both military and civilian applications.⁴⁴ However, some might fall under the jurisdiction of the State
1000 Department's International Traffic in Arms Regulations.⁴⁵

1001 A number of scientific journals and families of journals have policies for identifying and reviewing
1002 manuscripts that raise biosecurity and biosafety concerns. These efforts are commendable but some
1003 have noted the challenges associated with trying to identify DURC or implement risk mitigation
1004 measures at the publication stage.^{46,47} NSABB has previously developed strategies and a risk assessment
1005 tool to assist in the development of a responsible communication plan for DURC, which might include
1006 altering the content, distribution, or timing of a publication.⁴⁸ The U.S. government has no authority to
1007 mandate redaction, restriction, or classification of a scientific publication that it does not own or control,
1008 and the development of a mechanism for restricting communication of unclassified information to only
1009 those who require access, remain challenging and to date unsuccessful.⁴⁹

⁴³ NSDD 189 (September 21, 1985) defines fundamental research as "basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons." <https://research.archives.gov/id/6879779>

⁴⁴ Export Administration Regulations, 15 CFR Parts 730, 734, 736, 742, 744, and 745.

<https://www.bis.doc.gov/index.php/regulations/export-administration-regulations-ear>

⁴⁵ International Traffic and Arms Regulations, 22 U.S.C. 2778 https://www.pmddtc.state.gov/regulations_laws/itar.html

⁴⁶ Casadevall A et al. Dual-Use Research of Concern Review at American Society for Microbiology Journals. *mBio* 6(4):e01236-15. 2015.

⁴⁷ Atlas et. al. Journal editors and authors group statement on scientific publication and security. *Science*, 299:1149. 2003.

⁴⁸ Proposed Framework for the Oversight of Dual Use Life Sciences Research: Strategies for Minimizing the Potential Misuse of Research Information. NSABB, June, 2007.

<http://osp.od.nih.gov/sites/default/files/resources/Framework%20for%20transmittal%20duplex%209-10-07.pdf>

⁴⁹ Research information produced under a U.S. government grant is not considered to be owned or controlled by the Federal Government. However, under the Invention Secrecy Act, the U.S. government can nevertheless impose secrecy orders on patent applications if the publication or disclosure of the ensuing patent would be detrimental to national security.

1010 **Analysis:** Once a study has been completed, it is difficult to limit the distribution of or access to the
1011 findings, particularly if the study was conducted in an open, academic environment. Oversight of
1012 DURC, and in particular GOF studies involving pathogens with pandemic potential, may be most
1013 feasible and effective if it occurs 1) upstream (i.e., during the review of proposed studies and before
1014 experiments are initiated) and 2) in an ongoing manner while the research is being conducted.

1015 Classification may be an option for certain GOF studies, but this would require these studies to be
1016 conducted in significantly different settings than they are currently. Further, although certain GOF
1017 studies have raised concerns about whether they should be published, it is unlikely that such
1018 manuscripts would meet the criteria for classification under U.S. government classification
1019 authorities. It is conceivable that certain studies should not be undertaken at all or not published
1020 because of unanticipated findings. However, it may be very difficult to predict at the proposal stage
1021 whether findings of concern might arise during the experiment, and unanticipated findings that raise
1022 concern may be unavoidable. Individual investigators or journal editors have, on security grounds,
1023 decided to redact certain material from publication, possibly triggering export controls on the
1024 redacted material, but in general such a redaction could not be mandated by the U.S. government.

1025 **Broader U.S. Biosafety and Biosecurity Efforts**

1026 Parallel to the GOF deliberative process, the USG has also initiated additional, broader reviews of
1027 biosafety and biosecurity policies and procedures following a series of laboratory incidents occurring at
1028 federal institutions in 2014. The Holdren-Monoco memorandum⁵⁰ called for Federal and non-Federal
1029 reviews to provide recommendations to strengthen the biosafety and biosecurity practices and
1030 oversight system for USG funded research. The memo outlined three immediate actions for Federal
1031 Agencies:

- 1032 1. Conduct a comprehensive review of current biosafety and biosecurity protocols to ensure
1033 adequacy and appropriateness for today's infectious disease research
- 1034 2. Inventory and document culture collections
- 1035 3. Increase attentiveness throughout research community to ensure the safety of laboratory
1036 workers and the American public.

1037 In September 2015, The White House National Security Council tasked the Federal Experts Security
1038 Advisory Panel (FESAP) to 1) identify needs and gaps and make recommendations to optimize biosafety,
1039 biosecurity, oversight, and inventory management and control for biological select agents and toxins
1040 (BSAT); 2) identify actions and any regulatory changes to improve biosafety and biosecurity; and 3)
1041 identify an approach to determine the appropriate number of high-containment U.S. laboratories
1042 required to possess, use, or transfer BSAT. To obtain broad stakeholder recommendations, the National
1043 Science and Technology Council established the Fast Track Action Committee on Select Agent
1044 Regulations (FTAC-SAR). In October 2015, USG released the FESAP and FTAC-SAR recommendations⁵¹
1045 that address the culture of responsibility, oversight, outreach and education; applied biosafety research;

⁵⁰ https://www.whitehouse.gov/sites/default/files/microsites/ostp/enhancing_biosafety_and_biosecurity_19aug2014_final.pdf

⁵¹ <http://www.phe.gov/s3/Documents/fesap.pdf>; <http://www.phe.gov/s3/Documents/ftac-sar.pdf>.

1046 incident reporting; material accountability; inspection processes; and regulatory changes and guidance
1047 to improve biosafety and biosecurity. The USG has developed a plan to implement these
1048 recommendations.⁵²

1049

1050

DRAFT

⁵² Implementation of Recommendations of the Federal Experts Security Advisory Panel and the Fast Track Action Committee on Select Agent Regulations, October 2015. <http://www.phe.gov/s3/Documents/fesap-ftac-ip.pdf>

1051 **5. Findings of the NSABB Working Group**

1052 In developing the findings below (Box 2), the NSABB working group considered the results of the risk and
1053 benefit assessments, policy analysis and decision-making frameworks, discussions of ethics, and
1054 perspectives of domestic and international stakeholders.
1055

Box 2. Summary of Findings

Finding 1. There are many types of GOF studies and not all of them have the same level of risks. Only a small subset of GOF research—GOF research of concern (GOFROC)—entail risks that are potentially significant enough to warrant additional oversight.

Finding 2. The U.S. government has several policies in place for identifying and managing risks associated with life sciences research. There are several points throughout the research life cycle where, if the policies are implemented effectively, risks can be managed and oversight of GOF research of concern could be implemented.

Finding 3. Oversight policies vary in scope and applicability, and do not cover all potential GOFROC, therefore, current oversight is not sufficient for all GOF research of concern.

Finding 4. An adaptive policy approach is a desirable way to ensure that oversight and risk mitigation measures remain commensurate with the risks associated with the research and the benefits of the research are being fully realized.

Finding 5. There are life sciences research studies, including possibly some GOF research of concern, that should not be conducted because the potential risks associated with the study are not justified by the potential benefits. Decisions about whether specific GOFROC should be permitted will entail an assessment of the potential risks and anticipated benefits associated with the individual experiment in question. The scientific merit of a study is a central consideration during the review of proposed studies but other considerations, including legal, ethical, public health, and societal values are also important and need to be taken into account.

Finding 6. Managing risks associated with GOF research of concern, like all life sciences research, requires both Federal-level and institutional oversight, awareness and compliance, and a commitment by all stakeholders to safety and security.

Finding 7. Funding and conducting GOF research of concern involves many issues that are international in nature.

1056
1057
1058

1059 **Finding 1. There are many types of GOF studies and not all of them have the same level of risks. Only**
1060 **a small subset of GOF research—GOF research of concern (GOFROC)—entail risks that are potentially**
1061 **significant enough to warrant additional oversight.** As with all life sciences research involving
1062 pathogens, GOF studies entail inherent biosafety and biosecurity risks. GOF research involving the
1063 generation of pathogens with pandemic potential involves the greatest risks. A laboratory accident
1064 involving such a pathogen could potentially release a pathogen that could spread rapidly and efficiently
1065 through the human population. A laboratory pathogen with enhanced characteristics could also, if
1066 malevolently used, pose a greater threat to national security or public health than similar misuse
1067 involving a wild type pathogen. The probability that such events would occur is low but non-zero and
1068 the potential consequences are uncertain but potentially significant.

1069 Gryphon’s biosafety risk assessment identified
1070 studies involving enhanced transmissibility,
1071 enhanced pathogenicity, and evasion of immunity as
1072 entailing the highest risks for coronaviruses, seasonal
1073 influenza, and avian influenza.⁵³ Manipulations that
1074 increase transmissibility, increase pathogenicity, and
1075 enable a pathogen to more readily spread through
1076 the population have the greatest potential to
1077 increase risk; in some strains even a moderate
1078 increase might be a concern.

1079 To help categorize studies based on the level of
1080 concern stemming from their associated risks, the
1081 working group has designated studies as: GOF
1082 research and GOF research of concern
1083 (GOFROC) (Figure 4). The term “GOF research”
1084 would encompass all studies whereby some
1085 characteristic of the pathogen is enhanced. The
1086 vast majority of GOF research does not raise
1087 any significant concerns; these studies do not
1088 entail novel or significant risks and are subject
1089 to oversight to manage risks. GOF research of concern, or GOFROC, represents the small subset of
1090 studies that result in the generation of a pathogen with pandemic potential—that is, a pathogen that is
1091 highly virulent and highly transmissible, as judged by its likely ability to spread among human
1092 populations (see Recommendation 1 for more thorough description of these attributes).

1094 **Finding 2. The U.S. government has several policies in place for identifying and managing risks**
1095 **associated with life sciences research. There are several points throughout the research life cycle**
1096 **where, if the policies are implemented effectively, risks can be managed and oversight of GOF**

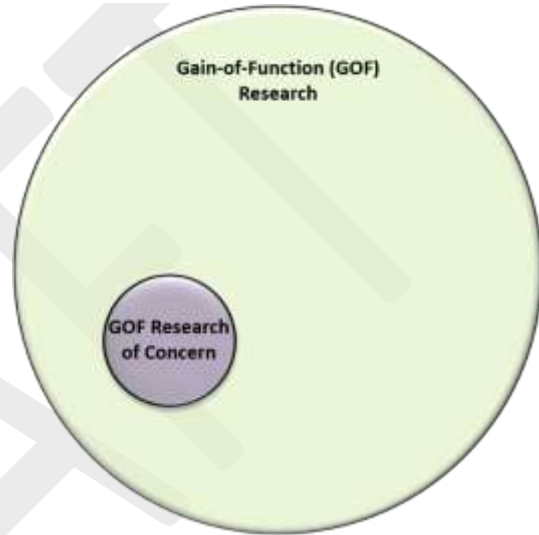


Figure 4. Conceptual categorization of GOF research involving human or animal pathogens. GOF research includes a broad range of experimental approaches, most of which do not raise significant concerns. GOF research of concern represents a small subset of all GOF research that can be reasonably anticipated to result in generation of a pathogen with pandemic potential, as described as a pathogen that is likely both highly transmissible and highly virulent in humans.

⁵³ Risk and Benefit Analysis of Gain-of-Function Research, Final Draft Report. Gryphon Scientific, December, 2015. <http://osp.od.nih.gov/sites/default/files/Risk%20and%20Benefit%20Analysis%20of%20Gain%20of%20Function%20Research%20-%20Draft%20Final%20Report.pdf>

1097 **research of concern could be implemented.** Federally-funded life sciences research in the U.S. is
1098 conducted in accordance with occupational health and safety laws and regulations, the *NIH Guidelines*,
1099 the BMBL, policies for the Federal and institutional oversight of DURC, the Select Agent Regulations,
1100 export control regulations, international treaties and agreements, and other relevant policies. HHS has
1101 also developed a framework for guiding funding decisions for certain GOF studies involving H5N1 and
1102 H7N9 influenza viruses. Together, these policies aim to mitigate biosafety risks, biosecurity risks, and
1103 other risks associated with life sciences research, including many of the GOF studies that have raised
1104 concerns.

1105
1106 U.S. policies involve oversight and help manage risks at several points throughout the research life cycle
1107 including the proposal review, the funding decision, the time during which the research is being
1108 conducted, and at the time at which the research is being communicated. There are also numerous
1109 entities that are responsible for providing oversight, managing risks or issuing guidance, including
1110 funding agencies, institutional review and compliance committees, individual investigators, federal
1111 advisory committees, and journal editors.

1112 While effective implementation of these policies can manage much of the risk associated with life
1113 sciences research, some GOFROC is more thoroughly monitored than others. Additionally, coverage
1114 under current policies is incomplete (e.g., GOF research funded and conducted by/within the private
1115 sector may not be covered). Institutional oversight also varies. For example, IBCs differ in capabilities
1116 and expertise, and institutional resources and cultures vary. In addition, there is limited data describing
1117 the rate and extent of laboratory accidents, near-misses, and security breaches. Little comprehensive
1118 data about these critical issues exist, and no entity is currently authorized to collect all of the desirable
1119 information that would inform risk-benefit assessments.

1120
1121 **Finding 3. Oversight policies vary in scope and applicability, and do not cover all potential GOFROC,**
1122 **therefore, current oversight is not sufficient for all GOF research of concern.** U.S. policies are
1123 applicable to some but not all GOFROC. Risks associated with GOFROC that do not involve select agents
1124 or pathogens subject to oversight under the USG DURC policies or the *HHS Framework*, would largely be
1125 managed at the institutional level, in accordance with guidance in the *NIH Guidelines* and BMBL. In
1126 general, GOFROC that is not conducted with U.S. government funds is not subject to oversight by a
1127 Federal funding agency.⁵⁴ Other countries also fund and conduct life sciences research, including GOF
1128 studies, which are beyond the purview of the U.S. government as well.

⁵⁴ Research involving a select agent, whose oversight is articulated in Federal statute and requires compliance from all researchers and institutions, would be subject to Federal oversight, regardless of the funding source. Some privately-funded research being conducted at institutions that receive Federal funding for that research may also be subject to oversight under the *NIH Guidelines*, USG DURC policies, or other policies.

1129 In addition, the U.S. government's oversight policies vary. Different policies are aimed at managing
1130 different risks, and each is implemented by various Federal Departments and Agencies. This can result
1131 in redundancies as well as gaps in oversight, as the various policies have not been harmonized.

1132 Finally, full compliance with policies is essential to their effectiveness. The effectiveness of policies can
1133 be enhanced by a commitment to proper implementation and enforcement at the Federal, institutional,
1134 and individual investigator levels. This can include training, education, codes of conduct, and other
1135 mechanisms for continuing to build a culture of responsibility.

1136

1137 **Finding 4. An adaptive policy approach is a desirable way to ensure that oversight and risk mitigation**
1138 **measures remain commensurate with the risks associated with the research and the benefits of the**
1139 **research are being fully realized.** Many, but not all, of the policies that apply to GOF studies are
1140 adaptive in nature. The BMBL is updated periodically. The *NIH Guidelines* and the select agent
1141 programs are updated or revised periodically as well and both have processes for seeking external
1142 advice for informing policy development. The DURC policies and the *HHS Framework* do not have
1143 articulated mechanisms for seeking input on policy development, reviewing, or updating the policies,
1144 though both state an intention to be updated as necessary. Great uncertainty is inherent in conducting
1145 risk-benefit assessments with currently available data and several key parameters of the risk and benefit
1146 assessment made its interpretation challenging. Such uncertainty about risks and benefits may also
1147 make risk management difficult. An adaptive policy approach would facilitate refinement of GOF risk
1148 management as knowledge and experience are acquired.

1149

1150 **Finding 5. There are life sciences research studies, including possibly some GOF research of concern,**
1151 **that should not be conducted because the potential risks associated with the study are not justified by**
1152 **the potential benefits. Decisions about whether specific GOFROC should be permitted will entail an**
1153 **assessment of the potential risks and anticipated benefits associated with the individual experiment**
1154 **in question. The scientific merit of a study is a central consideration during the review of proposed**
1155 **studies but other considerations, including legal, ethical, public health, and societal values are also**
1156 **important and need to be taken into account.** Examples of studies that should not be conducted for
1157 ethical reasons include those that: involve human subjects who have not been provided and signed an
1158 informed consent document approved by an IRB; are anticipated to cause undue harm to a human
1159 subject; or that entail benefits that are unjustifiable in the light of the risks. For example, the
1160 development of biological weapons is unethical and has been banned by international treaty.⁵⁵

⁵⁵ Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction. Signed at London, Moscow and Washington on 10 April 1972; entered into force on 26 March 1975. Depositaries: UK, US and Soviet governments. <http://www.opbw.org/>

1161 There may be GOFROC that should not be funded on ethical grounds but it is difficult to identify or
1162 describe such studies based on general or hypothetical descriptions. An ethical evaluation of a research
1163 study would entail an evaluation of the risks and benefits, which requires a thorough understanding of
1164 the scientific details of the proposal, including its aims and any foreseeable adverse consequences. In
1165 addition, the scientific, public health, and national security landscape is dynamic. Public health needs
1166 change as new diseases emerge. Risks may arise or diminish based on the availability (or lack) of
1167 effective countermeasures. Benefits may become more or less likely to be realized based on other
1168 enabling factors, such as new scientific findings or technologies. Decisions to fund GOF studies must
1169 take into account these nuances in the risk-benefit landscape.

1170 The NSABB did not seek to develop a list of studies that should not be conducted but rather sought to
1171 develop general principles that describe what is acceptable and not acceptable for funding. A principle-
1172 based approach to guiding funding decisions is adaptable and likely more effective.

1173 However, one example of a scientific study that should not be conducted might be the insertion of a
1174 virulence gene from an unrelated organism into the genome of a virus transmissible through the
1175 respiratory route, which would be highly unlikely to occur by natural recombination. This study, and
1176 others that involve the transfer of virulence genes between disparate microbes would appear to lack
1177 public health benefit, since the novel, laboratory-generated pathogen is unlikely to arise naturally and
1178 would therefore entail potentially significant and unnecessary risks.

1179

1180 **Finding 6. Managing risks associated with GOF research of concern, like all life sciences research,**
1181 **requires both Federal-level and institutional oversight, awareness and compliance, and a commitment**
1182 **by all stakeholders to safety and security.** Biosafety and biosecurity risks associated with life sciences
1183 research are managed through engineering controls, laboratory practices, medical surveillance and
1184 support, appropriate training, and other interventions. However, GOFROC has the potential to generate
1185 strains with significant risks that may require additional oversight and containment mechanisms.
1186 Managing the risks associated with GOFROC in particular requires a commitment to safety and security
1187 at the Federal and institutional level that includes a strong foundation of training and a demonstrated
1188 commitment to compliance by the research institution, and the individual investigators at the local level.

1189

1190 **Finding 7. Funding and conducting GOF research of concern involves many issues that are**
1191 **international in nature.** The potential risks and benefits associated with GOFROC are international in
1192 nature. Laboratory accidents and intentional misuse could have global consequences. The benefits of
1193 vaccine and other medical countermeasure development and disease surveillance likely also have
1194 important international implications. The research enterprise is international as well, and GOFROC is
1195 being conducted in a number of countries already. While U.S. government funding policy regarding
1196 GOFROC only directly affects domestic and international research within the purview of the U.S.
1197 government, decisions made by the United States in this area can influence GOFROC oversight policies
1198 globally.

1199 Notably, as highlighted during presentations at NSABB and NAS meetings, GOF research and GOFROC
1200 research is being conducted in a number of countries and a variety of oversight mechanisms at the
1201 national and regional level are in place. In addition, a number of countries and international scientific
1202 organizations have been considering issues related to biosafety, biosecurity, dual use research, and
1203 GOFROC.^{56, 57, 58, 59, 60, 61} International perspectives are important to the development of U.S. policy in
1204 this area and global engagement is necessary to foster effective oversight mechanisms and an
1205 international culture of responsibility around research involving pathogens.

1206 The U.S. government, often in concert with the NSABB, has been engaged with the international
1207 community for many years and continues to work with those governments and organizations now
1208 actively considering GOFROC-related issues. Presentations to the NSABB, its working groups, and at the
1209 NAS meetings have provided perspectives about the activities of foreign governments, international
1210 organizations, researchers and others have greatly aided the NSABB during the development of this
1211 report.

1212

1213

1214

⁵⁶ *Gain-of-Function Research: Summary of the Second Symposium*, March 10-11, 2016. The National Academies of Sciences, Engineering, and Medicine. The National Academies Press, Washington DC.

⁵⁷ *Gain of function: experimental applications relating to potentially pandemic pathogens*. European Academies Science Advisory Council, EASAC policy report 27, October 2015. <http://www.easac.eu/>

⁵⁸ *Summary report: Dual Use Research On Microbes: Biosafety, Biosecurity, Responsibility*. December 10 – 12, 2014, Herrenhausen Palace, Hanover, Germany. <https://www.volkswagenstiftung.de/dualuseresearch>

⁵⁹ *France-US Bilateral Workshop on Dual Use Research Issues: Summary Report*, February 11, 2016. U.S. Department of State.

⁶⁰ Draghia-Akli, Ruxandra, Director of the Health Directorate at the Research DG, European Commission, presentation to NSABB working group, July 23, 2015.

⁶¹ Donker, Marianne, Ministry of Health, Welfare and Sport, Netherlands, presentation to NSABB working group, July 23, 2015.

1215 **6. Recommendations of the NSABB Working Group**

1216 Based on its analyses and findings, the NSABB working group has developed the following
1217 recommendations (Box 3) to the U.S. government.

1218

Box 3. Summary of Recommendations of the NSABB Working Group

Recommendation 1. Research proposals involving GOF research of concern entail significant potential risks and should receive an additional, multidisciplinary review, prior to determining whether they are acceptable for funding. If funded, such projects should be subject to ongoing oversight at the Federal and institutional levels.

Recommendation 2. An external advisory body that is designed for transparency and public engagement should be utilized as part of the U.S. government’s ongoing evaluation of oversight policies for GOF research of concern.

Recommendation 3. The U.S. government should pursue an adaptive policy approach to help ensure that oversight remains commensurate with the risks associated with the GOF research of concern.

Recommendation 3.1. The U.S. government should consider developing a system to collect and analyze data about laboratory safety incidents to inform GOF research of concern policy development over time.

Recommendation 4. In general, oversight mechanisms for GOF research of concern should be incorporated into existing policy frameworks when possible.

Recommendation 5. The U.S. government should consider ways to ensure that all GOF research of concern conducted within the U.S. or by U.S. companies be subject to oversight, regardless of funding source.

Recommendation 6. The U.S. government should undertake broad efforts to strengthen laboratory biosafety and biosecurity and, as part of these efforts, seek to raise awareness about the specific issues associated with GOF research of concern.

Recommendation 7. The U.S. government should engage the international community in a dialogue about the oversight and responsible conduct of GOF research of concern.

1219

1220

1221 **Recommendation 1. Research proposals involving GOF research of concern entail significant potential**
1222 **risks and should receive an additional, multidisciplinary review, prior to determining whether they are**
1223 **acceptable for funding. If funded, such projects should be subject to ongoing oversight at the Federal**
1224 **and institutional levels.**

1225 GOFROC entails the generation of pathogens—perhaps novel pathogens—with anticipated pandemic
1226 potential. The risks associated with such studies are uncertain but potentially significant. It is possible
1227 that generating a laboratory pathogen with pandemic potential introduces a risk of a pandemic, albeit a
1228 low probability risk, that did not exist before that pathogen was generated. Therefore, a new, pre-
1229 funding review and approval mechanism is warranted before such studies should be undertaken. The
1230 NSABB working group proposes a conceptual approach for guiding funding decisions about GOFROC,
1231 which entails identifying GOFROC and subjecting such studies to an additional pre-funding review and
1232 approval process. The attributes that describe GOFROC, the principles that should guide funding
1233 decisions for GOFROC, and the steps in a proposed review/approval process for GOFROC are described
1234 below.

1235

1236 **Identifying GOF research of concern**

1237

1238 GOFROC is research that can be reasonably anticipated to generate a pathogen with pandemic
1239 potential. Determining whether a proposed research project is likely to do so will entail uncertainty and
1240 will require scientific and other expert judgment.

1241

1242 To be considered GOFROC, the research must, in a single step or over the course of manipulations, be
1243 reasonably anticipated to generate a pathogen with both of the following attributes:

1244

- 1245 i. **The pathogen generated is likely highly transmissible and likely capable of wide and**
1246 **uncontrollable spread in human populations.** To be considered “highly transmissible” the
1247 pathogen must be judged to have the capacity for sustained secondary transmission among
1248 humans, particularly but not exclusively by the respiratory route. Such a determination might
1249 be informed by data describing human infections by naturally-circulating isolates of the
1250 pathogen or studies in relevant experimental mammalian models that serve as a proxy for
1251 human infections. To be considered “capable of wide and uncontrollable spread in human
1252 populations” it must be judged that there would be limited options for controlling the spread of
1253 the pathogen other than patient isolation or quarantine. Such a determination might be made,
1254 for instance, if humans lack population immunity to the resulting pathogen, if the pathogen
1255 would evade or suppress the human immune response, if the pathogen would be resistant to
1256 medical countermeasures, or if existing countermeasures would be unavailable globally in
1257 sufficient quantities.

1258

1259 **AND**

1260

1261 ii. **The pathogen generated is likely highly virulent and likely to cause significant morbidity**
1262 **and/or mortality in humans.** To be considered “highly virulent” the pathogen must be judged
1263 to have the capacity for causing significant consequences in humans, such as severe disease
1264 and/or a high case fatality rate. Such a determination might be informed by data describing
1265 human infections by naturally-circulating strains of the pathogen or studies in relevant
1266 experimental mammalian models that serve as a proxy for human disease.

1267 Any study involving the generation of a pathogen exhibiting the two attributes above would be
1268 considered GOFROC. However, it is generally anticipated that the following types of activities would not
1269 be considered GOFROC:

- 1270 • Studies to characterize the virulence and transmission properties of circulating pathogens
- 1271 • Surveillance activities, including sampling and sequencing
- 1272 • Activities associated with developing and producing vaccines, such as generation of high-
1273 growth strains

1274 **Importantly, a proposed experiment need not involve the simultaneous enhancement of both**
1275 **phenotypes.** Thus, research involving a naturally-occurring pathogen that exhibits one of the above
1276 attributes would be considered GOFROC if a study were anticipated to confer the second attribute to
1277 the agent (while retaining the first attribute). Other studies may generate a pathogen with the above
1278 attributes after a series of manipulations that enhance the phenotypes separately but ultimately result
1279 in a pathogen with both attributes. Any route of experimentation that is anticipated to ultimately
1280 generate a pathogen that exhibits both of the characteristics above would be considered GOFROC and
1281 should be reviewed carefully before it can be funded.

1282
1283 Appendix C describes examples of studies that would and would not be considered GOFROC. These
1284 examples are provided as general guidance. A more detailed consideration of the specific characteristics
1285 of a pathogen in question as well as the proposed experimental manipulations would be required to
1286 determine whether a research proposal is GOFROC.

1287

1288 **Pre-funding review and approval of GOF research of concern**

1289

1290 Proposals anticipated to involve GOFROC should be subject to additional review prior to making a
1291 funding decision and to substantial Federal oversight throughout the course of the research, if funded.
1292 The working group has developed principles that should guide the review and funding of these
1293 proposals. There should be a high degree of confidence that a study will be conducted in accordance
1294 with these principles before determining that the proposal is suitable for funding. Studies that cannot
1295 be or are not anticipated to be conducted in accordance with the principles below should not be funded.

1296

1297

1298

1299

1300 **Principles for guiding review and funding decisions**

1301

1302 Only projects that are in line with **all of the following principles** should be considered acceptable for
1303 funding. The principles below are intended to embody the substantive ethical values described in
1304 section 4.2 and the process of applying these principles would involve scientific, security, ethical, and
1305 other considerations.

1306

1307 **i. The research proposal has been evaluated by a peer-review process and determined to be**
1308 **scientifically meritorious, with high impact on the research field(s) involved.** If GOFROC is
1309 to be funded and conducted it must first and foremost address a valuable scientific question
1310 or public health need.

1311

1312 **ii. The pathogen that is anticipated to be generated must be judged, based on scientific**
1313 **evidence, to be able to arise by natural processes.** It is difficult to predict the types of
1314 pathogens that can or will emerge in nature. Nevertheless, before a pathogen with
1315 pandemic potential is generated through laboratory manipulations it is essential to consider
1316 whether such a pathogen could arise in nature. GOFROC may be permissible if the study
1317 were to generate a pathogen that is anticipated to arise in nature or if the study were to
1318 provide insight into natural evolutionary processes. GOFROC would not be permissible if it
1319 were to generate a laboratory pathogen that is highly unlikely to arise in nature.

1320

1321 **iii. An assessment of the overall potential risks and benefits associated with the project**
1322 **determines that the potential risks as compared to the potential benefits to society are**
1323 **justified.** Prior to funding GOFROC, the anticipated risks and potential benefits must be
1324 carefully evaluated. In general, the potential benefits associated with a research project
1325 should be commensurate with or exceed the presumed risks. Projects involving significant
1326 risks and little anticipated benefits are ethically unacceptable and should not be funded. If
1327 the potential risks appear high, the possible benefits should also appear high. Risks should
1328 be managed and should be mitigated whenever possible. The extent to which risks can be
1329 mitigated should factor into the assessment.

1330

1331 **iv. There are no feasible, equally efficacious alternative methods to address the same**
1332 **scientific question in a manner that poses less risk than does the proposed approach.**
1333 Alternative approaches must be explored and critically examined before funding GOFROC. It
1334 is possible that the proposed experimental approach that raises concern is the only feasible
1335 approach for addressing the scientific question at hand. In other cases, modifications of the
1336 experimental design, use of attenuated or other strains that pose fewer risks to humans, or
1337 different approaches with less risk that may provide the same or very similar information
1338 may be feasible. Lines of experimentation that entail less risk should be pursued whenever
1339 possible.

1340

1341 **v. The investigator and institution proposing the research have the demonstrated capacity**
1342 **and commitment to conduct it safely and securely, and have the ability to respond rapidly**
1343 **and adequately to laboratory accidents and security breaches.** Prior to funding, the risks
1344 associated with proposed GOFROC must be identified and assessed, and clear, realistic plans
1345 for managing risks should be developed. In order to manage risks associated with GOFROC,

1346 an institution must have adequate facilities, resources, security, trained personnel,
1347 administrative structures, ongoing occupational health and safety monitoring procedures,
1348 relationships with local public health authorities and first responders, and the ability to
1349 adapt to unanticipated situations by increasing containment or adding additional safety or
1350 security features. In addition to adhering to standards of compliance, an institution (and the
1351 investigators proposing the study) should have a demonstrated commitment to laboratory
1352 safety and security, scientific integrity, and the responsible conduct of research. The
1353 researchers and institution should be committed to a culture of responsibility, perhaps
1354 demonstrated through adherence to a formal code of conduct or other measures.
1355

1356 **vi. The results of the research are anticipated to be broadly shared in compliance with**
1357 **applicable laws and regulations in order to realize its potential benefits to global health.**
1358 Prior to funding GOFROC, consideration should be given to the type of research-related
1359 information and products that are likely to be generated. The research-related information
1360 and products are expected to be shared appropriately and a responsible communication
1361 plan should be developed at the outset, as appropriate. NSABB⁶² and the U.S. government⁶³
1362 have issued guidance for developing communication plans for dual use research of concern
1363 that include consideration of the content, timing, and distribution of the research
1364 information.
1365

1366 **vii. The research will be supported through funding mechanisms that allow for appropriate**
1367 **management of risks and ongoing Federal and institutional oversight of all aspects of the**
1368 **research throughout the course of the project.** GOFROC should be funded through
1369 mechanisms to ensure that appropriate biocontainment conditions are utilized, adequate
1370 biosecurity precautions are in place, and that the data and materials generated will be
1371 shared appropriately. The funding mechanism should allow for modification of required
1372 mitigation and oversight features, as well as research objectives during the course of the
1373 research, if needed.
1374

1375 **viii. The proposed research is ethically justifiable.** Determinations of whether proposed
1376 GOFROC should be undertaken involve value judgments to assess the potential risks and
1377 benefits and to determine whether any potential risks are justified. Non-maleficence,
1378 beneficence, justice, respect for persons, scientific freedom, and responsible stewardship
1379 are among the values that should be considered when ultimately making decisions about
1380 whether to fund GOFROC.
1381
1382

1383

⁶² Appendix 5, *Proposed Framework for the Oversight of Dual Use Research Life Sciences Research: Strategies for Minimizing the Potential Misuse of Research Information*. National Science Advisory Board for Biosecurity, June, 2007.

⁶³ Section E, *Tools for the Identification, Assessment, Management, and Responsible Communication of Dual Use Research of Concern: A Companion Guide to the United States Government Policies for Oversight of Life Sciences Dual Use Research of Concern*. U.S. government, September, 2014.

1384 **The Review Process for Proposals Involving GOF Research of Concern**

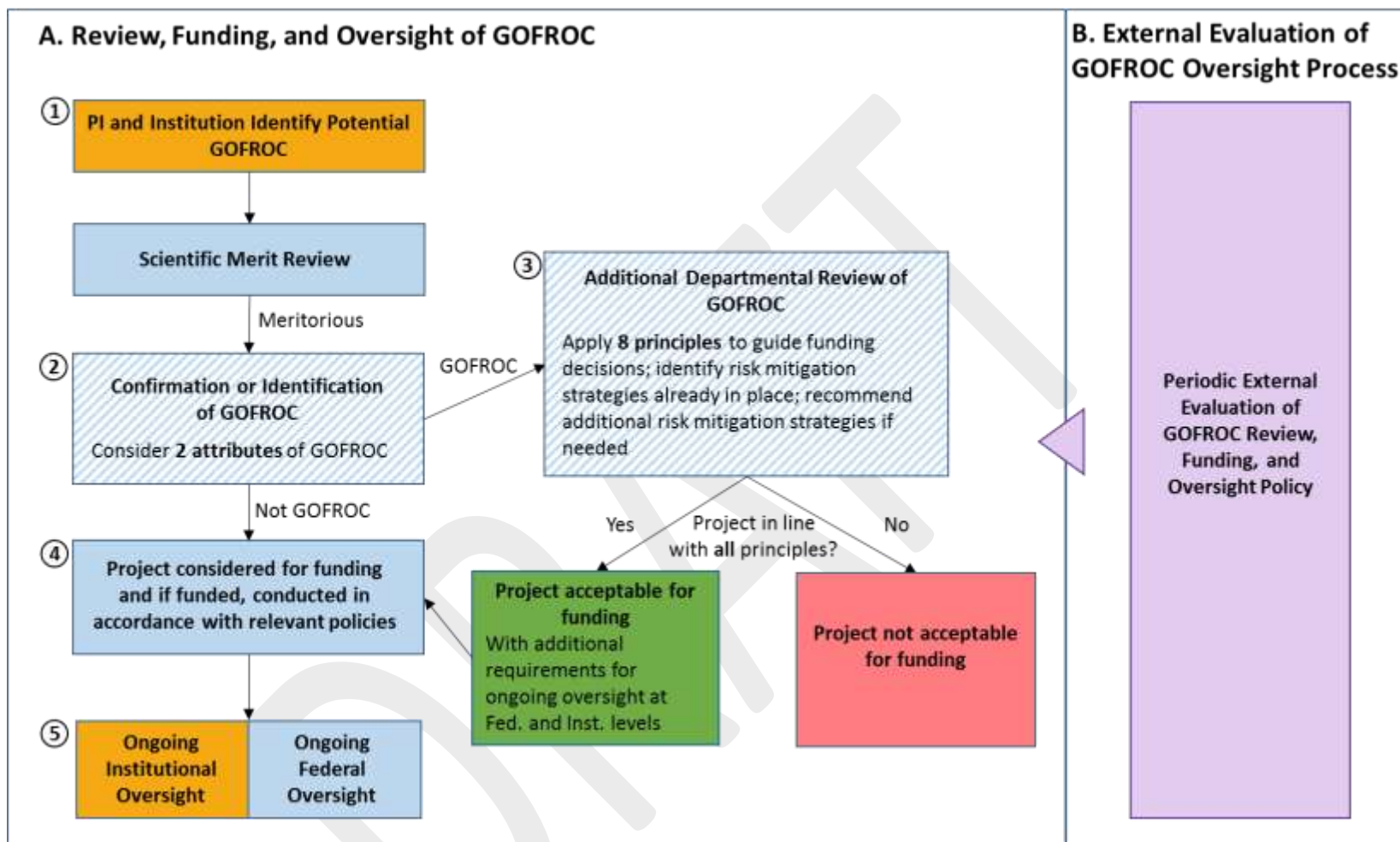
1385 The NSABB proposes the following conceptual approach for guiding funding decisions about GOFROC
1386 (Figure 5). Review of research projects that may involve GOFROC would involve five steps:

- 1387 1. Investigators and research institutions identify proposed GOFROC, as described by the two
1388 attributes for identifying GOFROC.
- 1389 2. Funding agencies identify or confirm proposed GOFROC.
- 1390 3. A Department-level Federal panel with diverse expertise reviews proposals involving GOFROC to
1391 determine whether the proposal meets the 8 principles for guiding funding decisions and to
1392 make recommendations as to whether the proposed research is acceptable for funding.
- 1393 4. Funding agencies make a funding decision, and if the proposal is funded, establish risk
1394 mitigation plans and issue the funding award with appropriate terms and conditions to help
1395 ensure ongoing oversight.
- 1396 5. Investigators and institutions conduct the research in accordance with any applicable Federal,
1397 State, and local oversight policies and employ any necessary additional mitigation strategies.
1398 Federal agencies provide oversight to ensure adherence to established risk mitigation plans and
1399 funding terms.

1400 **Investigators and institutions identify GOFROC (Step 1).** Prior to submission of an application for
1401 funding, investigators and research institutions should identify possible GOFROC and submit with the
1402 research proposal any relevant information such as plans for biosafety, biosecurity, and coordination
1403 with local and/or state public health and safety officials in the event of an accident or theft; descriptions
1404 of facilities available; a justification for the proposed approach that considers possible non-GOFROC
1405 alternatives that may be equally efficacious; and a discussion of the value and potential benefits of the
1406 proposed research. Identification of possible GOFROC should not affect a subsequent Federal scientific
1407 merit review either positively or negatively.

1408 **A need for guidance to investigators and institutions.** The U.S. government should develop a
1409 “Points to Consider” document to provide guidance to investigators and institutions when preparing
1410 research proposals that may involve GOFROC. Such a document would describe to investigators any
1411 requirements for proposals involving GOFROC and provide guidance on the type of information that
1412 should be included in a proposal to facilitate its review. This document should be reviewed and
1413 updated as necessary.

1414 **Agency and Department-level review of GOFROC (Step 2 & 3).** After the standard agency scientific
1415 merit review process, proposals that are determined to be scientifically meritorious and likely to be
1416 favorably considered for funding would also be reviewed by the funding agency (Step 2) to determine if
1417 they constitute GOFROC, as defined by whether the proposal can be anticipated to generate a pathogen
1418 that is highly transmissible and highly virulent, as described by the two attributes above (see p 43 – 44).
1419 Prior to being determined acceptable for funding, proposals identified by a funding agency as involving
1420 GOFROC would require an additional, higher level, Departmental review (Step 3). If a proposal does not



1421

1422

1423 **Figure 5. Proposed approach for the oversight of GOF research of concern.** A) A conceptual approach for the identification, review, funding, and ongoing
 1424 oversight of GOF research of concern. B) A Federally-appointed advisory committee would periodically evaluate the policies and processes developed for
 1425 funding and providing oversight for GOFROC.

1426 involve GOFROC, it would proceed along the normal pathway for further evaluation and funding
1427 decisions.

1428 The additional review of proposals involving GOFROC would determine whether the proposed research
1429 aligns with the 8 principles to guide funding decisions. Applying these principles will help to ensure that
1430 the GOFROC is scientifically and ethically acceptable, that the risk-benefit balance is favorable, that
1431 alternative approaches are explicitly considered, and that the research can be performed safely and
1432 securely. It is envisioned that the additional review of proposals involving GOFROC would involve
1433 diverse, multidisciplinary expertise including scientific, public health, biosafety, national security and
1434 intelligence, legal, bioethics, and other perspectives. To the extent possible, the Agency and
1435 Departmental review process should be efficient, well-documented, and adaptive. In addition, the
1436 process should be structured to avoid real or apparent conflicts of interest and to provide consistency
1437 across Federal agencies that might fund GOFROC. It is also envisioned that research institutions
1438 proposing the GOFROC might be asked for and would have an opportunity to provide any additional
1439 information that might be necessary for a thorough and substantive review of the research proposal.
1440 The NSABB also recommends (see Recommendation 2) that an external advisory body that is designed
1441 for transparency play a role in the evaluation of the oversight policies for GOFROC.

1442 **Funding decision and risk mitigation (Step 4).** During the course of the Department-level review the
1443 relevant risk management plans should be critically evaluated and additional risk mitigation measures
1444 may be recommended in order for GOFROC to be considered acceptable. A satisfactory risk
1445 management plan would entail appropriate biocontainment facilities and biosafety practices,
1446 appropriate standard operating procedures and administrative controls, occupational health and safety
1447 programs and security systems for protecting laboratory strains and reagents and promoting personal
1448 reliability. Some or all of the additional risk mitigation measures listed in Box 4 may also be
1449 recommended. These and a variety of additional measures could be required as a condition of funding.

1450

Box 4. Additional risk mitigation measures to be employed, as appropriate, for GOF research of concern.

Risk mitigation features that should be considered prior to funding GOFROC include requirements to:

- Provide additional training to researchers
- Enhance biosafety practices or features, as dictated by the specific strains and proposed manipulations
- Enhance security measures around strains, reagents, notebooks, and personnel
- Prohibit certain additional GOFROC experiments without prior approval
- Treat the research as if subject to the USG DURC policies, if it is not already
- Conduct more frequent institutional biosafety and biosecurity reviews of the research
- Conduct more frequent progress reports and discussions with Federal funding agency staff, particularly about unanticipated results that may raise concerns
- Conduct periodic site inspections/evaluations if not already required
- Identify certain experimental outcomes that would trigger a re-evaluation of the risks and benefits prior to proceeding with a study
- Develop a responsible communication plan, specifically, including a description of biosafety and biosecurity practices
- Communicate regularly and coordinate with Federal, State, and local public health and safety officials on accident and theft response
- Conduct bioethics consultations at the local and Federal level throughout the lifecycle of the research
- Develop and/or adhere to an appropriate code of conduct

1451

1452 **Ongoing oversight (Step 5).** Finally, throughout the course of the funding, both Federal and institutional
1453 oversight are critically important and the project should be carefully monitored to ensure that required
1454 conditions are met, that the principles guiding the decision to fund are still satisfied, and that any
1455 changes, significant developments, and publication/communication plans are discussed and addressed
1456 in a timely manner.

1457

1458 **Recommendation 2. An external advisory body that is designed for transparency and public**
1459 **engagement should be utilized as part of the U.S. government’s ongoing evaluation of oversight**
1460 **policies for GOF research of concern.** An external advisory body that is designed for transparency and
1461 public engagement should be utilized as part of the U.S. government’s ongoing evaluation of oversight
1462 policies for GOFROC (Figure 5.B). An external advisory mechanism, such as a committee governed by

1463 the Federal Advisory Committee Act⁶⁴, would allow for an independent examination of the U.S.
1464 government's policies for reviewing, funding, and conducting GOFROC. Such a group could evaluate the
1465 additional review and funding processes for GOFROC to understand how decisions were made, identify
1466 challenges to implementing the policy, and provide recommendations, as needed. Importantly, this
1467 mechanism would also provide transparency, promote public engagement, and would facilitate
1468 continued dialogue about GOFROC.

1469

1470 **Recommendation 3. The U.S. government should pursue an adaptive policy approach to help ensure**
1471 **that oversight remains commensurate with the risks associated with the GOF research of concern.**

1472 The risk/benefit profile for GOFROC may change over time and should be re-evaluated periodically to
1473 ensure that the risks associated with such research are adequately managed and the benefits are being
1474 realized. An adaptive approach to the oversight of GOFROC would entail the continual evaluation of the
1475 risks and benefits associated with the research as well as the burdens and effectiveness of the additional
1476 proposal review process and ongoing oversight measures. An adaptive approach would allow
1477 policymakers to learn from experience and update policies accordingly as the risk/benefit landscape
1478 changes. For instance, the risks associated with a research proposal or project may change if newly
1479 developed countermeasures become available or if new information emerges to clarify certain risks or
1480 enable certain benefits.

1481 **Recommendation 3.1. The U.S. government should consider developing a system to collect and**
1482 **analyze data about laboratory safety incidents to inform GOF research of concern policy**
1483 **development over time.** Examining such data would provide a better understanding of the risks,
1484 inform future risk assessments, and allow for the refinement of oversight policies over time.

1485

1486 **Recommendation 4. In general, oversight mechanisms for GOF research of concern should be**
1487 **incorporated into existing policy frameworks when possible.** Any additional oversight of GOFROC
1488 should be built into existing mechanisms rather than having the U.S. government develop a novel policy
1489 specific to GOFROC. Adapting or harmonizing current policies is preferable to developing entirely new
1490 oversight frameworks or wholly new approaches to manage the risks associated with these studies.
1491 There are precedents for additional Department-level pre-funding review of certain GOF studies (i.e.
1492 *HHS Framework*) as well as mechanisms for higher-level review and approval of certain studies (i.e.,
1493 Major Actions, under the *NIH Guidelines*; restricted experiments, under the Select Agent Program).
1494 There are also mechanisms for continual Federal-level monitoring of biosafety and biosecurity risks for
1495 individual projects (i.e., USG Policy for Federal Oversight of DURC, select agent programs) and
1496 established mechanisms for ongoing institutional oversight (i.e., IREs under the USG Policy for
1497 Institutional Oversight of Life Sciences DURC; IBCs under the *NIH Guidelines*). Wherever possible, these
1498 mechanisms should be employed to ensure the initial and ongoing oversight of GOFROC.

⁶⁴ *Federal Advisory Committee Act*. <http://www.gsa.gov/portal/content/100916>

1499 Importantly, not all GOFROC would necessarily be subject to the entire suite of U.S. oversight policies.
1500 For instance, some studies with pathogens not included in the USG policies for DURC oversight or on the
1501 select agent list could generate a pathogen with pandemic potential. Additional oversight measures
1502 may need to be stipulated at the time of funding for proposals involving potential GOFROC that are not
1503 subject to sufficient existing oversight. For instance, specific, enhanced containment practices may be
1504 required or a project may require ongoing monitoring for DURC potential at the Federal and institutional
1505 level. Box 4 describes a number of potential risk mitigation measures for GOFROC that could be
1506 implemented potentially by leveraging existing policy frameworks.

1507

1508 **Recommendation 5. The U.S. government should consider ways to ensure that all GOF research of**
1509 **concern conducted within the U.S. or by U.S. companies be subject to oversight, regardless of funding**
1510 **source.** GOFROC that is funded by the U.S. government or through private funding sources should be
1511 subject to equivalent oversight to ensure that the associated risks are adequately managed. The U.S.
1512 government should consider providing oversight not only as a term and condition of a funding award
1513 but also via other mechanisms that would enable oversight of all relevant research activities, regardless
1514 of the funding source.

1515

1516 **Recommendation 6. The U.S. government should undertake broad efforts to strengthen laboratory**
1517 **biosafety and biosecurity and, as part of these efforts, seek to raise awareness about the specific**
1518 **issues associated with GOF research of concern.** Current discussions about GOFROC relate to broader
1519 domestic and international discussions about laboratory safety and security. A “top down” approach to
1520 managing the risks associated with GOFROC through Federal policies and oversight is appropriate.
1521 However, top-down approaches alone, in the form of Federal and/or institutional policies and
1522 leadership, will likely not be sufficient. It is also critical to have adequately trained personnel that values
1523 safe and secure laboratory environments for conducting GOFROC. Therefore, it will also be important to
1524 facilitate a “bottom up” approach whereby scientific leaders and professional societies, as well as
1525 research staff involved in the design and conduct of GOFROC, are educated about biosafety, biosecurity,
1526 and the responsible conduct of their research. The U.S. government should engage the research
1527 community with the goal of promoting a culture of responsibility, or “scientific citizenship,” whereby all
1528 participants in the research enterprise have a sense of shared responsibility. Such a culture would
1529 incorporate and stress the values of safety, security, and compliance, and work to promote public trust
1530 in the scientific enterprise. For GOFROC, a combination of mandated and voluntary oversight and risk
1531 mitigation measures would be of great importance.

1532

1533 **Recommendation 7. The U.S. government should engage the international community in a dialogue**
1534 **about the oversight and responsible conduct of GOF research of concern.** Life sciences research is a
1535 global endeavor that continues to grow as more countries invest in their research capacities and as
1536 scientists move and collaborate across national boundaries. Life sciences research enables biomedical

1537 breakthroughs, pandemic preparedness, public health response efforts for emerging infectious diseases,
1538 and also provides an important economic driver. As more investigators undertake research involving
1539 pathogens, however, the associated risks become more likely to have international implications. The
1540 risks associated with GOFROC are especially international in nature since laboratory accidents or the
1541 deliberate misuse of pathogens with pandemic potential could have global consequences. Laboratories
1542 anywhere can undertake GOFROC and publications in the open scientific literature may enable others to
1543 generate pathogens with pandemic potential.

1544 NSABB has benefitted greatly from the extensive input into its deliberations by experts representing
1545 foreign governments, international organizations, academia, and others during presentations and
1546 comments at its meetings and the NAS conferences.

1547 The U.S. government should continue to engage the international community on issues related to dual
1548 use research, including policies, oversight mechanisms, science, research conduct, biosafety, biosecurity,
1549 containment, publication, funding, and bioethics. These issues are important in general and, especially,
1550 as they are related to GOFROC. The U.S. government's international engagement efforts should seek to
1551 promote a global culture of responsibility and enhance the quality, legitimacy and effectiveness of
1552 oversight processes.

1553 The U.S. government should build these efforts on the substantial international engagement activities
1554 that it and the NSABB have carried out since the NSABB was established. Such efforts have included
1555 three international roundtable meetings on dual use research issues, a series of DURC-focused webinars
1556 focusing on different global regions, and an international consultative workshop on GOF issues⁶⁵. In
1557 addition, the U.S. National Academy of Sciences and the European Academies Science Advisory Council
1558 have been engaged in the recent policy debates involving GOF studies and may be well positioned to
1559 continue the international dialogue on the issue in coordination with national governments and relevant
1560 international organizations. The USG is encouraged to participate in such activities.

⁶⁵ Information about these meetings and activities, including agendas, summaries, and archived videocasts, can be found on the NSABB website at: <http://osp.od.nih.gov/office-biotechnology-activities/biosecurity/nsabb/nsabb-meetings-and-conferences/international-engagement>

1561 **7. Appendices**

1562 **Appendix A. Description of NSABB Deliberations**

1563

1564 **NSABB Deliberations**

1565

1566 The NSABB established two working groups to accomplish the two portions of its charge, which were to
1567 result in discrete work products.

1568

1569 • **Deliverable 1.** A report conveying NSABB’s advice on the design, development, and conduct of
1570 the risk and benefit assessments.

1571 • **Deliverable 2.** A report conveying NSABB’s formal recommendations on the conceptual
1572 approach to the evaluation of proposed GOF studies.

1573

1574 **DELIVERABLE 1: ADVISING ON THE RISK AND BENEFIT ASSESSMENTS**

1575 The first NSABB working group was tasked with advising on the design and conduct of the risk and
1576 benefit assessments. The group met between December 2014 and April 2015 and consisted of 13
1577 NSABB voting members as well as non-voting *ex officio* members and other *ad hoc* members from
1578 Federal agencies. The group convened by telephone conference calls and held a one-day in-person
1579 meeting.

1580

1581 The working group developed a draft *Framework for Conducting Risk and Benefit Assessments of Gain-*
1582 *of-Function Research*, which was presented to the full NSABB, which was developed further based on
1583 input from all Board members, and ultimately approved by the full Board on May 5, 2015. The
1584 recommendations in this framework were intended to inform the NIH as it guided the work of Gryphon
1585 Scientific in its risk and benefit assessments. The aim of the NSABB’s framework was to help generate
1586 risk and benefit assessments that would provide information that would allow the NSABB to make
1587 sound, evidence-based recommendations.

1588

1589 The NSABB’s framework describes: principles that should underpin the risk and benefit assessments;
1590 pathogens, pathogen characteristics, and types of GOF experiments and phenotypes that should be
1591 examined; the types of risks and benefits that should be analyzed; scenarios, conditions, and events to
1592 be examined; and approaches and methods that should be considered when analyzing risks and
1593 benefits. In order for the risk and benefit assessments to be grounded in scientific data and evidence,
1594 the assessments needed to focus on specific pathogens, experimental manipulations, and scenarios
1595 whose risks and benefits could be modeled and analyzed. The NSABB recommended that the risk and
1596 benefit assessments focus on studies involving influenza viruses (seasonal strains, as well as high and
1597 low pathogenic avian strains) and SARS and MERS coronaviruses. Given that most pandemics are
1598 associated with respiratory transmission, pathogens capable of airborne transmission were considered
1599 to be of most acute concern. NSABB recognized that the risk and benefit assessments would provide
1600 information specific to the pathogens and scenarios that were examined, but intended that the

1601 assessment would generate information that could be more broadly interpreted and applied. Thus,
1602 NSABB’s recommended approach to the risk and benefit assessments was intended to align with the
1603 USG’s October 2014 statement, which states that while “gain-of-function studies that fall within the
1604 scope of research subject to the funding pause will be a starting point for deliberations, the suitability of
1605 other types of gain-of-function studies will be discussed.”
1606

1607 **DELIVERABLE 2: RECOMMENDATIONS ON A CONCEPTUAL APPROACH FOR EVALUATING PROPOSED**
1608 **GOF STUDIES**

1609
1610 The second NSABB working group was tasked with developing draft recommendations on the
1611 conceptual approach for the evaluation of proposed GOF studies. The group met beginning in June 2015
1612 and remains active the time of this writing. The working group consists of 18 NSABB voting members as
1613 well as non-voting *ex officio* members and other *ad hoc* members from Federal agencies. (Appendix F).
1614 The group convened by telephone conference calls and met twice in person.
1615

1616 In addition to the working group’s primary task of developing draft recommendations, it continued to
1617 provide input on the conduct of the risk and benefit assessments. The working group also received
1618 periodic status updates on the risk and benefit assessments from NIH and Gryphon, as well as reports on
1619 the commissioned ethics analysis by Dr. Michael Selgelid, examined draft work products, and reported
1620 back to the full NSABB.
1621

1622 In developing draft recommendations on a conceptual framework for evaluating proposed GOF studies,
1623 the working group structured its deliberations into three phases.
1624

1625 **Phase I.** Policy examination, research, and information gathering

1626 **Phase II.** Interpretation, analysis, and synthesis of information and results

1627 **Phase III.** Development of recommendations
1628

1629 In Phase I the working group sought to 1) identify and examine the information necessary to inform
1630 development of recommendations and 2) begin to identify principles that should guide the development
1631 of NSABB recommendations. The working group began its deliberations by considering the topic areas
1632 discussed at the NSABB meeting in May 2015, which included examination of relevant U.S. and
1633 international policy and consideration of broader perspectives such as those from funding agencies,
1634 national security experts, journal editors and scientific publishers, ethicists, and others. The working
1635 group held an in-person meeting to consult with experts on many of these topics. The working group
1636 also examined a number of published GOF studies and discussed how current policies might apply to
1637 such studies to provide oversight and risk mitigation.
1638

1639 During Phase II the working group focused on translating information about risks and benefits as well as
1640 ethics into decisions and recommendations. It examined how current policies apply to GOF studies and
1641 began to develop preliminary observations and findings. The working group discussed the ethical issues

1642 associated with funding and conducting GOF studies, particularly noting the values and ethical decision-
1643 frameworks that might be applied to policy decisions about GOF studies. The working group also
1644 developed analytic tools to assist it in systematically analyzing the results of the risk and benefit
1645 assessments. In November 2015, the working group began receiving briefings from Gryphon Scientific
1646 conveying the results of the risk and benefit assessments, as well as reports on ethics from Dr. Selgelid.
1647 The group sought to identify GOF studies that might raise particular concerns and may require
1648 additional oversight or consideration prior to being funded.

1649

1650 In Phase III, the working group developed its draft recommendations, based on its analysis of the risk
1651 and benefit assessments and the ethics report and consideration of all other information and
1652 perspectives that were examined.

1653

1654 **Deliberations by the Full NSABB**

1655

1656 The full NSABB convened times 5 times between October 2014 and January 2016. At these meetings the
1657 NSABB working groups provided progress updates and the full Board deliberated the issues further,
1658 consulted with various experts, and sought public feedback. Public comments made at NSABB meetings
1659 and delivered to the NSABB in writing were carefully considered by the Board during its deliberations.
1660 The articles, resources, and stakeholders consulted by the NSABB and its working groups throughout
1661 this process are listed in Appendix E.

1662

1663 On November 25, 2014, NSABB voted to approve a statement conveying to the USG concerns it heard
1664 regarding the implementation of the funding pause for certain GOF studies.⁶⁶ On May 5, 2015, NSABB
1665 voted to approve its *Framework for Conducting Risk and Benefit Assessments of Gain-of-Function*
1666 *Research*.⁶⁷ This working paper was shared for discussion by the full NSABB on January 7 & 8, 2016.

1667

1668 **Role of the National Academies in the Deliberative Process**

1669

1670 The National Academies play a critical role in the ongoing deliberative process. The National Research
1671 Council and the Institute of Medicine (now National Academy of Medicine) have been asked to convene
1672 two forums to engage the life sciences community and to solicit feedback from scientists, the public, and
1673 other stakeholders. These forums are to involve discussion of principles important for the design of risk
1674 and benefit assessments of GOF research and of NSABB draft recommendations.

1675

⁶⁶ Statement of the National Science Advisory Board for Biosecurity Regarding the USG Deliberative Process and Research Funding Pause on Selected Gain-of-Function Research Involving Influenza, MERS, and SARS Viruses. National Science Advisory Board for Biosecurity, November 25, 2014.

http://osp.od.nih.gov/sites/default/files/resources/Final%20NSABB%20Funding%20Pause%20Statement_12-12-14_0.pdf

⁶⁷

http://osp.od.nih.gov/sites/default/files/resources/NSABB_Framework_for_Risk_and_Benefit_Assessments_of_GOF_Research-APPROVED.pdf

1676 The first National Academies workshop was held on December 15 & 16, 2014 and focused on the
1677 potential risks and benefits associated with GOF studies, ways to assess risks and benefits, strengths and
1678 limitations of risk-benefit analyses, and the ethical and policy implications associated with funding and
1679 conducting GOF studies that have raised concerns.⁶⁸ The discussions at this meeting directly informed
1680 the development of NSABB recommendations for conducting the risk and benefit assessments and its
1681 subsequent deliberations. In particular, the discussions about the potential risks and benefits associated
1682 with GOF studies informed NSABB’s recommendations for the types of risks and benefits that should be
1683 analyzed by Gryphon Scientific. A common theme at this National Academies meeting was also that the
1684 term “gain-of-function” is too broad and that in fact, only a subset of GOF studies truly raise concerns.
1685 NSABB applied this insight in its subsequent analysis of the risk and benefit assessments by seeking to
1686 identify the subset of GOF studies that raised significant or unique concerns. Finally, the legal and policy
1687 discussions that were initiated at this meeting prompted to the NSABB to explore these topics, as well as
1688 ethical issues, further.

1689
1690 The second National Academies meeting was held on March 10 & 11, 2016 and included a discussion of
1691 the completed risk and benefit assessments and NSABB’s preliminary findings and draft
1692 recommendations. NSABB’s proposed attributes for identifying GOFROC were a major discussion point
1693 at this meeting, which resulted in NSABB refining and clarifying these attributes. In addition, there was
1694 significant discussion about the desirability of an adaptive policy approach, the need for data to inform
1695 policy decisions, and the role that a Federal advisory committee might play in evaluating GOFROC or
1696 GOFROC policy. This meeting also had a significant focus on international issues and perspectives, with
1697 specific discussion of ongoing and potential future international activities in this area.

1698
1699 **The Risk and Benefit Assessments of GOF Studies**

1700
1701 NIH commissioned Gryphon Scientific to perform a formal risk and benefit assessments to provide the
1702 NSABB with qualitative and quantitative information about the risks and benefits associated with
1703 conducting certain GOF studies. Dr. Rocco Casagrande, the principal investigator for the study,
1704 presented to the NSABB on May 5, 2015 an overview of Gryphon’s approach to conducting the risk and
1705 benefit assessments, which included a quantitative biosafety risk assessment, a semi-quantitative
1706 biosecurity risk assessment, and a qualitative benefit assessment. Prior to voting to finalize its
1707 *Framework for Conducting Risk and Benefit Assessments of Gain-of-Function Research*, NSABB discussed
1708 with Dr. Casagrande its draft recommendations and how Gryphon’s proposed approach aligned with
1709 NSABB’s proposed recommendations. In June 2015, Dr. Casagrande presented and discussed a more
1710 detailed work plan with the NSABB working group. Over the course of the study, the NSABB working
1711 group received occasional progress reports from Gryphon and NIH staff, and were provided draft
1712 sections of the risk and benefit assessments. In November 2015 the NSABB working group began

⁶⁸ Potential Risks and Benefits of Gain-of-Function Research: Summary of a Workshop. National Research Council and the Institute of Medicine of the National Academies. The National Academies Press, Washington D.C., 2015. www.nap.edu.

1713 receiving the results of the completed risk and benefit assessments. Gryphon’s final draft report was
1714 posted in advance of the NSABB meeting in January, 2016.⁶⁹

1715
1716 The NIH Office of Science Policy managed the contract with Gryphon Scientific. NIH staff met weekly
1717 with Gryphon to accomplish the goals of the Statement of Work and to ensure the recommendations
1718 provided in the NSABB’s *Framework for Conducting Risk and Benefit Assessments of Gain-of-Function*
1719 *Research* continued to inform the conduct of the risk and benefit assessments, as appropriate. NIH staff
1720 also consulted with NSABB *Ex officio* members to get broader expertise and advice, and to help ensure
1721 that the risk and benefit assessments would yield information that would inform subsequent policy
1722 deliberations by the U.S. government.

1723
1724 **Considering Ethical Issues Associated with GOF Studies**

1725
1726 To guide the NSABB’s evaluation of the risks and benefits associated with GOF studies and its
1727 development of recommendations, the Board sought additional ethical input and analysis. NIH
1728 commissioned Dr. Michael Selgelid, Monash University, to examine the literature regarding the ethical
1729 issues associated with funding and conducting GOF research and to explore different ethical frameworks
1730 that might be utilized when considering how to evaluate the potential risk and benefits associated with
1731 GOF studies. Dr. Selgelid was also asked to provide an ethical decision-making framework that NSABB
1732 could consider using when analyzing the information provided in the risk and benefit assessments of
1733 GOF studies. The decision framework was to identify and consider ethical values that may not be fully
1734 captured by a risk-benefit analysis. Dr. Selgelid’s analysis was to be accomplished in a neutral, objective
1735 manner, without making any definitive recommendations on whether and how to fund or conduct
1736 certain GOF studies or what policy course might be the most appropriate. Dr. Selegelid presented his
1737 initial work to the NSABB in September 2015 and delivered to the NIH a draft paper in December 2015,
1738 which was conveyed to the NSABB working group and posted in advance of the NSABB meeting in
1739 January, 2016.⁷⁰

⁶⁹ Risk and Benefit Analysis of Gain-of-Function Research, Final Draft Report. Gryphon Scientific, December, 2015.
<http://osp.od.nih.gov/sites/default/files/Risk%20and%20Benefit%20Analysis%20of%20Gain%20of%20Function%20Research%20-%20Draft%20Final%20Report.pdf>

⁷⁰ Selgelid, Michael. Gain-of-Function Research: Ethical Analysis. December 7, 2015.
http://osp.od.nih.gov/sites/default/files/GOF%20White%20Paper%20by%20Michael%20Selgelid_0.pdf

1740 **Appendix B. Summary of Federal Policies for Biosecurity and Biosecurity Oversight Analyzed by NSABB Working Group**

Oversight Measures	Risks Addressed	Description of Oversight	Analysis/Applicability to GOF Studies
<p>Biosafety in Microbiological and Biomedical Laboratories (BMBL), 5th Edition (December 2009) http://www.cdc.gov/biosafety/publications/bmbl5/index.htm</p>	Biosafety risks	<p>Applies to: Life sciences research involving infectious microorganisms or hazardous biological materials</p> <p>Description: General biosafety practices and biological containment for various classifications (risk groups) of microorganisms and etiological agents</p>	<p>BMBL does not describe GOF studies per se but does include summary statements and biocontainment guidance for research involving various influenza strains (including contemporary and non-contemporary human, high and low pathogenic avian, swine, the 1918 influenza strain, and reassortant viruses) and SARS-CoV. MERS-CoV had not emerged at the time of the last BMBL update but interim laboratory biosafety guidance was issued by CDC and is referenced by BMBL.</p> <p>BMBL is a guidance document and generally considered the authoritative reference for laboratory biosafety but it is not a regulatory document; compliance is voluntary.</p>
<p>NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules (November 2013) http://osp.od.nih.gov/office-biotechnology-activities/biosafety/nih-guidelines</p>	Biosafety risks	<p>Applies to: Basic or clinical life sciences research that involves recombinant or synthetic nucleic acid molecules and is conducted at an institution receiving NIH funding for any such research</p> <p>Description: Describes roles and responsibilities of institutions and investigators in safely conducting research. Requires institutional review with a focus on the concepts of risk assessment, risk group classification of agents, physical and biological containment levels, practices, personal protective equipment, and occupational health.</p> <p>Advised by: NIH Recombinant DNA Advisory Committee (RAC)</p>	<p>The NIH Guidelines have been amended to include additional guidance for work with Risk Group 3 influenza viruses (1918 H1N1, H2N2, highly pathogenic avian influenza (HPAI) H5N1) to specify enhancements to biosafety level 3 containment, practices, and occupational health requirements.</p> <p>NIH Guidelines were amended again to require further enhancements to facilities, biosafety equipment and practices, including occupational health practices, for research involving HPAI H5N1 strains transmissible among mammals by respiratory droplets.</p> <p>NIH Guidelines are often used as a model of biosafety guidance by the broader scientific community but compliance is required only by institutions receiving such funding from the NIH.</p> <p>The scope is also limited to research involving recombinant or synthetic nucleic acids. Some IBCs also review and approve non-recombinant pathogen research; however, not all institutions require their IBCs to do so.</p>
<p>HHS and USDA Select Agent Program (as of July 2014) http://www.selectagents.gov/regulations.html</p>	Biosecurity (physical and personnel) and biosafety risks	<p>Applies to: Biological agents and toxins that have the potential to pose a severe threat to public health and safety, based on a set of criteria.</p> <p>Description: Regulates the possession, use, and transfer of select agents and toxins. Overseen by the Federal Select Agent Program. Requires registration of individuals and entities; federal background investigations; federal review of restricted experiments; training; institutional compliance; etc.</p> <p>Advised by: Intragovernmental Select Agents and Toxins Technical Advisory Committee (ISATTAC)</p>	<p>Studies that could be considered GOF studies, which involve pathogens on the select agent list, are subject to oversight by the SAP. Researchers and institutions performing such studies must receive favorable security risk assessments by the FBI, register with the SAP, receive training on the proper procedures and practices for handling such agents, and abide by other aspects of the regulations.</p> <p>SARS-CoV, HPAI H5N1 influenza, and 1918 influenza viruses are select agents and GOF studies involving these pathogens are subject to oversight by the SAP.</p> <p>Restricted experiments that would entail conferring antiviral resistance to these viruses would require additional review and approval prior to being conducted.</p> <p>GOF experiments involving MERS, and other agents not included on the select agent list, would not be subject to oversight by the SAP.</p>

****DELIBERATIVE DRAFT****

<p>USG Policy for Federal Oversight of DURC (March 2012) http://www.phe.gov/s3/dualuse/Pages/USGOversightPolicy.aspx</p>	<p>Biosecurity risks, particularly involving misuse of research information, products, and technologies (DURC)</p>	<p>Applies to: Life sciences research conducted at an institution receiving USG funding that involves any of 15 agents that pose the greatest risk of deliberate misuse with most significant potential for mass casualties or devastating effects.</p>	<p>The federal DURC policy requires identification and oversight of certain pathogen research involving 7 experimental types, some of which can be described as GOF experiments (i.e., enhancing the harmful consequences of an agent; increase transmissibility; alter host range; etc.) by Federal funding agencies.</p> <p>DURC policies only apply to research involving 15 pathogens. Institutions may review other studies for DURC potential but are not required to do so. Certain GOF studies that involve other agents would not be subject to DURC oversight under the policies.</p>
<p>USG Policy for Institutional Oversight of DURC (September 2014) http://www.phe.gov/s3/dualuse/Pages/InstitutionalOversight.aspx</p>	<p>Biosecurity risks, particularly involving misuse of research information, products, and technologies (DURC)</p>	<p>Applies to: Life sciences research conducted at an institution receiving USG funding that involves any of 15 agents that pose the greatest risk of deliberate misuse with most significant potential for mass casualties or devastating effects.</p>	<p>The institutional DURC policy requires federally-funded institutions to establish a system for the identification and oversight of certain pathogen research involving 7 experimental types, some of which can be described as GOF experiments (i.e., enhancing the harmful consequences of an agent; increase transmissibility; alter host range; etc.)</p> <p>DURC policies only apply to research involving 15 pathogens. Institutions may review other studies for DURC potential but are not required to do so. Certain GOF studies that involve other agents would not be subject to DURC oversight under the policies.</p>
<p>HHS Funding Framework for GOF studies (August 2013) http://www.phe.gov/s3/dualuse/Pages/HHSh5n1Framework.aspx</p>	<p>Biosafety and biosecurity risks associated with certain GOF experiments involving agents with pandemic potential</p>	<p>Applies to: Gain-of-function studies that are reasonably anticipated to generate HP AI H5N1 viruses that are transmissible, and LPAI H7N9 viruses that have increased transmissibility, between mammals by respiratory droplets</p> <p>Description: Describes an HHS Department-level review pre-funding review and approval process for certain GOF studies, which can result in funding, not funding, or funding with certain conditions and ongoing oversight.</p>	<p>The only policy focused specifically on funding decisions related to the types of GOF studies that have raised concern.</p> <p>Narrowly focused only on specific GOF studies (enhancing mammalian transmissibility) on two avian influenza viruses; other GOF studies may raise concern and would not be reviewed under this framework.</p>
<p>USG Export Controls (as of July 2014) http://www.bis.doc.gov/index.php/regulations/export-administration-regulations-ear</p>		<p>Applies to: Export or release of equipment, software and technology, chemicals, microorganisms, toxins, and other materials and information deemed dual use or strategically important to U.S. national security, economic, and/or foreign policy interests</p>	<p>Comprehensive set of federal regulations that control and restrict the export and release of sensitive equipment, software and technology; chemical, biological, and other materials and information as a means to promote national security interests and foreign policy objectives.</p>

1741

1742

1743 **Appendix C. Identifying GOFROC: Examples of Studies that Would and Would Not be Considered GOFROC**

Experiment that is anticipated to entail GOFROC and therefore require additional pre-funding review and approval	Rationale (See NSABB Rec. 1 for description of GOFROC Attributes)
<p>An experiment that is anticipated to generate avian influenza viruses that are transmissible by the respiratory route in mammals, if the starting virus is highly virulent in humans.</p>	<p>Attribute 1. The experiment is anticipated to increase transmissibility by the respiratory route in a relevant experimental mammalian model. Further, altering the host range from birds to mammals could generate a virus to which there is no existing population immunity, resulting in a virus capable of wide and potentially uncontrollable spread among humans.</p> <p>Attribute 2. Since the starting virus is highly virulent in humans it can be reasonably anticipated that the resulting virus will remain highly virulent in humans.</p>
<p>Reassortant studies involving avian and human influenza virus strains conducted to identify reassortants with pandemic potential that could arise naturally.</p>	<p>Attribute 1. Given the starting viruses and the goal of the experiment to identify/select for reassortants that are potentially highly transmissible in mammals, it can be reasonably expected that one or more of the resulting strains could be highly transmissible in humans. Since the resulting viruses are reassortants between bird and human influenza viruses, it can be anticipated that the antigenicity of at least some will remain avian-specific such that human populations would not be expected to have been exposed to such a strain or have pre-existing immunity. Therefore, it can be anticipated that a resulting virus could be capable of wide and uncontrollable spread.</p> <p>Attribute 2. Whether or not any of the starting viruses are highly virulent in humans, it can be reasonably anticipated that the expression of novel combinations of gene segments, derived from different influenza strains, in reassortant viruses could result in a range of characteristics that includes high virulence.</p>
<p>Studies that would result in a strain of <i>Yersinia pestis</i> more likely to cause pneumonic forms of infection and be resistant to antibiotics.</p>	<p>Attribute 1. Given the ease of transmission of <i>Yersinia pestis</i> in previous pandemics, manipulations that would enhance its ability to spread by respiratory droplets and cause pneumonic infections would generate a highly transmissible pathogen. In addition, if this manipulation were performed in a strain that was resistant to antibiotics, there would be limited options for controlling the spread of the pathogen among humans.</p> <p>Attribute 2. Since the starting agent is highly virulent in humans, particularly when spread through the respiratory route, it can be reasonably anticipated that the resulting agent will remain highly virulent in humans.</p>

1744

Experiment NOT anticipated to entail GOFROC and therefore not require additional pre-funding review and approval	Rationale
Studies aimed at generating a mouse-adapted MERS-CoV or other emerging human respiratory pathogen	<p>Not Attribute 1. The starting virus is transmissible by the respiratory route among humans but is not highly transmissible. MERS-CoV transmission usually occurs as a result of close contact (e.g. providing unprotected care to an infected patient). Sustained community transmission has not been observed. Furthermore, the proposed adaptation to recapitulate human disease symptoms in mice would not be reasonably anticipated to enhance transmissibility thus the resulting virus would not be anticipated to be capable of wide and uncontrollable spread.</p> <p>Possibly Attribute 2. The starting virus is already highly virulent in humans and is associated with significant morbidity and mortality. However, it should also be noted that a mouse-adapted strain is likely to be less virulent in humans.</p>
Studies enhancing the growth of seasonal influenza viruses, which may be performed during vaccine production	<p>Not Attribute 1. The starting seasonal influenza virus is highly transmissible by the respiratory route in humans however, population immunity is likely to exist against circulating (and recently circulated) strains. Enhancement of growth is unlikely to result in a virus that can evade immunity, thus a virus capable of wide and uncontrollable spread would not be likely.</p> <p>Possibly attribute 2. Increasing seasonal virus' ability to replicate could potentially result in its increased ability to cause disease, which could result in highly virulent strains. Note: If this experiment were to involve an attenuated strain, as is often the case with vaccine production, it would be unlikely to result in a virus that is highly virulent in humans.</p>
Antigenic drift studies whereby seasonal influenza viruses that are no longer neutralized by vaccine-induced immunity are generated and selected for in the laboratory.	<p>Not Attribute 1. The starting seasonal influenza virus is highly transmissible by the respiratory route in humans. However, antigenic drift studies generate influenza viruses with some resistance to a specific immunization but do not change the antigenic character of the virus to a degree such that it would no longer be recognized by the human immune system. Given that the starting virus is a human virus—not one that naturally infects birds or other non-human hosts—there would likely be some pre-existing population immunity to the resulting strains.</p> <p>Possibly attribute 2. The experimental manipulation would not be anticipated to increase the virulence of the virus. The resulting strains are likely to exhibit a similar level of virulence as the starting strain. Whether its virulence is considered high or low would depend on the specific initial strain used.</p>

1746 **Appendix D. Summaries of Stakeholder Perspectives**

1747 The NSABB consulted a wide range of experts and stakeholder groups including not only scientists and
1748 institutions that fund and conduct life sciences research, but a much larger and diverse array of groups
1749 including public health officials, medical practitioners, emergency responders, vaccine developers,
1750 scientific journals, as well as the general public, non-governmental organizations, individuals with
1751 international perspectives and others. To accomplish this, NSABB organized meetings with expert
1752 presentations and panels that offered opportunities for interested groups there and for individuals and
1753 organizations to express their views and contribute throughout the deliberative process in ways that
1754 have informed the NSABB deliberations. These include: several public full NSABB advisory committee
1755 meetings that included sessions dedicated to obtaining public comment, two public symposia hosted by
1756 the National Academies that obtained comments from the public at the meetings and online, as well as
1757 comments submitted to the NIH/OSP and NSABB by email, and discussions with subject matter experts
1758 during NSABB WG conference calls and in-person meetings. Also included below are views expressed in
1759 some of the articles that have been published on this topic. A complete list of the individuals consulted
1760 and articles examined by NSABB are listed in Appendix E. Note that Gryphon Scientific also conducted
1761 extensive consultations with experts as part of their risk and benefit assessments. Those experts are not
1762 listed here but a listing is available in Gryphon's report.⁷¹

1763 The following is a synthesis of stakeholder ideas and opinions expressed during the deliberative process.
1764 Many of these points were conveyed in more than one venue and by more than one person or group.

1765 **Scientists and Others Favoring GOF Research**

1766 A variety of influenza and coronavirus researchers who conduct GOF research, and other life sciences
1767 researchers have stated that GOF studies are widely used and fundamental for understanding viruses,
1768 and therefore are crucial to undertake. This group generally favors conducting such research because it
1769 aims to benefit society. In their view, such research can be safely conducted under current oversight
1770 frameworks and further restrictions will impede valuable work that will lead to important scientific
1771 information about these viruses, leading to better drugs and vaccines, as well as to improving the
1772 specificity of surveillance, particularly for influenza. In addition, some GOF studies are viewed as
1773 essential, specifically those that alter host range or enhance pathogenicity in order to develop animal
1774 models of disease (for example, with SARS-CoV) or GOF studies that generate drug or countermeasure
1775 resistance, which are important in satisfying various FDA requirements for marketing approval. Those
1776 who support GOF studies also point out that such studies are needed for predicting what amino acid
1777 changes are important for human transmission and therefore are important for the selection of
1778 candidate vaccine viruses. They also argue that GOF studies are important for prioritizing viruses for risk
1779 management (surveillance) and that further work will make these applications more robust. The risks

⁷¹ Risk and Benefit Analysis of Gain-of-Function Research, Final Draft Report. Gryphon Scientific, December, 2015.
<http://osp.od.nih.gov/sites/default/files/Risk%20and%20Benefit%20Analysis%20of%20Gain%20of%20Function%20Research%20-%20Draft%20Final%20Report.pdf>

1780 associated with not doing GOF research (generally due to a lack of preparedness for natural public
1781 health threats) must also be considered.

1782 While acknowledging there are risks associated with GOF research, proponents believe those risks are
1783 manageable and have been overstated by some, as evidenced by the fact that laboratory acquired
1784 infections are rare and infections in the community as a result of releases from a laboratory are almost
1785 unknown. While risk cannot be zero, the work can be conducted safely and securely with appropriate
1786 risk mitigation including containment along with good training and with the implementation of robust
1787 occupational medicine programs. Alternatives to GOF do not always provide the full answer to key
1788 questions and may yield misinformation. Supporters of GOF studies have also expressed concerns about
1789 the effects of the current funding pause and possible additional oversight on the field of virology and
1790 young researchers, and feel that there are costs of not undertaking the work in question. A major need
1791 is for better definition of what is meant by GOF with a clear distinction between GOF studies and GOF
1792 studies of concern. Some have suggested that only viruses with increased transmissibility and
1793 pathogenicity represent risks that exceed those of other infectious diseases research. They have also
1794 noted that SARS and MERS viruses are different from influenza, and require a different risk assessment
1795 approach since they are already virulent human pathogens; GOF research is needed to develop animal
1796 models that will benefit development of countermeasures for coronaviruses. Some supporters have
1797 acknowledged that there may be some experiments that should not be done. Finally, proponents of
1798 GOF research have stated that the risks from naturally occurring influenza viruses, which they argue
1799 could be reduced through GOF work, are greater than risks from performing GOF studies.

1800 **Scientists and Others Critical of GOF Studies**

1801 Opponents and critics of GOF research have generally focused their concern on a subset of GOF
1802 studies—those that involve enhancing the pathogenicity and/or transmissibility in mammals
1803 (particularly by the respiratory route), which may result in the generation of novel pathogens with
1804 pandemic potential. Critics have argued that the generation of novel laboratory pathogens with
1805 pandemic potential poses major public health risks and some have argued such studies should not be
1806 conducted. They have presented and published calculations that suggest a high probability of global
1807 outbreaks of influenza that might kill hundreds of millions of people, as a result of the release from a
1808 laboratory of a novel GOF virus. There is some disagreement about these estimates and how likely a
1809 pandemic might be, but opponents generally argue that even a relatively low probability of a potentially
1810 massive outbreak with major consequences is unacceptable. Some critics of GOF studies have
1811 acknowledged that there are a number of GOF studies that can and should be conducted.

1812 Opponents of certain GOF studies have also argued that the benefits of GOF studies have been
1813 overstated, or are questionable, and that the benefits generally do not outweigh the biosafety risks.
1814 They also question claims about the effectiveness of risk mitigation strategies, since human factors and
1815 human error are unavoidable and hard to control, and institutional compliance and competence may
1816 vary. Critics have disputed the value of GOF studies to surveillance stating that it is not possible to
1817 predict phenotype from genotype; therefore predicting the pandemic risk of newly emergent strains is

1818 not achievable given the current state of knowledge. Also, in their view, controlling outbreaks doesn't
1819 require GOF research.

1820 Opponents of GOF research tend to favor alternative types of research that, in their view, can provide
1821 the same public health benefits without the large risks. It was suggested that the approach should be on
1822 reducing the risk by reducing the hazard, as opposed to focusing on mitigation of the risk. For example,
1823 if a universal influenza vaccine was developed, the need for many GOF experiments would be
1824 eliminated. Critics want to see funds currently used for GOF work provided to other types of research,
1825 which would be a better use of scarce resources in their view. Overall, they view preventing major public
1826 health problems as paramount, and see a need to define a critical set of experiments that should not be
1827 done, or only be done with additional strong oversight. Opponents are also concerned about
1828 proliferation and other factors that may lead to misuse and biosecurity threats. Finally, opponents have
1829 pointed out a moral issue if risks and benefits of certain GOF studies are not fairly distributed globally.

1830 **Funding Agencies**

1831 Public and private funding agencies support GOF research that has raised concerns with the goal of
1832 improving public health and well-being. These organizations in the US and abroad are aware of the
1833 issues surrounding DURC/GOF studies and are working diligently to implement and comply with existing
1834 policies in their countries. Most funders have requirements and procedures in place as they apply
1835 policies and guidance to evaluate proposed work and to oversee funded work. Current approaches
1836 involve education and awareness campaigns, project risk evaluation, ethics reviews, development of risk
1837 mitigation plans, and post-award monitoring. Funders believe they can contribute to the GOF
1838 deliberative process as a result of their practical, on-the-ground experience with DURC and GOF. They
1839 are concerned that interpreting policy can be very challenging, since it requires considerable expertise
1840 and judgment. They would welcome workable policies with clear guidance and have noted some
1841 unintended consequences of the funding pause, which affected some GOF projects that had not raised
1842 particular concerns. Some foreign government funders view government funding as a poor control
1843 mechanisms because this does not cover privately funded research and research funded by other
1844 entities. National legislation, regulations, compliance, training, awareness-raising, and self-monitoring
1845 have been noted as important.

1846 **Biosecurity Experts and Others Concerned about National Security**

1847 The ultimate goal of national security professionals, as it pertains to life sciences research, is to protect
1848 public health from natural or man-made health threats. Those concerned with national security aim to
1849 prevent terrorists and others with malicious intent or misguided motives from using products or
1850 information from GOF research to cause harm. This may include deliberate release of pathogens into
1851 the community, targeting of researchers or research facilities, or interference with on-going research
1852 activities. GOF research represents biosecurity risks in addition to biosafety risks; these overlap but are
1853 different with regard to important legal, policy and regulatory issues. Managing biosafety risks may or
1854 may not also manage biosecurity risks; GOF policy must take both types of risk into account.

1855 When trying to assess biosecurity threats, security professionals have noted the importance of avoiding
1856 assumptions and predictions about the motives and capabilities of those who might be planning
1857 biosecurity actions. Those in the security field gather a large variety of data, but often their information
1858 is imprecise and may require consideration of what is feasible and plausible. Because of the paucity of
1859 biosecurity events, it is very difficult to evaluate and predict the likelihood and consequences of a
1860 deliberate release or determine how to prevent and/or mitigate one, and different experts view this
1861 issue very differently. It was stated that research policy in itself is not be the appropriate solution to
1862 prevent specific biological threats but specific research policies could help raise awareness of security
1863 issues among researchers, which would be important.

1864 Security and intelligence professionals have described the challenges associated with using classification
1865 as a potential risk mitigation strategy. Classification would effectively restrict access to sensitive
1866 research information and research products and would limit the number of laboratories able to perform
1867 the studies. This could be described as both a strength and a limitation, depending on one's
1868 perspective. Life sciences research that requires classification is typically classified at the outset; the
1869 retroactive classification of research that had been conducted in an open, academic setting is
1870 exceedingly difficult.

1871 **Scientific and Medical Journals**

1872 Scientific and medical journals have been at the forefront of the GOF issue. While a number of journals
1873 and families of journals have procedures in place for identifying DURC, including GOF and other
1874 biosecurity concerns in submitted manuscripts, many journal editors are not entirely comfortable with
1875 their role. Their mission is to transmit scientific information, not control it, and they may not have the
1876 security expertise or the access to such expertise to make the necessary judgments and decisions about
1877 risks associated with communicating certain research findings. Rejection and redaction are the major
1878 tools journals have to control dissemination of dual use information, and neither may actually address
1879 the concerns; they are also impractical to implement effectively. One suggestion voiced was to require
1880 that a description of the steps that were taken during conduct of the research to ensure safety be
1881 included in all manuscripts. Some journal editors and staff expressed a desire to get help in evaluating
1882 risks and mitigation strategies from an independent national group such as the NSABB and to involve
1883 them earlier in the overall process. Most think the publication stage is not the best point to exercise
1884 control or prevent misuse of data from GOF studies but realize they are the final gatekeepers. Earlier
1885 identification of DURC/GOF along with risk mitigation earlier in the research life cycle would reduce the
1886 burden on them. Also, new technology and novel publication venues make controlling information
1887 increasingly difficult, and, as noted above, not all journals are able to or choose to impose a rigorous
1888 review of manuscripts.

1889 **Countermeasure Developers**

1890 Companies and others that are attempting to develop vaccines and drugs against pathogens were
1891 represented in several discussions. Medical countermeasure (MCM) developers expressed quite
1892 divergent views and opinions. Those favoring GOF research argued that such work is absolutely

1893 necessary for antiviral drug development because GOF experiments to select for drug resistant mutants
1894 as well as to develop animal models are part of the critical path to marketing approval. In their view,
1895 GOF studies also have had a major influence on developing influenza vaccines, both seasonal and
1896 pandemic, and are likely to result in improved ways to make even better vaccines in the future. GOF
1897 experiments are required for selection of strains with better growth properties, with key mutations that
1898 alter important phenotypes needed in the vaccine strain, and with incorporating characteristics of
1899 strains that are likely to emerge into proven backbones. It was noted that GOF studies that enhance
1900 virulence can help inform vaccine designers about which mutations to avoid incorporating into vaccine
1901 strains. This group is concerned that their efforts to improve public health may be limited or impeded
1902 by new policies and urge careful consideration of their needs as decisions are made.

1903 Conversely, other MCM developers expressed the view that vaccine production now is little dependent
1904 on GOF research and that any possible benefits will be far into the future, although some feel long-term
1905 potential is there. Those who criticize GOF studies on these grounds have argued that vaccines are
1906 developed in response to strains that emerge as threats, rather than preemptively based on strains that
1907 might be predicted as threats. Rather than supporting GOF studies to enhance vaccine production and
1908 drug development, it has been suggested that the other constraints that impede MCM development be
1909 addressed, such as streamlining FDA approval procedures and improving manufacturing processes,
1910 which would have a much greater impact. These critics suggest limiting current GOF-related efforts and
1911 focusing attention and resources in other directions. Overall, they believe that impact of GOF research
1912 on vaccine and drug development has been overstated, and that the benefits articulated are more
1913 theoretical than practical.

1914 **The General Public and Organizations Representing their Views.**

1915 A number of stakeholders stressed the importance of having meaningful public engagement with input
1916 and participation as part of the deliberative process. It is important that communities that might be
1917 affected by accidents or the misuse of research have a say in the research that is being conducted,
1918 however, but this may not generally be the case in their view. Real transparency, with the public good as
1919 the foremost consideration, must be part of a truly independent decision-making process. They note
1920 that it is important to maintain public trust in the scientific enterprise by involving non-scientists at
1921 stages when their views can still have an impact on policy-making. Public opinion of science is harmed
1922 when decisions that influence public health and safety are made without such input or the input has no
1923 real impact. Conversely, effective community engagement can convert sceptics to supporters. More
1924 than one participant raised the concern that if risks and benefits are not equitably distributed, it is a
1925 serious ethical issue⁷².

1926 Other issues that were mentioned include: how harms will be compensated if a laboratory incident were
1927 to affect the surrounding community; the need for enough resources to conduct research safely; and
1928 the opportunity to learn from other industries such as nuclear industry.

⁷² The ethical issues are discussed in more depth elsewhere, notably, Dr. Michael Selgelid's ethical analysis and the section of this report on Ethical Values and Decision-Making Frameworks.

1929 **Research Institutions**

1930 Representatives of universities and other research institutions generally noted that there is already
1931 significant oversight of DURC and GOF at both the Federal and institutional levels. Biosafety
1932 professionals noted that potentially high risk projects would receive thorough scientific review and risk
1933 assessment, resulting in the development of risk mitigation plans, and on-going monitoring as a result of
1934 policies and requirements that are already in place. They cited concerns over any increase in compliance
1935 that would impose burdens on their already-limited resources or impede researchers from doing
1936 valuable work. They have difficulty, at times, deciding what is DURC when reviewing specific projects
1937 and would welcome more specificity and guidance. Many emphasized the need for policies that are
1938 unambiguous and straightforward to implement.

1939 **Public Health Officials**

1940 Public health officials have expressed diverse opinions. Some believe that GOF research has and can
1941 continue to improve surveillance efforts, as well as vaccine and therapeutic development. Others
1942 expressed concerns that an accident involving a laboratory pathogen for which there are no
1943 countermeasures would be very concerning and difficult to respond to. At the local level it is important
1944 to have public health involvement in the decision-making process because they will be incident
1945 responders. Strong connections with state and local laboratories should be established for sharing
1946 information and might include involving them in the review process. It was also noted that GOF and
1947 related policies may impact sample sharing and impede international relations relating to public health
1948 efforts.

1949 **International Perspectives**

1950 A number of participants noted that there is much interest in the GOF/DURC issue internationally, and
1951 the international community is looking to see what the USG will do as a result of the deliberative
1952 process. It was noted that U.S. policy often influences policies globally and the international
1953 ramifications should be considered. Recent biosafety incidents in U.S. Federal labs have raised concerns
1954 among many in other countries about the ability of the U.S. to adequately manage risks. A number of
1955 countries have well-developed systems of policy and regulation that would address many or some GOF
1956 and DURC issues, though international policy approaches are generally somewhat different from those
1957 in the U.S. International experiences, activities, and perspectives were cited as important to consider in
1958 the deliberative process. A collaborative approach and active attempts to engage the international
1959 community was viewed as the most effective way to benefit all. Many favored launching an
1960 international dialogue soon, with development of broad concepts and points of agreement that could be
1961 shared by all, while still respecting national differences. In addition, it was suggested that academies of
1962 science and multi-national organizations such as WHO can play an important role in such interactions at
1963 the right time. Those with a particular interest in the international aspects of GOF research also cited
1964 ethical issues associated with the unequal distribution of risks and benefits across rich and poor

1965 countries. It was noted that the European Commission uses a comprehensive ethics process for
1966 screening and monitoring DURC/GOF in research projects.⁷³

1967 **Those with an Interest in the Deliberative Process Itself**

1968 A broad group of individuals offered comments on the deliberative process itself. This included: federal
1969 government personnel, ethicists, decision-making experts, policy experts, other scientists, and includes
1970 people who are also members of the previously-mentioned groups. Those concerned with the
1971 deliberative process generally called for a well-planned and executed, thorough, scientifically rigorous,
1972 and impartial RBA that is technically sound and socially acceptable. They favored a democratic
1973 deliberative process and a policy that incorporates decisions made by neutral parties. Policy should be
1974 created using risk-based and value-based approaches to achieve desired outcomes. They want the final
1975 policy resulting from the deliberative process to be capable of reasonably identifying and mitigating risks
1976 related to GOF while protecting scientific autonomy, research progress, discovery and innovation, public
1977 health, national security, and other critical interests.

1978 Many see an adaptive process as desirable, and recommend collecting appropriate data about
1979 laboratory accidents and mitigation effectiveness. It was noted that risks and benefits will change as
1980 science advances. The funding decision-making process should be accountable and limit inherent
1981 conflicts of interest; the individuals or entities that make decisions is critical. Most favor using existing
1982 policies as the basis of policy for GOF, while acknowledging that current frameworks are not entirely
1983 adequate. The question of how to incorporate non-USG funded research into an acceptable framework
1984 was raised several times. Deciding how to decide is a key point.

1985 Both proponents and critics of GOF studies criticized the term “gain-of-function” as being too broad and
1986 not descriptive enough. There was much discussion about the appropriate definition of GOF research of
1987 concern; many strong, often conflicting, views were expressed. Unfortunately while it is important to
1988 have a working definition and criteria for what is GOF of concern as opposed to GOF, a binary distinction
1989 needed for deciding what requires extra scrutiny, GOF experiments are actually a continuum of
1990 increasing risk.

1991 The funding pause was criticized for being too broad, and some described it as disruptive to scientific
1992 process. Finally, some feel that a definitive quantitative risk assessment is not possible because of the
1993 very large uncertainties and lack of critical information associated with doing such studies, and they
1994 question the value of any studies that are done.

⁷³ The EU Framework Programme for Research and Innovation, Horizon 2020. How to complete your ethics self-assessment, version 1.0, 11 July 2014. http://ec.europa.eu/research/participants/data/ref/h2020/call_ptef/pt/h2020-call-pt-ria-ia_en.pdf#page=27

1995 **Appendix E. Consultations, Comments, and Sources Considered During NSABB Deliberations**

1996 **Table 1A. Invited speakers, presenters, and panelists.** This table lists invited individuals who presented at NSABB, NSABB working group, and
1997 the National Academy of Sciences meetings. Members of the NSABB or an NSABB working group are listed if they presented as a subject matter
1998 expert on a specific topic.

Speaker/Commenter	Affiliation/Location	Venue
Regine Aalders, M.Sc.	Embassy of the Netherlands, Washington, D.C.	NSABB Full Board Meeting (January 7-8, 2016)
Nisreen AL-Hmoud, Ph.D, M.Phil.	Royal Scientific Society of Jordan	National Academies Workshop (March 10-11, 2016)
Ronald Atlas, Ph.D.	University of Louisville	National Academies Workshop (December 15, 2014)
Ralph Baric, Ph.D.	University of North Carolina at Chapel Hill	National Academies Workshop (December 15, 2014)
Kavita Berger, Ph.D.	Gryphon Scientific	NSABB Full Board Meeting (September 28, 2015), In-person WG Meeting (November 9, 2015)
Thomas Briese, Ph.D.	Columbia University	National Academies Workshop (December 15, 2014)
Michael Callahan, M.D., D.T.M.&H., M.S.P.H.	Massachusetts General Hospital; Harvard Medical School	National Academies Workshop (March 10-11, 2016)
Arturo Casadevall, M.D., Ph.D.	Johns Hopkins Bloomberg School of Public Health; mBio	NSABB Full Board Meeting (October 22, 2014), In-person WG Meeting (July 23, 2015)
Rocco Casagrande, Ph.D.	Gryphon Scientific	NSABB Full Board Meetings (September 28, 2015 and January 7-8, 2016), In-person WG Meeting (November 9, 2015), National Academies Workshop (March 10-11, 2016)
R. Alta Charo, J.D.	University of Wisconsin–Madison	National Academies Workshop (December 15, 2014), NSABB Full Board Meeting (January 7-8, 2016)
Susan Collier-Monarez, Ph.D.	U.S. Department of Homeland Security	In-person WG Meeting (July 23, 2015)
Louis (Tony) Cox, Ph.D., S.M.	Cox Associates	National Academies Workshop (March 10-11, 2016)
Mark Denison, M.D.	Vanderbilt University	National Academies Workshop (December 15, 2014), NSABB Full Board Meeting (January 7-8, 2016)
Dennis Dixon, Ph.D.	U.S. Department of Health and Human Services/National Institutes of Health	NSABB Full Board Meeting (November 25, 2014)
Marianne Donker, Ph.D.	Ministry of Health, Welfare and Sport, Netherlands	In-person WG Meeting (July 23, 2015)
Philip Dormitzer, M.D., Ph.D.	Novartis Vaccines	National Academies Workshop (December 15, 2014)
Ruxandra Draghia-Akli, M.D., Ph.D.	European Commission	In-person WG Meeting (July 23, 2015), National Academies Workshop (March 10-11, 2016)
Rebecca Dresser, J.D.	Washington University in St. Louis	NSABB Full Board Meeting (September 28, 2015)
Paul Duprex, Ph.D.	Boston University, NEIDL Institute	NSABB Full Board Meeting (October 22, 2015)

****DELIBERATIVE DRAFT****

Gerald Epstein, Ph.D.	White House Office of Science and Technology Policy	In-person WG Meeting (July 23, 2015)
Stephen Eubank, Ph.D.	Virginia Polytechnic Institute and State University	NSABB Full Board Meetings (October 22, 2014 and January 7-8, 2016)
Scott Ferson, Ph.D.	Applied Biomathematics	NSABB Full Board Meeting (October 22, 2014)
David Fidler, J.D., M.Phil.	Indiana University, Bloomington	NSABB Full Board Meeting (January 7-8, 2016)
Harvey Fineberg M.D, Ph.D.	University of California, San Francisco	National Academies Workshops (December 15, 2014 and March 10-11, 2016)
Adam Finkel, Sc.D., M.P.P.	University of Pennsylvania Law School	National Academies Workshops (March 10-11, 2016)
Baruch Fischhoff, Ph.D.	Carnegie Mellon University	NSABB Full Board Meeting (October 22, 2014), National Academies Workshop (December 15, 2014)
Robert Fisher, Ph.D.	U.S. Department of Health and Human Services/Food and Drug Administration	National Academies Workshop (March 10-11, 2016)
Ron Fouchier, Ph.D.	Erasmus Medical Center	National Academies Workshop (December 15, 2014), NSABB Full Board Meeting (January 7-8, 2016)
David Franz, D.V.M., Ph.D.	Former Commander, United States Army Medical Research Institute for Infectious Diseases	In-person WG Meeting (July 23, 2015)
Christophe Fraser, Ph.D.	Imperial College	National Academies Workshop (December 15, 2014)
Richard Frothingham	Duke University	National Academies Workshop (March 10-11, 2016)
Keiji Fukuda, M.D., M.P.H.	World Health Organization	National Academies Workshop (March 10-11, 2016)
George F. Gao, D.V.M., D.Phil.	Chinese Academy of Sciences; Chinese Center for Disease Control and Prevention	National Academies Workshop (March 10-11, 2016)
Gigi Kwik Gronvall, Ph.D.	University of Pittsburgh Medical Center Center for Health Security	National Academies Workshop (December 15, 2014), NSABB Full Board Meeting (January 7-8, 2016)
Charles Haas, Ph.D.	Drexel University	National Academies Workshop (December 15, 2014)
Andrew M. Hebbeler, Ph.D.	U.S. Department of State	NSABB Full Board Meeting (October 22, 2014), National Academies Workshop (December 15, 2014)
Ruthanne Huisling, Ph.D., M.Sc.	McGill University	National Academies Workshop (March 10-11, 2016)
Gavin Huntley-Fenner, Ph.D.	Huntley-Fenner Advisors	National Academies Workshops (December 15, 2014 and March 10-11, 2016)
Jo Husbands, Ph.D.	Board on Life Sciences of the U.S. National Academy of Sciences	In-person WG Meeting (July 23, 2015), NSABB Full Board Meeting (January 7-8, 2016)
Michael Imperiale, Ph.D.	University of Michigan	National Academies Workshop (December 15, 2014), NSABB Full Board Meeting (January 7-8, 2016)
Thomas Inglesby, M.D.	University of Pittsburgh	NSABB Full Board Meeting (October 22, 2014 and January 7-8, 2016)
Barbara Jasny, Ph.D.	Science	In-person WG Meeting (July 23, 2015), NSABB Full Board Meeting (January 7-8, 2016)
Daniel Jernigan, M.D., M.P.H.	U.S. Department of Health and Human Services/Centers for Disease Control and Prevention	NSABB Full Board Meeting (January 7-8, 2016)
Barbara Johnson, Ph.D., R.B.P.	Biosafety Biosecurity International	National Academies Workshop (December 15, 2014)

****DELIBERATIVE DRAFT****

John Kadwany, Ph.D.	Independent consultant on decision science	Full Board Meeting (January 7-8, 2016)
Joseph Kanabrocki, Ph.D., C.B.S.P.	University of Chicago	In-person WG Meeting (January 22, 2015), In-person WG Meeting (July 23, 2015)
Isidoros Karatzas, Ph.D.	European Commission	WG Meeting (February 16, 2016)
Yoshihiro Kawaoka, D.V.M., Ph.D.	University of Wisconsin, Madison	NSABB Full Board Meetings (October 22, 2014 and January 7-8, 2016), National Academies Workshop (December 15, 2014)
George Kemble, Ph.D.	3-V Biosciences	National Academies Workshop (December 15, 2014)
Lawrence Kerr, Ph.D.	U.S. National Security Council Staff	WG Meeting (November 5, 2015), National Academies Workshop (March 10-11, 2016)
Gregory Koblentz, Ph.D., M.P.P.	George Mason University	National Academies Workshop (December 15, 2014)
Todd Kuiken, Ph.D.	The Wilson Center	In-person Meeting (July 23, 2015)
Robert Lamb, Ph.D., Sc.D.	Northwestern University; Howard Hughes Medical Institute	National Academies Workshop (December 15, 2014)
Linda Lambert, Ph.D.	U.S. Department of Health and Human Services/National Institutes of Health	In-person WG Meeting (July 23, 2015)
Gabriel Leung, M.D., M.P.H.	University of Hong Kong	National Academies Workshop (March 10-11, 2016)
Carol Linden, Ph.D.	U.S. Department of Health and Human Services/Biomedical Advanced Research and Development Authority	National Academies Workshop (December 15, 2014)
W. Ian Lipkin, M.D.	Columbia University	NSABB Full Board Meeting (October 22, 2014)
Marc Lipsitch, Ph.D.	Harvard School of Public Health	NSABB Full Board Meetings (October 22, 2014 and January 7-8, 2016), National Academies Workshop (December 15, 2014)
Patricia Long, J.D., LL.M.	U.S. Department of Health and Human Services/Office of Security and Strategic Information	In-person WG Meeting (July 24, 2015)
Nicole Lurie, M.D., M.S.P.H.	U.S. Department of Health and Human Services/Assistant Secretary for Preparedness and Response	NSABB Full Board Meeting (October 22, 2014); In-person WG Meeting (July 23, 2015)
Eric Meslin, Ph.D.	Indiana University School of Medicine	NSABB Full Board Meeting (September 28, 2015)
Corey Meyer, Ph.D.	Gryphon Scientific	NSABB Full Board Meeting (September 28, 2015), In-person WG Meeting (November 9, 2015)
Jonathan Moreno, Ph.D.	University of Pennsylvania	NSABB Full Board Meeting (January 7-8, 2016), National Academies Workshop (March 10-11, 2016)
Kara Morgan, Ph.D., M.S.E.S.	Battelle	National Academies Workshop (March 10-11, 2016)
Rebecca Moritz, M.S., C.B.S.P., S.M.(NRCM)	University of Wisconsin–Madison	National Academies Workshop (December 15, 2014)
Kalyani Narasimhan, Ph.D.	Nature Publishing Group	In-person WG Meeting (July 23, 2015)
Kimberly Orr, Ph.D.	U.S. Department of Commerce	In-person WG Meeting (July 23, 2015)
Michael Osterholm, Ph.D., M.P.H.	University of Minnesota	NSABB Full Board Meeting (October 22, 2015)

****DELIBERATIVE DRAFT****

Kenneth Oye, Ph.D.	Massachusetts Institute of Technology	In-person WG Meeting (July 23, 2015)
Christopher Park	U.S. Department of State	In-person WG Meeting (July 23, 2015)
Jean Patterson, Ph.D.	Texas Biomedical Research institute	In-person WG Meeting (January 22, 2015)
Daniel Perez, Ph.D.	University of Maryland	NSABB Full Board Meeting (October 22, 2014)
Janet Peterson, C.B.S.P.	University of Maryland	NSABB Full Board Meeting (October 22, 2014)
Philip Potter, Ph.D.	St. Jude Children's Research Hospital	NSABB Full Board Meeting (January 7-8, 2016), National Academies Workshop (March 10-11, 2016)
David Relman, M.D.	Stanford University	National Academies Workshop (December 15, 2014), NSABB Full Board Meeting (January 7-8, 2016)
David B. Resnik, J.D., Ph.D.	U.S. Department of Health and Human Services/National Institutes of Health	NSABB Full Board Meeting (October 22, 2014)
Colin Russell, Ph.D.	University of Cambridge	National Academies Workshop (December 15, 2014)
Monica Schoch-Spana, Ph.D.	University of Pittsburgh Medical Center (UPMC) Center for Health Security	National Academies Workshops (December 15, 2014 and March 10-11, 2016)
Stacey Schultz-Cherry, Ph.D.	St. Jude Children's Research Hospital	NSABB Full Board Meeting (October 22, 2014), National Academies Workshop (December 15, 2014)
Michael Selgelid, Ph.D.	Monash University	NSABB Full Board Meetings (September 28, 2015 and January 7-8, 2016), National Academies Workshop (March 10-11, 2016)
Ethan Settembre, Ph.D.	Seqirus	National Academies Workshop (March 10-11, 2016)
Richard Sever, Ph.D.	Cold Spring Harbor Laboratories Press; bioRxiv	In-person WG Meeting (July 23, 2015)
Michael Shaw, Ph.D.	U.S. Department of Health and Human Services/Centers for Disease Control and Prevention	In-person WG Meeting (July 23, 2015)
Bill Sheridan, M.B., B.S.	BioCryst Pharmaceuticals Inc.	NSABB Full Board Meeting (October 22, 2014)
Kanta Subbarao, M.B.B.S., M.P.H.	U.S. Department of Health and Human Services/National Institutes of Health	National Academies Workshop (December 15, 2014), NSABB Full Board Meeting (January 7-8, 2016)
Jill Taylor, Ph.D.	Wadsworth Center, NYS Department of Health	NSABB Full Board Meeting (January 7-8, 2016)
Robert Temple, M.D.	U.S. Department of Health and Human Services/Food and Drug Administration	In-person WG Meeting (July 23, 2015)
Volker ter Meulen, M.D., Ph.D.	European Academies Science Advisory Council	National Academies Workshop (March 10-11, 2016)
Eileen Thacker, D.V.M., Ph.D., D.A.C.V.M.	Department of Agriculture	In-person WG Meeting (July 23, 2015)
Silja Vöneky, Prof., Dr., jur.	University of Freiburg; German Ethics Council	National Academies Workshop (March 10-11, 2016)
Robert Webster, Ph.D.	St. Jude Children's Research Hospital	National Academies Workshop (December 15, 2014)
Jerry Weir, Ph.D.	U.S. Department of Health and Human Services/Food and Drug Administration	National Academies Workshop (December 15, 2014)
Robbin Weyant, Ph.D., R.B.P. (ABSA)	U.S. Department of Health and Human Services/Centers for Disease Control and Prevention	National Academies Workshop (December 15, 2014), In-person WG Meeting (July 23, 2015)

Beth Willis	Co-founder, Frederick Citizens for Bio-lab Safety	NSABB Full Board Meeting (January 7-8, 2016)
Carrie Wolinetz, Ph.D.	U.S. Department of Health and Human Services/National Institutes of Health	NSABB Full Board Meetings (May 5, 2015 and January 7-8, 2016)

1999

2000 **Table 1B. Public Commenters.** Individuals and organizations that provided written or oral public comments to the NSABB via email and/or at
2001 NSABB meetings.

Commenter	Affiliation/Location (if provided)
Regine Aalders, M.Sc.	Embassy of the Netherlands, Washington, D.C.
Richard S. Adams	
Ralph Baric, Ph.D.	University of North Carolina at Chapel Hill
RADM Kenneth W. Bernard, M.D.	U.S. Public Health Service (ret.)
Rolan O. Clark	
Derrin Culp	White Plains, New York
Annie De Groot M.D.	EpiVax Inc.
Mark Denison, M.D.	Vanderbilt University
Nicholas Evans, Ph.D.	University of Pennsylvania
David S. Fedson, M.D.	Sergy Haut, France
Ron Fouchier, Ph.D.	Erasmus Medical Center
Gregory Frank, Ph.D.	Infectious Diseases Society of America
Matthew Frieman, Ph.D.	University of Maryland
Deborah Gold, M.P.H., C.I.H.	Pacifica, California
Peter Hale	Foundation for Vaccine Research
Elizabeth Hart	Adelaide, South Australia
Denise Hein	
Thomas Inglesby, M.D.	University of Pittsburgh
Laura H. Kahn, M.D., M.P.H., M.P.P.	Woodrow Wilson School of Public and International Affairs, Princeton University
Andy Kilianski, Ph.D.	National Research Council Fellow at US Army
Lynn C. Klotz, Ph.D.	Center for Arms Control and Non-proliferation
Bill Kojola	Silver Spring, Maryland
F. Gerard Lelieveld	The Hague, Netherlands

Marc Lipsitch, Ph.D.	Harvard School of Public Health
Kim R. Loll	Frederick County & City Containment Laboratories Community Advisory Committee
Carlos S. Moreno, Ph.D.	Emory University School of Medicine
Kara Morgan, Ph.D.	Battelle
Peter Murakami	Baltimore, Maryland
Daniel O'Connell	Albany, Oregon
Megan Palmer, Ph.D.	Center for International Security and Cooperation, Stanford University
Dustin Phillips	Louisville, Kentucky
Stanley Plotkin, M.D.	University of Pennsylvania
George Rudy	Frederick County & City Containment Laboratory Community Advisory Committee
Steven L. Salzberg, Ph.D.	Johns Hopkins University School of Medicine
Shannon Scott	
Billie Sellers	
Nariyoshi Shinomiya, M.D., Ph.D.	National Defense Medical College, Japan
Lone Simonsen, Ph.D.	George Washington University
Andrew Snyder-Beattie	Future of Humanity Institute, University of Oxford
Charles R. Stack, M.P.H.	University of Illinois at Chicago
Kanta Subbarao, M.B.B.S., M.P.H.	National Institutes of Health
John Steel, Ph.D.	Emory University
Kimball Ward	
Simon Warne Ph.D.	UK Scientific Advisory Committee on Genetic Modification
Gary Whittaker, Ph.D.	Cornell University
Beth Willis	Frederick Citizens for Bio-lab Safety
David Wolinsky	Fredrick, Maryland
American Association of Immunologists	American Association of Immunologists (AAI)
Infectious Diseases Society of America	Infectious Diseases Society of America (IDSA)

2003 **References and Sources of Information**

2004 Resources consulted include but are not limited to the following:

- 2005 Baek, Y.H., et al. (2015), Profiling and Characterization of Influenza Virus N1 Strains Potentially Resistant to Multiple
2006 Neuraminidase Inhibitors. *J Virol.* 89(1):287-299
- 2007 Boddie, C., et al. (2015), Assessing the bioweapons threat. *Science* 349(6250):792-793
- 2008 Cambridge Working Group statement (July 2014). <http://www.cambridgeworkinggroup.org/documents/statement.pdf>
- 2009 Casadevall, A., and Imperiale, M.J. (2014), Risks and benefits of gain-of-function experiments with pathogens of pandemic
2010 potential, such as influenza virus: A call for a science-based discussion. *mBio* 5(4):e01730-14
- 2011 Casadevall, A., et al. (2014), An epistemological perspective on the value of gain-of-function experiments involving pathogens
2012 with pandemic potential. *mBio* 5(5): e01875-14
- 2013 Doshi, P. (2008), Trends in Recorded Influenza Mortality - United States 1900–2004. *Am J Public Health* 98(5):939–945
- 2014 Duprex, P., and Casadevall, A. (2014), Falling down the Rabbit Hole: aTRIP Toward Lexiconic Precision in the “Gain-of-Function”
2015 Debate. *mBio* 5(6):e02421-14
- 2016 Environmental Protection Agency Science Policy Council (2000), Risk Characterization - EPA Science Policy Council Handbook.
2017 https://www.epa.gov/sites/production/files/2015-10/documents/osp_risk_characterization_handbook_2000.pdf
- 2018 European Academies Science Advisory Council (2015), Gain of function: experimental applications relating to potentially
2019 pandemic pathogens.
2020 http://www.easac.eu/fileadmin/PDF_s/reports_statements/Gain_of_Function/EASAC_GOF_Web_complete_centred.pdf
- 2021 European Center for Disease Prevention and Control (2012), Risk Assessment: Laboratory-created A(H5N1) viruses transmissible
2022 between ferrets. [http://ecdc.europa.eu/en/publications/Publications/TER-RA-120229-Laboratory-created-A-H5N1-viruses-](http://ecdc.europa.eu/en/publications/Publications/TER-RA-120229-Laboratory-created-A-H5N1-viruses-transmissible-between-ferrets.pdf)
2023 [transmissible-between-ferrets.pdf](http://ecdc.europa.eu/en/publications/Publications/TER-RA-120229-Laboratory-created-A-H5N1-viruses-transmissible-between-ferrets.pdf)
- 2024 European Commission Guidance — How to complete your ethics self-assessment (October 2015).
2025 http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/ethics/h2020_hi_ethics-self-assess_en.pdf
- 2026 European Commission Guidance note — Research involving dual-use items.
2027 http://ec.europa.eu/research/participants/data/ref/h2020/other/hi/guide_research-dual-use_en.pdf
- 2028 European Commission Guidance note — Research with an exclusive focus on civil applications.
2029 http://ec.europa.eu/research/participants/data/ref/h2020/other/hi/guide_research-civil-apps_en.pdf
- 2030 European Commission Guidance note — Potential misuse of research.
2031 http://ec.europa.eu/research/participants/data/ref/h2020/other/hi/guide_research-misuse_en.pdf
- 2032 Evans, N.G. (2013), Great expectations - Ethics, avian flu and the value of progress. *J Med Ethics* 39(4):209-213
- 2033 Evans, N.G., et al. (2015), The ethics of biosafety considerations in gain-of-function research resulting in the creation of
2034 potential pandemic pathogens. *J Med Ethics* 41(11):901-908
- 2035 Fedson, D.S., and Opal, S.M. (2013), The controversy over H5N1 transmissibility research. *Hum Vaccin Immunother.* 9(5):977-
2036 986
- 2037 Fedson, D.S. (2013), How Will Physicians Respond to the Next Influenza Pandemic? *Clin Infect Dis.* 58(2):233-7

- 2038 Fouchier, R., et al. (2012), Preventing Pandemics - The fight over flu. *Nature* 481(7381):257-9
- 2039 German Ethics Council (2014), Biosecurity — Freedom and Responsibility of Research. <http://www.ethikrat.org/files/opinion-biosecurity.pdf>
- 2040
- 2041 Gronvall, G. (2013), H5N1: A case study for dual-use research. <http://www.cfr.org/public-health-threats-and-pandemics/h5n1-case-study-dual-use-research/p30711>
- 2042
- 2043 Gronvall, G., and Rozo, M. (2015), A Synopsis of Biological Safety and Security Arrangements.
- 2044 http://www.upmchealthsecurity.org/our-work/pubs_archive/pubs-pdfs/2015/Synopsis%20of%20Biological%20Safety%20and%20Security%20Arrangements%20UPMC%20072115.pdf
- 2045
- 2046 Guthrie, S., et al. (2013), Measuring Research - A guide to research evaluation frameworks and tools.
- 2047 <http://www.rand.org/pubs/monographs/MG1217.html>
- 2048 Herfst, S., et al. (2012), Airborne transmission of influenza A/H5N1 virus between ferrets. *Science* 336(6088):1534-1541
- 2049 Imai, M., et al. (2012), Experimental adaptation of an influenza H5 HA confers respiratory droplet transmission to reassortant H5 HA/H1N1 virus in ferrets. *Nature* 486(7403):420-430
- 2050
- 2051 Imperiale, M.J., and Casadevall, A. (2014), Vagueness and Costs of the Pause on Gain-of-Function (GOF) Experiments on Pathogens with Pandemic Potential, Including Influenza Virus. *mBio* 5(6):e02292-14
- 2052
- 2053 Imperiale, M.J., and Casadevall, A. (2015), A New Synthesis for Dual Use Research of Concern. *PLoS Med* 12(4):e1001813
- 2054 Inglesby, T.V., and Relman, D.A. (2015), How likely is it that biological agents will be used deliberately to cause widespread harm? *EMBO Rep.* 17(2):127-30
- 2055
- 2056 Jaffe, H., et al. (2013), Extra oversight for H7N9 experiments. *Science* 341(6147):713-714
- 2057 Kilianski, A., et al. (2015), Gain-of-Function Research and the Relevance to Clinical Practice. *J Infect Dis.* 213(9):1364-9
- 2058 Kilianski, A., and Murch, R.S. (2015), When gain-of-function research is not “gain-of-function” research. *EMBO Rep.* 16(12):1586-7
- 2059
- 2060 Linster, M., et al. (2014), Identification, characterization, and natural selection of mutations driving airborne transmission of A/H5N1 virus. *Cell* 157(2):329-339
- 2061
- 2062 Lipsitch, M., and Bloom, B.R. (2012), Rethinking Biosafety in research on potential pandemic pathogens. *mBio* 3(5):e00360-12
- 2063 Lipsitch, M., and Galvani, A. (2014), Ethical alternatives to experiments with novel potential pandemic pathogens. *PLoS Med* 11(5):e1001646
- 2064
- 2065 Lipsitch, M., and Inglesby, T.V. (2014), Moratorium on research intended to create novel potential pandemic pathogens. *mBio* 5(6):e02366-14
- 2066
- 2067 Lipsitch, M., and Relman, D.A. (2015), New Game, New Rules - Limiting the Risks of Biological Engineering.
- 2068 <https://www.foreignaffairs.com/articles/2015-08-31/new-game-new-rules>
- 2069 Lipsitch, M., et al. (2016), Six policy options for conducting gain-of-function research. <http://www.cidrap.umn.edu/news-perspective/2016/03/commentary-six-policy-options-conducting-gain-function-research>
- 2070
- 2071 Maines, T.R., et al. (2011), Effect of receptor binding domain mutations on receptor binding and transmissibility of avian influenza H5N1 viruses. *Virology* 413(1):139-147
- 2072

- 2073 Miller, M., and Palese, P. (2014), Peering into the crystal ball: Influenza pandemics and vaccine efficacy. *Cell* 157(2): 294-299
- 2074 National Research Council/Institute of Medicine (2015), Potential Risks and Benefits of GOF Research – NRC/IOM Workshop
2075 Summary (Full Report). <http://dels.nas.edu/Workshop-Summary/Potential-Risks-Benefits-Gain/21666?bname=bls>
- 2076 Nature Editorial (2014), A ripe time for gaining ground. *Nature* 514(7523):403
- 2077 NIH Blue Ribbon Panel (2008), Blue Ribbon Panel Scientific Subcommittee Teleconference slide presentation (May 2008).
2078 http://www.nihbrp.com/AR/completed/BRPScientificSubcommittee/FINAL_Brief_BRP_Scientific_Subcommittee_May_2008.pdf
- 2079 Osterholm, M., and Relman, D. (2012), Creating mammalian-transmissible A/H5N1 influenza virus: Social contracts, prudence,
2080 and alternative perspectives. *J Infect Dis.* 205(11):1636-1638
- 2081 Palmer, M.J., et al. (2015), A more systematic approach to biological risk. *Science* 350(6267):1471-3
- 2082 Pascua, P.N., et al. (2012), Virulence and transmissibility of H1N2 influenza virus in ferrets imply the continuing threat of triple-
2083 reassortant swine viruses. *Proc Natl Acad Sci USA* 109(39):15900-15905
- 2084 Patterson, A., et al. (2013), A framework for decisions about research with HPAI H5N1 viruses. *Science* 339(6123):1036-1037
- 2085 Patterson, A., et al. (2014), Biocontainment laboratory risk assessment: perspectives and considerations. *Pathog Dis.* 71(2):102-
2086 108
- 2087 Peng, X., et al. (2016), Amino acid substitutions occurring during adaptation of an emergent H5N6 avian influenza virus to
2088 mammals. *Arch Virol.* 2016 Mar 21. [Epub ahead of print] DOI 10.1007/s00705-016-2826-7
- 2089 Presidential Commission for the Study of Bioethical Issues (2010), *New Directions: The Ethics of Synthetic Biology and Emerging*
2090 *Technologies.* http://bioethics.gov/sites/default/files/PCSBI-Synthetic-Biology-Report-12.16.10_0.pdf
- 2091 Richard, M. et al. (2013), Limited airborne transmission of H7N9 influenza A virus between ferrets. *Nature* 501(7468): 560-563
- 2092 Roberts, A., et al. (2007), A Mouse-Adapted SARS-Coronavirus Causes Disease and Mortality in BALB/c Mice. *PLoS Pathog.*
2093 3(1):e5
- 2094 Rozell, D.J. (2015), Assessing and Managing the Risks of Potential Pandemic Pathogen Research. *mBio* 6(4):e01075-15
- 2095 Rozo, M., and Gronvall, G. (2015), The Reemergent 1977 H1N1 Strain and the Gain-of-Function Debate. *mBio* 6(4):e01013-15
- 2096 Russell, C., et al. (2012), The potential for respiratory droplet-transmissible A/H5N1 influenza virus to evolve in a mammalian
2097 host. *Science* 336(6088):1541-1547
- 2098 Russell, C., et al. (2014), Improving pandemic influenza risk assessment. *eLife* 3:e03883
- 2099 Schultz-Cherry, S., et al. (2014), Influenza Gain-of-Function Experiments: Their Role in Vaccine Virus Recommendation and
2100 Pandemic Preparedness. *mBio* 5(6):e02430-14
- 2101 Scientific Management Review Board Report (2014), Approaches to Assess the Value of NIH-Supported Research.
2102 http://smrb.od.nih.gov/documents/reports/VOBR%20SMRB__Report_2014.pdf
- 2103 Scientists for Science statement (July 2014). <http://www.scientistsforscience.org>
- 2104 Stern, P.C., and Fineberg, H.V. (1996), *Understanding Risk - Informing Decisions in a Democratic Society.*
2105 <http://www.nap.edu/catalog/5138/understanding-risk-informing-decisions-in-a-democratic-society>

****DELIBERATIVE DRAFT****

- 2106 Sullivan, M., et al. (2013), Influenza Pandemic Risk - The Contribution of Laboratory Pathogens to Excess Mortality Risk (RMS
2107 White Paper). [http://static.rms.com/email/documents/liferisks/papers/rms-liferisks-whitepaper-influenza-pandemic-risk-jan-
2108 2013.pdf](http://static.rms.com/email/documents/liferisks/papers/rms-liferisks-whitepaper-influenza-pandemic-risk-jan-2013.pdf)
- 2109 Sutton, T., et al. (2014), Airborne transmission of highly pathogenic H7N1 influenza virus in ferrets. *J Virol.* 88(12):6623-6635
- 2110 Taubenberger, J., et al. (2012), Reconstruction on the 1918 influenza virus: Unexpected rewards from the past. *mBio*
2111 3(5):e00201-12
- 2112 Tharakaraman, K., et al. (2014), Structural determinants for naturally evolving H5N1 hemagglutinin to switch its receptor
2113 specificity. *Cell* 153(7):1475-1485
- 2114 Trevan, T. (2015), Biological Research: Rethink Biosafety. *Nature* 527(7577):155-158
- 2115 Trock, S., et al. (2015), Development of Framework for Assessing Influenza Virus Pandemic Risk. *Emerg Infect Dis.* 21(8):1372-
2116 1378
- 2117 USG (June 2013), Biological Safety Guidance for Research with Risk Group 3 Influenza Viruses - Human H2N2, 1918 H1N1, and
2118 HPAI H5N1 http://osp.od.nih.gov/sites/default/files/NIH_Guidelines.html#_Toc446948454
- 2119 USG (December 2009), Biosafety in Microbiological and Biomedical Laboratories BMBL (5th Edition).
2120 <http://www.cdc.gov/biosafety/publications/bmb15/>
- 2121 USG (September 2014), Companion Guide to the USG Policies for Oversight of Life Sciences Dual Use Research of Concern.
2122 <http://www.phe.gov/s3/dualuse/Documents/durc-companion-guide.pdf>
- 2123 USG (February 2005), Environmental Impact Statement For the Galveston National Laboratory for Biodefense and Emerging
2124 Infectious Diseases
- 2125 USG (July 2015), Federal Select Agents and Toxins List. <http://www.selectagents.gov/SelectAgentsandToxinsList.html>
- 2126 USG (July 2012), Final Supplementary Risk Assessment for the Boston University National Emerging Infectious Diseases
2127 Laboratories (NEIDL). <http://www.bu.edu/neidl/files/2013/01/SFEIR-Volume-III.pdf>
- 2128 USG (February 2016), France-US Bilateral Workshop on Dual Use Research Issues: Summary Report
- 2129 USG (August 2013), A Framework for Guiding U.S. Department of Health and Human Services Funding Decisions about Research
2130 Proposals with the Potential for Generating Highly Pathogenic Avian Influenza H5N1 Viruses that are Transmissible among
2131 Mammals by Respiratory Droplets. <http://www.phe.gov/s3/dualuse/Documents/funding-hpai-h5n1.pdf>
- 2132 USG (February 2013), NIH Guidelines for Research Involving Recombinant DNA Molecules - Amendment Notice. February 21,
2133 2013. http://osp.od.nih.gov/sites/default/files/resources/FR%202_21_2013_78_FR_12074.pdf
- 2134 USG (April 2016), NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules.
2135 http://osp.od.nih.gov/sites/default/files/NIH_Guidelines.html
- 2136 USG (October 2014), USG Gain-of-function GOF Deliberative Process and Funding Pause Statement.
2137 <http://www.phe.gov/s3/dualuse/documents/gain-of-function.pdf>
- 2138 USG (September 2014), USG Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.
2139 <http://www.phe.gov/s3/dualuse/documents/durc-policy.pdf>
- 2140 USG (March 2012), USG Policy for Oversight of Life Sciences Dual Use Research of Concern.
2141 <http://www.phe.gov/s3/dualuse/Documents/us-policy-durc-032812.pdf>

- 2142 United Nations (April 1972), Biological Weapons Convention.
2143 http://www.un.org/disarmament/WMD/Bio/pdf/Text_of_the_Convention.pdf
- 2144 Volkswagen Foundation and Max Plank Society (2014), Dual Use Research on Microbes - Biosafety, Biosecurity, Responsibility -
2145 Hanover Symposium Summary Report. <https://www.volkswagenstiftung.de/dualuseresearch.html>
- 2146 Watanabe, T., et al. (2014), Circulating Avian Influenza Viruses closely related to the 1918 virus have pandemic potential. *Cell*
2147 *Host Microbe* 15(6):692-705
- 2148 Zhang, Y., et al. (2013), H5N1 hybrid viruses bearing 2009/H1N1 virus genes transmit in guinea pigs by respiratory droplet.
2149 *Science* 340(6139):1459-1463
- 2150
- 2151

DRAFT

Appendix F. National Science Advisory Board for Biosecurity Roster

[†] NSABB Working Group Co-chair

[‡] NSABB Working Group on Evaluating the Risks and Benefits of Gain-of-Function Studies

NSABB Voting Members

Samuel L. Stanley, Jr., M.D. (Chair)

President, Stony Brook University
Office of the President
Stony Brook University

Kenneth I. Berns, M.D., Ph.D. ^{†‡}

Distinguished Professor
Dept. of Molecular Genetics & Microbiology
Genetics Institute
College of Medicine
University of Florida

Craig E. Cameron, Ph.D. [‡]

Eberly Chair in Biochemistry and Molecular
Biology
The Pennsylvania State University

Andrew (Drew) Endy, Ph.D. [‡]

Assistant Professor
Stanford Bioengineering
Stanford University

J. Patrick Fitch, Ph.D.

Laboratory Director
National Biodefense Analysis &
Countermeasures Center
President, Battelle National Biodefense
Institute, LLC

Christine M. Grant, J.D. [‡]

CEO/Founder
InfecDetect Rapid Diagnostic Tests, LLC

Marie-Louise Hammarskjöld, M.D., Ph.D. [‡]

Charles H. Ross Jr. Professor and
Professor of Microbiology, Immunology and
Cancer Biology,
Associate Director of the Myles H. Thaler Center
University of Virginia School of Medicine

Clifford W. Houston, Ph.D. [‡]

Associate Vice President for Educational
Outreach
Herman Barnett Distinguished Professorship in
Microbiology and Immunology
School of Medicine
University of Texas Medical Branch

Joseph Kanabrocki, Ph.D., NRCM(SM) ^{†‡}

Associate Vice President for Research Safety
Professor of Microbiology
University of Chicago

Theresa M. Koehler, Ph.D. [‡]

Chair, Department of Microbiology
and Molecular Genetics
Herbert L. and Margaret W. DuPont
Distinguished Professor in Biomedical Science
University of Texas Medical School at Houston

Marcelle C. Layton, M.D. [‡]

Assistant Commissioner
Bureau of Communicable Disease
New York City Dept. of Health
and Mental Hygiene

Jan Leach, Ph.D.

University Distinguished Professor
Bioagricultural Sciences and Pest Management
Plant Sciences
Colorado State University

James W. LeDuc, Ph.D. [‡]

Director, Galveston National Laboratory and
Professor, Department of Microbiology
and Immunology
University of Texas Medical Branch

Margie D. Lee, D.V.M., Ph.D.†

Professor of Population Health
Poultry Diagnostic and Research Center
College of Veterinary Medicine
The University of Georgia

Francis L. Macrina, Ph.D.†

Vice President for Research and Innovation
Virginia Commonwealth University

Joseph E. McDade, Ph.D.†

Deputy Director (Retired)
National Center for Infectious Diseases
Centers for Disease Control and Prevention

Jeffery F. Miller, Ph.D.

Fred Kavli Chair in NanoSystems Sciences
Director, California NanoSystems Institute
Professor, Department of Microbiology,
Immunology and Molecular Genetics University
of California, Los Angeles

Stephen S. Morse, Ph.D.†

Director, Infectious Disease Epidemiology
Certificate Program
Professor of Epidemiology
Mailman School of Public Health
Columbia University

Jean L. Patterson, Ph.D.†

Chair, Department of Virology
and Immunology
Texas Biomedical Research Institute

I. Gary Resnick, Ph.D.†

President, IGR Consulting
Guest Scientist
Global Security Directorate
Los Alamos National Laboratory

Susan M. Wolf, J.D.†

McKnight Presidential Professor of Law,
Medicine & Public Policy
Faegre Baker Daniels Professor of Law
Professor of Medicine
University of Minnesota

David L. Woodland, Ph.D.†

Chief Scientific Officer
Keystone Symposia on Molecular
and Cellular Biology

Non-Voting Ex Officio Members

Jason E. Boehm, Ph.D.

Director, Program Coordination Office
Office of Program Analysis and Evaluation
National Institute of Standards and Technology

Brenda A. Cuccherini, Ph.D., M.P.H.

Special Assistant to Chief Research &
Development Officer
Veteran's Health Administration
Department of Veteran's Affairs

Amanda Dion-Schultz, Ph.D.

Office of the Chief Scientist

Gerald L. Epstein, Ph.D.†

Assistant Director for Biosecurity and Emerging
Technologies
National Security and International Affairs
Division
Office of Science and Technology Policy

Anthony S. Fauci, M.D.

Director of National Institute of Allergy
and Infectious Disease
National Institutes of Health

Wendy Hall, Ph.D.[‡]

Special Senior Advisor for Biological Threats
Office of Chemical, Biological, and Nuclear
Policy
Department of Homeland Security

David Christian Hassell, Ph.D.

Deputy Assistant Secretary of Defense
for Chemical and Biological Defense
Department of Defense

Steven Kappes, Ph.D.

Animal Production and Protection
General Biological Science
Animal Production and Protection
Department of Agriculture

Anne E. Kinsinger

Associate Director for Biology
U.S. Geological Survey
Biological Resources Discipline
Department of the Interior

David R. Liskowsky, Ph.D.

Director, Medical Policy & Ethics
Office of the Chief Health and Medical Officer
National Aeronautics and Space Administration

CAPT Carmen Maher

Deputy Director
Office of Counterterrorism and
Emerging Threats (OCET)
Office of the Commissioner
Food and Drug Administration

Robert M. Miceli, Ph.D.[‡]

Biological Issue Manager and Advisor to the
Director
Office of the Director of National Intelligence
National Counterproliferation Center

Christopher Park[‡]

Director, Biological Policy Staff
Bureau of International Security
and Nonproliferation
Department of State

Sally Phillips, R.N., Ph.D.

Deputy Assistant Secretary
Office of Policy and Planning
Office of the Assistant Secretary for
Preparedness and Response
Department of Health and Human Services

Gregory Sayles, Ph.D.

Acting Director
National Homeland Security Research Center
Environmental Protection Agency

Michael W. Shaw, Ph.D.

Senior Advisor for Laboratory Science
Office of Infectious Diseases
Centers for Disease Control and Prevention

Sharlene Weatherwax, Ph.D.

Associate Director of Science
for Biological and Environmental Research
Department of Energy

Edward H. You

Supervisory Special Agent
Biological Countermeasures Unit
FBI Weapons of Mass Destruction Directorate
Federal Bureau of Investigation

Additional Non-Voting Federal Representatives

Robert T. Anderson, Ph.D.[‡]

Director, Biological Systems Science
Division, SC-23.2
Office of Biological and Environmental Research
Department of Energy

Diane DiEuliis, Ph.D.[‡]

Senior Research Fellow
National Defense University
Department of Defense

Dennis M. Dixon, Ph.D.†

Branch Chief, Bacteriology and Mycology
National Institutes of Allergy and Infectious
Diseases
National Institutes of Health

Meg Flanagan, Ph.D.†

Microbiologist, Biological Policy Staff
Bureau of International Security and
Nonproliferation
Department of State

Denise Gangadharan, Ph.D.†

Associate Director for Science
Division of Select Agents and Toxins
Office of Public Health Preparedness and
Response
Centers for Disease Control and Prevention

Teresa Hauguel, Ph.D.†

Program Officer
National Institutes of Allergy and Infectious
Diseases

Richard Jaffe, Ph.D., M.T. (ASCP)†

Director of the Division of Medical
Countermeasures Strategy and Requirements
Office of the Assistant Secretary for
Preparedness and Response
Department of Health and Human Services

Betty Lee, Ph.D.†

Bureau of Industry and Security
Department of Commerce

Kimberly Orr, D.V.M, Ph.D.†

Bureau of Industry and Security
Department of Commerce

Diane Post, Ph.D.†

Program Officer
Influenza Project Officer
Respiratory Diseases Branch
National Institutes of Allergy and Infectious
Diseases
National Institutes of Health

David B. Resnik, J.D., Ph.D.†

Bioethicist and IRB Chair
National Institute for Environmental Health
Sciences
National Institutes of Health

Sharlene Weatherwax, Ph.D.†

Associate Director of Science
For Biological and Environmental Research
Department of Energy

NSABB Staff

Christopher Viggiani, Ph.D.

Executive Director, NSABB
Office of Science Policy, Office of the Director
National Institutes of Health

Shayla Beckham

Program Specialist
Office of Science Policy, Office of the Director
National Institutes of Health

Kelly Fennington

Chief of Staff
Office of Science Policy, Office of the Director
National Institutes of Health

Rona Hirschberg, Ph.D.

Consultant
Office of Science Policy, Office of the Director
National Institutes of Health

Stuart Nightingale, M.D.

Consultant
Office of Science Policy, Office of the Director
National Institutes of Health

Marina O'Reilly, Ph.D.

Biotechnology Program Advisor
Office of Science Policy, Office of the Director
National Institutes of Health

****DELIBERATIVE DRAFT****

Kevin Ramkissoon, Ph.D.
Health Science Policy Analyst
Office of Science Policy, Office of the Director
National Institutes of Health

DRAFT



THE SECRETARY OF HEALTH AND HUMAN SERVICES
WASHINGTON, D.C. 20201

CHARTER

NATIONAL SCIENCE ADVISORY BOARD FOR BIOSECURITY

AUTHORITY

Authorized by 42 U.S.C. 217a, section 222 of the Public Health Service Act, as amended and Pub. L. 109–417, section 205 of the Pandemic and All-Hazards and Preparedness Act. The National Science Advisory Board for Biosecurity (NSABB) is governed by the provisions of the Federal Advisory Committee Act, as amended (5 U.S.C. app.), which sets forth standards for the formation and use of advisory committees.

OBJECTIVES AND SCOPE OF ACTIVITIES

The purpose of the NSABB is to provide, as requested, advice, guidance, and leadership regarding biosecurity oversight of dual use research, defined as biological research with legitimate scientific purpose that may be misused to pose a biologic threat to public health and/or national security. The NSABB will provide advice on and recommend specific strategies for the efficient and effective oversight of federally conducted or supported dual use biological research, taking into consideration both national security concerns and the needs of the research community to foster continued rapid progress in public health and agricultural research. Toward this end, the NSABB will also include providing strategies to raise awareness of dual use issues relevant to the life science and related interdisciplinary research communities.

DESCRIPTION OF DUTIES

The NSABB will be composed of subject matter experts who are not full-time employees of the Federal Government as well as ex officio members from Federal entities listed in the “Membership and Designation” section below, and will perform the following activities:

- Provide recommendations on the development of programs for outreach, education and training in dual use research issues for scientists, laboratory workers, students, and trainees in relevant disciplines.
- Advise on policies governing publication, public communication, and dissemination of dual use research methodologies and results.
- Recommend strategies for fostering international engagement on dual use biological research issues.
- Advise on the development, utilization and promotion of codes of conduct to interdisciplinary life scientists, and relevant professional groups.

- Advise on policies regarding the conduct, communication, and oversight of dual use research and research results, as requested.
- Advise on the Federal Select Agent Program, as requested.
- Address any other issues as directed by the Secretary of HHS.

AGENCY OR OFFICIAL TO WHOM THE COMMITTEE REPORTS

The NSABB will advise the Secretary of the Department of Health and Human Services (HHS), the Director of the National Institutes of Health (NIH), and the heads of all Federal entities that conduct, support or have an interest in life sciences research.

SUPPORT

Management and support services for the NSABB will be provided by the Office of Science Policy (OSP), within the Office of the Director, NIH. HHS and NIH staff will hold security clearances at the level of Secret or higher, as needed, to provide support to the NSABB.

ESTIMATED ANNUAL OPERATING COSTS AND STAFF YEARS

The estimated annual cost for operating the Committee, including compensation and travel expenses for members, but excluding staff support, is \$274,900. The estimated annual person-years of staff support required is 1.5 at an estimated cost of \$156,637.

DESIGNATED FEDERAL OFFICER

The Director, NIH, will assign a full-time or permanent part-time NIH employee to serve as the Designated Federal Officer (DFO) of the NSABB. In the event that the DFO cannot fulfill the assigned duties of the NSABB, one or more full-time or permanent part-time NIH employees will be assigned these duties on a temporary basis.

The DFO will approve or call all of the NSABB and subcommittee meetings, prepare and approve all meeting agendas, attend all Committee and subcommittee meetings, adjourn any meetings when it is determined to be in the public interest, and chair meetings when directed to do so by the Director, NIH, or the Director, OSP.

ESTIMATED NUMBER AND FREQUENCY OF MEETINGS

Meetings of the full committee will be held approximately two times within a fiscal year, and may be convened on an as-needed basis, at the call of the NSABB Executive Director or DFO. Meetings of the NSABB will be open to the public except as determined otherwise by the Secretary of Health and Human Services (Secretary), in accordance with subsection (c) of section 552b of Title 5 U.S.C. Notice of all meetings will be given to the public. In the event a portion of a meeting is closed to the public, as determined by the Secretary, in accordance with the Government in the Sunshine Act (5 U.S.C. 522b(c)) and the Federal Advisory Committee Act, a report will be prepared which will contain, as

a minimum, a list of members and their business addresses, the Committee's functions, dates and places of meetings, and a summary of the Committee's activities and recommendations made during the fiscal year. A copy of the report will be provided to the Department Committee Management Officer.

DURATION

Continuing.

TERMINATION

Unless renewed by appropriate action, the NSABB will terminate two years from the date this charter is filed.

MEMBERSHIP AND DESIGNATION

The NSABB will consist of not more than 25 voting members, including the Chair. Members will be appointed by the Secretary, HHS, in consultation with the heads of Federal departments and agencies that conduct or support life science research. The Secretary, HHS, will designate the Chair. All members will hold security clearances at the level of Secret or higher. Voting members are Special Government Employees and as such serve in their individual capacity as subject matter experts. None of these members serve as Representatives.

Areas of expertise to be represented on the NSABB, may include but are not be limited to:

- Molecular Biology/Genomics
- Microbiology (Bacteriology)
- Microbiology (Virology)
- Clinical Infectious Diseases/Diagnostics
- Laboratory Biosafety and Biosecurity
- Public Health/Epidemiology
- Health Physicist/Radiation Safety
- Pharmaceutical Production
- Veterinary Medicine
- Plant Health
- Food Production
- Bioethics
- National Security
- Military Biodefense Programs and Military Medicine
- Intelligence
- Biodefense
- Law
- Law Enforcement
- Academia

- Scientific Publishing
- Industry Perspective
- NIH Recombinant DNA Advisory Committee Experience/Perspective
- Public Perspective
- IBC perspective
- Export Controls

There may be non-voting ex officio members from each of the following Federal entities:

- Executive Office of the President
- Department of Health and Human Services
- Department of Energy
- Department of Homeland Security
- Department of Veterans Affairs
- Department of Defense
- Department of the Interior
- Environmental Protection Agency
- Department of Agriculture
- National Science Foundation
- Department of Justice
- Department of State
- Department of Commerce
- Intelligence Community
- National Aeronautics and Space Administration
- Others as appropriate

Voting members will be invited to serve for overlapping terms of up to four years; terms of more than two years are contingent upon the renewal of the NSABB's Charter by appropriate action prior to its expiration. A voting member's term may be extended until a successor has been appointed.

A quorum for the NSABB and each of its subcommittees will consist of a majority of the appointed members eligible to vote. The nonvoting agency representatives will not be counted in calculating a quorum. Of the voting members, any who are recused from participating in an action on a particular issue, (e.g., due to a conflict of interest), will not be counted in calculating the quorum. All votes relating to any review of a recommendation by the NSABB will be open to the public unless the meeting has been closed to the public in accordance with the Government in the Sunshine Act and the Federal Advisory Committee Act.

SUBCOMMITTEES

As necessary, subcommittees and ad hoc working groups may be established by the NSABB Executive Director or DFO to perform functions within the Committee's

jurisdiction. The advice/recommendations of the subcommittee/working group must be deliberated by the parent advisory committee. A subcommittee may not report directly to a Federal official unless there is statutory authority to do so.

Subcommittee membership may be drawn in whole or in part from the parent advisory committee. All subcommittee members may vote on subcommittee actions and all subcommittee members count towards the quorum for a subcommittee meeting. Ad hoc consultants do not count towards the quorum and may not vote. The Department Committee Management Officer will be notified upon establishment of each standing subcommittee and will be provided information on its name, membership, function, and estimated frequency of meetings.

RECORDKEEPING

Meetings of the Committee and its subcommittees will be conducted according to the Federal Advisory Committee Act, other applicable laws and Department policies. Committee and subcommittee records will be handled in accordance with General Records Schedule 6.2, Federal Advisory Committee Records, or other approved agency records disposition schedule. These records will be available for public inspection and copying, subject to the Freedom of Information Act, 5 U.S.C. 552.

FILING DATE

April 7, 2016

APPROVED

MAR 15 2016

Date


Sylvia M. Burwell