



## Supplementary Materials for **Assessing the bioweapons threat**

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### **This PDF file includes**

Materials and Methods  
Fig. S1  
Table S1

## Materials and Methods

We used a Delphi Method study to elicit, combine and analyze the collective judgments of multiple experts. Focused on obtaining collective expert opinion, but avoiding “groupthink”, the Delphi Method’s salient features are preserving the anonymity of participant inputs, iterated response and feedback, and statistical aggregation of expert judgments. Individuals were invited to participate in this study if they held responsibility for shaping public policy at the nexus of life science and national security, based on their expertise and knowledge in the field, or based on recommendations of other participants (using a snowball sampling methodology). Participant affiliations included USG, former USG, academia, NGO, and private sector/industry organizations. Participant training and background included biological and non-biological science, medicine, public health, national security, political science, foreign policy and international affairs, economics, history, and law. Of the 63 experts originally approached to participate in the study, 62 completed the first round of the survey, and 59 completed the second round.

Participants were asked to anonymously respond to questions about the biological threat, review each other’s answers, and either amend or maintain their answers after reflecting on others’ opinions. Participants were asked to supply rationales for their responses. The process was terminated when, for successive rounds, the mean response did not change more than 1 standard deviation across all questions, which occurred after two rounds. The final results of the study were analyzed with STATA statistical package 11.2. Wilcoxon-Mann-Whitney nonparametric tests were conducted to evaluate the difference in distributions of responses between groups of participants and between question sub-parts (significance level  $p \leq 0.05$ ).

## List of Delphi study participants

Individuals were invited to participate in the study if they held responsibility for shaping public policy at the nexus of life science and national security, based on their expertise and knowledge in the field, or based on recommendations of other participants (using a snowball sampling methodology). Participant affiliations included USG, former USG, academia, NGO, and private sector/industry organizations. Participant training and background included biological and non-biological science, medicine, public health, national security, political science, foreign policy and international affairs, economics, history, and law. Participants’ affiliations are current as of the time of Delphi study administration. Listing an individual’s employer does not imply institutional endorsement of our conclusions.

Bruce Altevogt, Institute of Medicine  
Scott Becker and Chris Mangal (completed together), Association of Public Health Laboratories  
Kenneth Bernard, Former White House National Security & Biodefense Advisor  
David Blazes, US Department of Defense  
Patrick Boyle, Ginkgo BioWorks  
Roger Breeze, Centaur Science Group  
Rob Carlson, Biodesic, LLC  
Hillary Carter, US Department of State  
Seth Carus, National Defense University  
Rocco Casagrande, Gryphon Scientific  
Susan Collier-Monarez, National Security Council, Executive Office of the President  
Andrew Ellington, The University of Texas at Austin  
Julie Fischer, The George Washington University  
Pat Fitch, Battelle National Biodefense Institute, LLC  
Robert Friedman, J. Craig Venter Institute  
Daniel Gerstein, RAND  
John Glass, J. Craig Venter Institute  
John Grabenstein, Merck & Co.  
Lauren Grosso, University of Maryland  
Richard Hatchett, US Department of Health and Human Services  
Donald A. Henderson, UPMC Center for Health Security  
India Hook-Barnard, The National Academies of Science  
Kendall Hoyt, Dartmouth College  
Emily A. Iarocci, University of Maryland  
Michael Imperiale, University of Michigan Medical School  
Tom Inglesby, UPMC Center for Health Security  
Barbara Johnson, Biosafety and Biosecurity International  
Robert Kadlec, East West Protection, LLC  
Laura Kelley, Harvard Business School  
Gregory Koblenz, George Mason University  
George Korch, US Department of Health and Human Services  
Jens H. Kuhn, National Institute of Allergy & Infectious Diseases  
Todd Kuiken, The Woodrow Wilson International Center for Scholars  
Randall Larsen, UPMC Center for Health Security  
Carol Linden, Food and Drug Administration  
Tracey McNamara, Western University of Health Sciences  
Michael Montague, Washington University

Christina Murata, Department of Homeland Security  
Stuart Olmsted, RAND  
Michael Osterholm, University of Minnesota  
Rich Ozanich, Battelle, Pacific Northwest National Laboratories  
Christopher Park, US Department of State  
Amy Patterson, National Institutes of Health  
Alan Pearson, US Department of Agriculture  
Erik Prentice, Proactive Worldwide  
Kunal Rambhia, University of Michigan  
Philip Russell, US Army (Retired)  
Ren Salerno, Sandia National Laboratories  
Tom Slezak, Lawrence Livermore National Laboratory  
Amy E. Smithson  
Daniel Sosin, US Centers for Disease Control and Prevention  
Kathleen Vogel, North Carolina State University  
Jaime Yassif, US Department of Defense  
Raymond A. Zilinskas, Middlebury Institute of International Studies at Monterey  
1 Anonymous member of a scientific non-profit organization  
1 Anonymous DHS official  
3 Anonymous representatives of the intelligence community

Table S1. Delphi Data

Respondent ID	Gender	Age	Training	Affiliation	Government Expertise	Terrorism Expertise	Scientific Expertise	Biological Science Expertise	Question 2: What do you estimate to be the likelihood of a large-scale biological weapons attack occurring within the next 10 years?	
1	0	1	0	1	0	1	0	0		20
2	0	1	9	3	1	0	0	0		25
3	1	0	5	3	1	0	1	1		90
4	0	1	4	3	1	0	1	0		10
5	1	1	5	0	0	0	1	1		40
6	0	1	5	0	0	0	1	1		25
7	0	1	4	3	1	0	1	0		90
8	1	1	9	1	0	0	0	0		100
9	1	1	5	3	1	0	1	1		75
10	0	2	4	4	1	0	1	0		70
11	0	2	6	3	1	0	1	0		95
12	0	2	5	2	0	0	1	1		50
13	0	2	3	0	0	0	1	0		50
14	0	2	1	3	1	1	0	0		50
15	1	0	5	0	0	0	1	1		75
16	1	2	6	3	1	0	1	0		90
17	0	1	5	3	1	0	1	0		80
18	1	1	5	1	0	0	1	1		60
19	1	1	5	3	1	0	1	1		75
20	0	2	5	0	0	0	1	1		60
21	0	1	4	0	0	0	1	0		75
22	1	1	5	3	1	0	1	1		5
23	0	1	5	0	0	0	1	1		20
24	0	3	3	0	0	0	1	0		100
25	0	1	2	3	1	1	0	0		25
26	1	2	0	0	0	1	0	0		45
27	0	2	4	2	0	0	1	0		90

Table S1. Delphi Data

Respondent ID	Gender	Age	Training	Affiliation	Government Expertise	Terrorism Expertise	Scientific Expertise	Biological Science Expertise	Question 2: What do you estimate to be the likelihood of a large-scale biological weapons attack occurring within the next 10 years?	
28	0	1	7	2	0	0	1	0		50
29	0	0	5	1	0	0	1	1		75
30	1	2	8	1	0	0	1	0		80
31	1	1	5	0	0	0	1	1		20
32	0	2	7	3	1	0	1	0		50
33	0	2	8	2	0	0	1	0		80
34	0	2	5	3	1	0	1	1		5
35	0	2	4	3	1	0	1	0		75
36	0	2	5	2	0	0	1	1		75
37	0	0	5	2	0	0	1	1		10
38	0	1	5	0	0	0	1	1		75
39	0	2	9	0	0	0	0	0		80
40	0	2	5	2	0	0	1	1		50
41	0	2	5	2	0	0	1	1		90
42	1	2	9	4	1	0	0	0		100
43	0	1	9	3	1	0	0	0		90
44	1	1	5	2	0	0	1	1		85
45	0	2	5	3	1	0	1	1		5
47	0	1	5	2	0	0	1	1		67
48	0	2	2	0	0	1	0	0		99
49	1	2	5	3	1	0	1	1		1
51	0	3	5	4	1	0	1	1		90
52	1	1	5	3	1	0	1	1		5
53	0	1	5	2	0	0	1	1		30
54	1	0	3	0	0	0	1	0		80
55	0	1	5	2	0	0	1	1		20
56	0	2	2	3	1	1	0	0		80

Table S1. Delphi Data

Respondent ID	Gender	Age	Training	Affiliation	Government Expertise	Terrorism Expertise	Scientific Expertise	Biological Science Expertise	Question 2: What do you estimate to be the likelihood of a large-scale biological weapons attack occurring within the next 10 years?	
57	0	1	5	3	1	0	1	1		5
58	0	2	5	1	0	0	1	1		80
60	0	2	5	3	1	0	1	1		80
61	0	2	5	3	1	0	1	1		50
62	1	1	5	1	0	0	1	1		25

Table S1. Delphi Data

Question 3: In your opinion, what is the likelihood of different types of actors to be the perpetrator of a biological weapons attack resulting in at least 100 illnesses if it occurs within the next 10 years?

Respondent ID	State (covert)	State (overt)	State (within its borders)	Criminal Group	Right-Wing Violent Non-State Actor	Left-Wing Violent Non-State Actor	Disgruntled/ Mentally ill individual	Single-Issue Actor	Religious Extremist
1	2	1	4	1	6	1	1	1	6
2	1	1	1	1	1	1	1	1	3
3	2	1	4	3	7	7	8	8	9
4	6	1	5	1	5	1	8	1	7
5	3	1	3	1	6	4	5	4	8
6	1	1	1	1	2	1	4	1	2
7	4	1	2	2	5	5	5	2	5
8	5	2	1	6	7	7	10	7	9
9	5	3	4	1	8	8	1	1	8
10	4	2	6	6	7	4	8	7	9
11	9	6	5	2	4	4	3	2	2
12	1	1	3	1	5	5	5	5	5
13	2	1	1	1	5	5	7	3	3
14	3	1	4	2	6	6	5	4	7
15	8	3	8	2	4	3	5	3	8
16	3	3	2	2	4	4	2	9	1
17	5	1	2	2	7	5	7	7	9
18	3	1	1	1	9	9	10	9	7
19	9	4	7	4	3	4	8	7	9
20	5	3	3	6	7	6	8	5	8
21	4	2	2	4	2	2	1	3	5
22	6	2	6	1	2	2	1	1	2
23	4	1	3	8	9	9	5	3	4
24	6	1	1	8	3	5	2	8	2
25	3	1	3	2	5	5	9	5	8
26	2	2	4	2	4	4	4	3	5
27	2	7	3	3	4	4	6	4	9

Table S1.Delphi Data

Question 3: In your opinion, what is the likelihood of different types of actors to be the perpetrator of a biological weapons attack resulting in at least 100 illnesses if it occurs within the next 10 years?

Respondent ID	State (covert)	State (overt)	State (within its borders)	Criminal Group	Right-Wing Violent Non-State Actor	Left-Wing Violent Non-State Actor	Disgruntled/ Mentally ill individual	Single-Issue Actor	Religious Extremist
28	8	1	8	3	2	2	5	2	2
29	9	1	8	7	7	7	9	8	5
30	6	6	6	1	5	5	5	2	9
31	3	3	2	4	6	4	5	3	6
32	4	1	3	2	7	3	8	3	9
33	7	1	6	3	8	2	5	1	9
34	3	1	2	2	2	2	4	2	5
35	3	1	1	2	8	6	3	1	7
36	1	2	2	3	4	3	8	3	8
37	2	1	1	2	2	1	3	1	3
38	8	6	6	8	3	3	8	3	3
39	2	1	3	2	4	4	2	2	4
40	3	1	1	3	6	4	5	2	7
41	8	2	8	8	8	8	8	8	8
42	10	2	10	3	4	2	4	4	4
43	6	2	7	7	9	3	9	9	9
44	3	1	9	1	6	1	6	6	9
45	1	1	1	2	1	1	2	1	4
47	8	1	4	3	3	3	4	3	8
48	4	5	2	6	2	4	3	2	8
49	3	1	4	3	5	5	5	3	4
51	3	1	3	2	2	2	4	2	9
52	3	1	5	3	4	4	4	4	5
53	2	2	3	2	2	1	2	1	2
54	6	4	4	4	8	7	9	8	7
55	7	1	3	3	3	3	3	3	5
56	4	1	2	1	8	8	8	2	8



Table S1. Delphi Data

Question 3: In your opinion, what is the likelihood of different types of actors to be the perpetrator of a biological weapons attack resulting in at least 100 illnesses if it occurs within the next 10 years?

Respondent ID	State (covert)	State (overt)	State (within its borders)	Criminal Group	Right-Wing Violent Non-State Actor	Left-Wing Violent Non-State Actor	Disgruntled/ Mentally ill individual	Single-Issue Actor	Religious Extremist
57	2	1	2	1	2	1	3	1	1
58	2	1	1	7	8	7	9	8	5
60	7	2	6	6	7	7	8	8	9
61	3	1	2	1	8	8	5	6	8
62	3	1	5	4	9	8	7	10	7

Table S1 Delphi Data

Question 4: In your opinion, which biological agents are most likely to be used as weapons within the next 10 years?

Respondent ID	Non-spore forming bacterial agents	Spore-forming bacterial agents	Viral agents	Biological toxins	Prions	Fungi	Synthetic pathogen that does not exist in nature
1	6	6	2	9		1	1
2	4	2	2	2		2	2
3	8	8	6	8		4	5
4	8	3	6	10		1	1
5	3	3	5	4		2	2
6	2	2	2	2		1	1
7	5	6	5	5		1	2
8	3	10	6	6		3	3
9	6	6	9	8		2	8
10	6	9	9	9		2	7
11	8	10	9	9		3	7
12	4	5	5	6		2	2
13	7	8	7	2		2	5
14	8	7	5	10		1	3
15	7	8	8	8		1	6
16	8	9	7	5		1	2
17	7	7	8	8		1	7
18	10	5	10	8		4	1
19	7	8	7	8		5	6
20	8	7	3	9		1	1
21	5	10	5	10		3	6
22	4	4	3	4		1	2
23	7	7	5	8		2	5
24	9	6	7	3		1	1
25	4	7	3	10		1	2
26	3	4	3	6		2	2
27	8	8	9	8		3	2

Table S1. Delphi Data

Question 4: In your opinion, which biological agents are most likely to be used as weapons within the next 10 years

Respondent ID	Non-spore forming bacterial agents	Spore-forming bacterial agents	Viral agents	Biological toxins	Prions	Fungi	Synthetic pathogen that does not exist in nature
28	3	5	7	7	2	3	2
29	9	8	8	7	1	1	2
30	8	10	10	9	1	1	10
31	5	5	5	7	1	3	4
32	6	8	5	7	2	3	3
33	8	8	8	6	2	3	4
34	4	3	3	5	1	2	1
35	5	5	5	8	1	1	2
36	5	5	10	4	1	2	3
37	1	4	2	1	1	2	2
38	9	5	9	9	1	2	6
39	3	4	3	7	1	3	5
40	4	8	4	8	1	2	4
41	5	9	5	9	1	4	2
42	10	4	5	8	8	1	7
43	7	10	7	9	2	5	9
44	9	2	5	6	1	4	1
45	2	1	1	2	1	1	2
47	3	3	6	5	2	3	5
48	4	8	4	6	3	3	4
49	7	8	3	9	1	1	1
51	9	9	4	9	1	1	3
52	4	4	4	6	1	1	1
53	8	9	8	10	1	3	1
54	8	8	6	9	1	1	6
55	3	3	2	5	1	1	1
56	8	8	8	6	1	1	3

Table S1. Delphi Data

Question 4: In your opinion, which biological agents are most likely to be used as weapons within the next 10 years?

Respondent ID	Non-spore forming bacterial agents	Spore-forming bacterial agents	Viral agents	Biological toxins	Prions	Fungi	Synthetic pathogen that does not exist in nature
57	4	2	2	8	1	2	1
58	8	6	9	5	2	4	1
60	6	7	6	9	1	2	1
61	3	8	3	8	1	1	3
62	5	5	4	7	6	5	2

Table S1. Delphi Data

Respondent ID	Question 6: If a biological attack were being planned today, what is the probability that intelligence information will provide actionable indications and warning preceding the attack?	Question 11: In your opinion, are there laboratory experiments that should not be performed as part of biological threat characterization in the US (e.g., Is there a "red line" that should not be crossed)?
1	10	1
2	20	1
3	50	1
4	10	1
5	30	1
6	25	1
7	30	1
8	20	1
9	20	1
10	30	1
11	5	1
12	50	1
13	10	0
14	10	1
15	50	1
16	50	0
17	50	1
18	40	1
19	30	1
20	30	1
21	20	1
22	50	0
23	20	1
24	3	1
25	5	1
26	20	1
27	1	0

Table S1. Delphi Data

Respondent ID	Question 6: If a biological attack were being planned today, what is the probability that intelligence information will provide actionable indications and warning preceding the attack?	Question 11: In your opinion, are there laboratory experiments that should not be performed as part of biological threat characterization in the US (e.g., Is there a "red line" that should not be crossed)?
28	60	1
29	15	1
30	50	1
31	25	1
32	30	1
33	10	0
34	2	1
35	10	1
36	25	1
37	10	1
38	40	1
39	50	1
40	40	1
41	20	1
42	0	0
43	60	1
44	75	1
45	20	1
47	55	0
48	10	1
49	0	1
51	5	1
52	5	1
53	75	1
54	10	1
55	50	1
56	10	1

Table S1. Delphi Data

Respondent ID	Question 6: If a biological attack were being planned today, what is the probability that intelligence information will provide actionable indications and warning preceding the attack?	Question 11: In your opinion, are there laboratory experiments that should not be performed as part of biological threat characterization in the US (e.g., Is there a "red line" that should not be crossed)?
57	25	1
58	20	0
60	75	1
61	25	1
62	25	1

**Data Key**

Gender

0=Male

1=Female

Age

0=21-33

1=34-49

2=50-68

3=69-86

Affiliation

0= NGO

1= Academia

2= Private Sector/Industry

3= Government

4= Former Government (retired)

Expertise (all types)

0=No

1=Yes

Primary Training

0= Political Science

1= Foreign Policy/International Affairs

2= National Security

3= Public Health

4= Medicine

5= Biological Science

6= Chemistry

7= Physical Science

8= Veterinary medicine

9= Other (Econ, History, Law)

Question 7

0=No

1=Yes

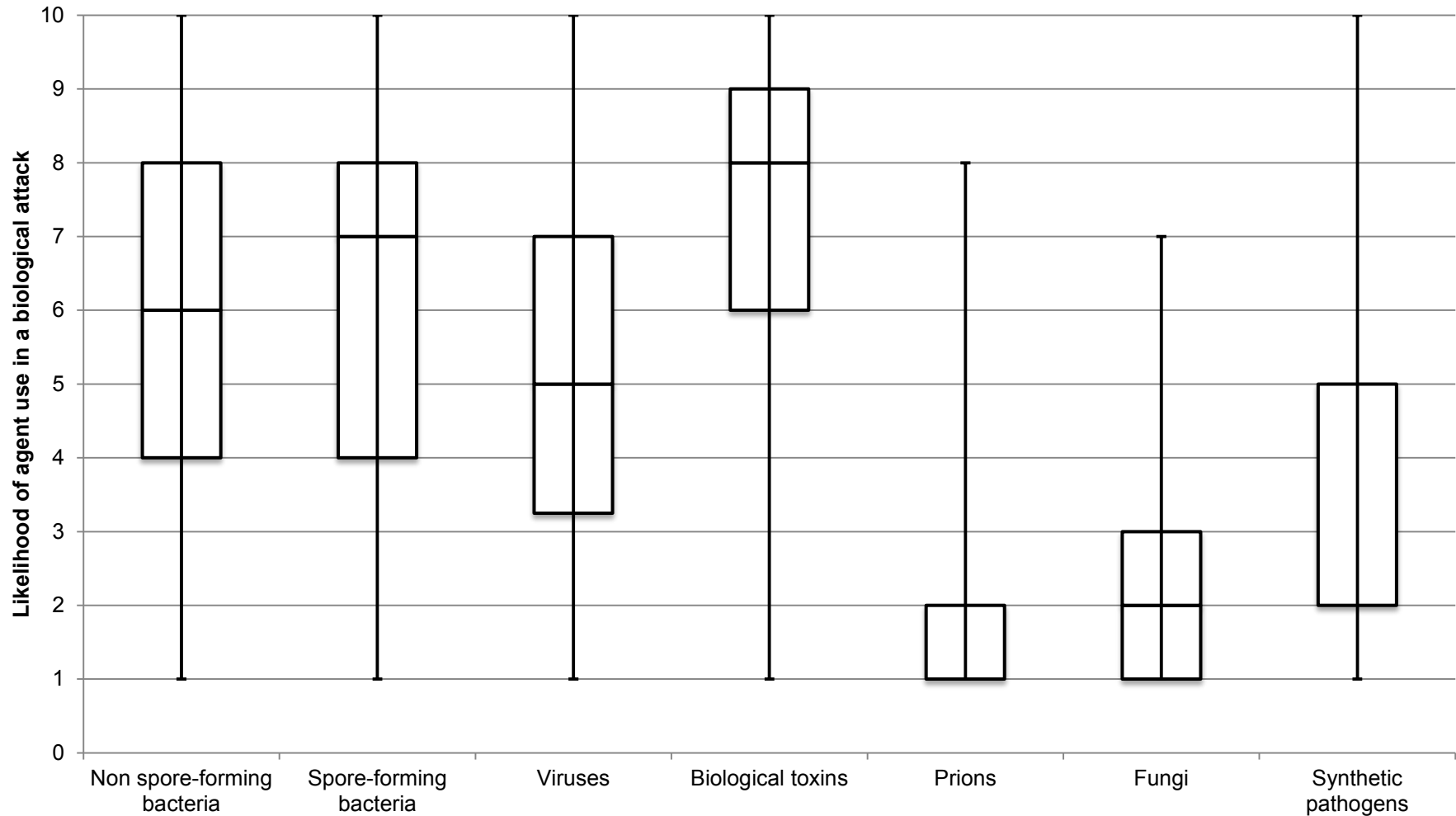
2=Don't Know

Question 11

0=No

1=Yes

Figure S1. Interquartile ranges for likelihood that a biological agent will be used as a weapon in the next 10 years



The rated likelihood of toxin use was higher than any agent except for spore forming bacteria, and when compared to non spore-forming bacteria, the next highest rated agent after spore-forming bacteria, this difference was statistically significant  $z=-2.4$ ,  $p=0.015$ . When likelihood of synthetic pathogen use was compared to that of viruses (the next lowest rated agent after synthetic pathogens), the difference was statistically significant  $z=4.86$ ,  $p<0.001$ . Prions were rated significantly lower than all other agents except for fungi.