

## Mapping of networks to detect priority zoonoses in Jordan

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Provisional

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21 **Running Title: Mapping Priority Zoonoses in Jordan**

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22 **Abstract**

23 Early detection of emerging disease events is a priority focus area for cooperative  
24 bioengagement programs. Communication and coordination among national disease surveillance  
25 and response networks are essential for timely detection and control of a public health event.  
26 Although systematic information sharing between the human and animal health sectors can help  
27 stakeholders detect and respond to zoonotic diseases rapidly, resource constraints and other  
28 barriers often prevent efficient cross-sector reporting. The purpose of this research project was  
29 to map the laboratory and surveillance networks currently in place for detecting and reporting  
30 priority zoonotic diseases in Jordan in order to identify the nodes of communication,  
31 coordination, and decision-making where health and veterinary sectors intersect, and to identify  
32 priorities and gaps that limit information-sharing for action. We selected three zoonotic diseases  
33 as case studies: highly pathogenic avian influenza (HPAI) H5N1, rabies, and brucellosis.  
34 Through meetings with government agencies and health officials, and desk research, we mapped  
35 each system from the index case through response – including both surveillance and laboratory  
36 networks, highlighting both areas of strength and those that would benefit from capacity-building  
37 resources. Our major findings indicate informal communication exists across sectors; in the  
38 event of emergence of one of the priority zoonoses studied there is effective coordination across  
39 the Ministry of Health and Ministry of Agriculture. However, routine formal coordination is  
40 lacking. Overall, there is a strong desire and commitment for multi-sectoral coordination in  
41 detection and response to zoonoses across public health and veterinary sectors. Our analysis  
42 indicates that the networks developed in response to HPAI can and should be leveraged to  
43 develop a comprehensive laboratory and surveillance One Health network.

44  
45 Keywords: One Health, zoonotic disease, Jordan, laboratory, disease surveillance

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48

49 **Introduction**

50 The emergence and spread of new pathogens is one of today's highest global health security  
51 risks with zoonotic diseases arguably the chief contributor. Zoonoses occur at the interface of  
52 human and animal health, impacting a wide range of health services and livelihoods. Social and  
53 political issues surround their assessment and management. Zoonotic viruses, parasites,  
54 bacteria and fungi are recognized as threats to human health and sustainable development  
55 worldwide, and are a major concern for national and international agencies (1). Significant risk  
56 factors for the emergence and rapid spread of zoonotic diseases include: international travel;  
57 global trade; increasing interactions among humans, wildlife, exotic, and companion animals;  
58 human behavior; rapid microbial adaptation; changing climates and ecosystems; and changing  
59 livestock management practices (2). Domestic animals and wildlife are well-known reservoirs  
60 of many emerging infectious diseases; roughly 75% of recent emerging infections and 60% of  
61 all human pathogens are of zoonotic origin (3-6).

62  
63 Although zoonotic diseases clearly present a significant threat to human and animal public  
64 health, many remain neglected due to competing priorities: for example, ministries of health are  
65 coping with growing burdens of non-communicable chronic diseases alongside existing  
66 maternal and child health needs, while ministries of agriculture/wildlife tend to prioritize  
67 livestock management for food production and trade. The costs of zoonoses in lives and  
68 livelihoods can be enormous. The effects of zoonoses on human health and economies have  
69 recently been underscored by notable outbreaks such as the 2009 H1N1 influenza virus  
70 pandemic, which began in swine farms on the Mexico-US border. Unfounded fears that meat  
71 products could transmit "swine flu" led to major losses to the North American pork industry,  
72 amounting to 25 million USD per week, and the banning of importation of pigs and pork  
73 products by at least 15 countries (7). In addition to natural disease threats, several zoonoses are  
74 among agents that have the potential to cause severe health threats if accidentally or  
75 deliberately released.

76  
77 Understanding zoonotic disease emergence, prevention, and control requires multi-disciplinary,  
78 collaborative basic and applied research. Communication and coordination among national  
79 disease surveillance and response networks are vital in ensuring the timely response to a public  
80 health event. Through systematic infectious zoonotic disease data collection, we can gain a  
81 better understanding of disease emergence and spread and provide mechanisms upon which to  
82 build early warning and response systems for animal and human health. Various frameworks  
83 aim to support capacity building for disease surveillance and response, including the World  
84 Health Organization's International Health Regulations (IHR), the World Organisation for  
85 Animal Health's (OIE) Animal Terrestrial Code and Pathway to Veterinary Services (PVS),  
86 and the Global Health Security Agenda (GHSa) (8-11). Although systematic information-  
87 sharing between the human and animal health sectors can help decision makers detect and  
88 respond to zoonotic diseases rapidly, resource constraints and other barriers often prevent  
89 efficient cross-sector reporting. Despite significant investments in technology, knowledge, and  
90 the availability of the frameworks and programs noted above, many countries still face  
91 significant gaps in their abilities to prevent, detect, and respond effectively to public health  
92 threats, including zoonotic diseases.

93

94 The Hashemite Kingdom of Jordan's abilities to prevent, detect, and respond to zoonoses have  
95 been tested and strengthened over recent years, spurred by a large brucellosis outbreak nearly a  
96 decade ago and a highly pathogenic avian influenza (HPAI) H5N1 outbreak in 2006. The  
97 Ministry of Health's (MOH) Division of Zoonotic Diseases and the Ministry of Agriculture's  
98 (MOA) Veterinary Services have developed a strong and cooperative relationship across  
99 surveillance and laboratory sectors. While these relationships exist, they are informal and used  
100 only in the context of response to major outbreaks or events. By mapping zoonotic disease  
101 detection, reporting, and response capacities across surveillance and laboratory systems, we  
102 sought to determine where mechanisms exist to integrate single-disease networks into national  
103 zoonotic response and to identify best practices/systems that can be applied across all priority  
104 zoonoses. Such mapping can help identify hotspots where zoonoses pose significant health  
105 threats, but also where efforts can be focused to improve prevention, communication, and  
106 coordination across veterinary and human health.

107

## 108 **Materials and Methods**

109 The methodology consisted of systematically mapping the laboratory and surveillance networks  
110 currently in place for detecting and reporting priority zoonotic diseases in Jordan. Our analysis  
111 does not include geographical mapping but rather an analysis reviewing major elements of  
112 systematic capacity building as outlined by Potter and Brough (12). We identified, collated, and  
113 then mapped the current surveillance and laboratory systems in place to detect, assess, report and  
114 respond to zoonotic diseases using publically available reports and key informant interviews.  
115 The relevant subject matter experts and other stakeholders for interviews and discussion were  
116 selected by the MOH Directorate of Communicable Diseases and the MOA Chief Veterinary  
117 Officer. We selected three priority zoonotic diseases for our analysis with varying burdens on  
118 human and veterinary health sectors to better define nodes of communication and coordination as  
119 well as gaps for capacity building and systems strengthening. This type of analysis may identify  
120 current vertical, disease-specific strategies and frameworks that can be applied horizontally to  
121 develop national zoonotic disease strategies. It is important to note that our mapping does not  
122 address the role of livestock keepers and/or the density and number of livestock, which play a  
123 major role in disease outbreaks, transmission, and at times subsequent epidemics.

124

### 125 ***Selection of priority zoonoses***

126 There are multiple methods used in prioritizing disease detection and response capacity-building,  
127 including analysis of the local and national burden of disease; global trends in emergence;  
128 economic costs associated and cross-sector impacts; human morbidity and mortality; and  
129 population health (3, 13-15). Our goal was to examine coordination and communications from  
130 the index case to notification at the national and international levels. In order to determine the  
131 mechanisms that promote and/or prevent information sharing across surveillance and laboratory  
132 networks both within and among ministries, it was first important to determine the priority  
133 zoonoses from both the public and veterinary health sectors. Both MOH and MOA have  
134 established priority notifiable disease lists, which are used to strengthen surveillance and  
135 laboratory capacities; however, there had not yet been a collaborative discussion on cross-linking  
136 these lists to develop formalized multi-sectoral priorities, particularly with respect to zoonotic  
137 diseases. We began with reviewing existing MOH and MOA notifiable disease lists and  
138 selecting the zoonotic diseases on each list for consideration. Through collaborative strategic  
139 discussions, we identified five MOH-MOA priority zoonoses for further ranking. We selected

140 priority zoonotic diseases for case study analysis that aligned with three major categories of  
141 focus for intervention at the animal-human interface: endemic zoonoses, epidemic-prone  
142 zoonoses, and emerging zoonoses. Endemic zoonoses account for the majority of human cases  
143 and deaths, and the greatest reduction in livestock production. Epidemic-prone zoonoses occur  
144 sporadically or cyclically and the spatial distribution of outbreaks may vary, but epidemic-prone  
145 diseases are often prioritized due to their impact on health and trade. Emerging zoonoses  
146 (diseases they are either new to a population or are rapidly increasing in incidence or geographic  
147 range) generally account for only a fraction of the zoonotic disease burden, but outbreaks may  
148 have unpredicted and highly disruptive effects (16). We assigned weight to pathogens associated  
149 with a high human disease burden (morbidity and mortality); impact on livestock and wildlife  
150 (production, economic loss); amenability to practice- or veterinary medicine-based interventions;  
151 existing surveillance systems; and, finally, mechanisms for improved stakeholder  
152 communication and coordination (17-20).

153

### 154 ***Mapping of surveillance and laboratory networks***

155 In collaboration with Jordan's Field Epidemiology Training Program (FETP), we developed case  
156 studies based on past zoonotic events to examine coordination and communications from the  
157 index case to notification at the national and international levels, in order to identify priorities  
158 and gaps that limit information sharing for action. (Figure 1) For the three selected priority  
159 zoonoses, we developed case studies outlined in a five-step process: 1) Case Reporting; 2)  
160 Reporting and Sample Submission; 3) Laboratory Testing; 4) Case Management; and 5)  
161 Outbreak Investigation (Figure 2). For each case study, we created a decision tree at each of the  
162 steps noted above, identified the strengths and weaknesses of the system, and recommended  
163 steps for improvement. This resulted in a systems map that identified the nodes of  
164 communication, coordination, and decision-making where the human and veterinary health  
165 sectors intersect, highlighting areas of strength as well as gaps that would benefit from capacity-  
166 building resources. This information can be translated into recommendations for strengthening  
167 policies, protocols, and practices for preventing and responding to priority zoonoses across  
168 veterinary and public health sectors.

169

## 170 **Results**

### 171 ***Selecting priority zoonoses for analysis***

172 In collaboration with the MOH-Directorate of Communicable Diseases (DCD) and the MOA  
173 Veterinary Services, the combined Jordan FETP and The George Washington University Global  
174 Health Security Program (GWU) research team determined that the most suitable priority  
175 diseases for our analysis included highly pathogenic avian influenza (HPAI) H5N1, brucellosis,  
176 and rabies. These priority diseases represent endemic zoonoses (brucellosis), epidemic-prone  
177 zoonoses (rabies, defined as a disease in which exposures to a single infected animal can lead to  
178 multiple human cases) (16), and emerging zoonoses (HPAI H5N1).

179

### 180 ***Mapping surveillance networks***

181 MOH is the largest financer and provider of health services in Jordan. Disease surveillance  
182 efforts in Jordan fall under the oversight of the Director of Primary Health Care Administration,  
183 which oversees eight directorates within MOH (21). The DCD within the Primary Health Care  
184 Administration is charged with disease surveillance and is most active in detection, surveillance,  
185 assessment, response, and reporting activities. Within DCD, the Surveillance Department,

186 Division of Applied Epidemiology, and Division of Infection Control (among others) oversee  
187 specific programs and functions. DCD's Surveillance Department receives and manages  
188 information from 22 surveillance sites throughout Jordan that track the 42 reportable diseases in  
189 country. Information flows from the health facility level to the health directorates, and then to  
190 DCD, where data is compiled and analyzed to prepare the weekly reporting bulletin. Within  
191 MOA, the Secretary General Assistant for Livestock and the Chief Veterinary Officer have  
192 responsibility for the organization and implementation of veterinary services, while the majority  
193 of administrative control falls to 13 agricultural departments. Veterinarians are trained in the  
194 field on zoonoses communication and reporting, sample collection, and packaging. Within the  
195 Veterinary Services Department, there is an Animal Health Section, Poultry Health Section, and  
196 Veterinary Quarantine Section, which coordinate with the governorate level departments on  
197 disease surveillance and response. Both MOH and MOA have notifiable disease lists for  
198 immediate, weekly and monthly reporting.  
199

### 200 ***Mapping laboratory networks***

201 Diagnostic and confirmatory laboratory services are provided from the Central Public Health  
202 Laboratory (CPHL) to the health center level. CPHL oversees laboratory biosafety and  
203 biosecurity programs for MOH laboratories and hospitals. Each health directorate has a  
204 laboratory coordinator at the governorate level. Although Laboratory Quality Management  
205 Systems (LQMS) and the logistical support to manage supplies and safe specimen transport exist  
206 they are uneven at the subnational level. Diagnostic and confirmatory testing capabilities are  
207 shared across public and private sector laboratories, which can provide challenges in the event of  
208 major outbreaks. CPHL coordinates with the U.S. Naval Medical Research Unit 3 (NAMRU-3)  
209 located in Cairo for confirmatory testing when necessary. MOA has veterinary laboratories in  
210 each of the 12 governorates that perform routine diagnostics at varying levels of capacity. A  
211 lack of resources, both human and financial, leads to a majority of diagnostic and confirmatory  
212 testing falling to the Central Veterinary Laboratory (CVL) (22). MOA coordinates with the UN  
213 Food and Animal Organization (FAO) and OIE to assist with confirmatory testing, as well as  
214 gold standard diagnostic tests when these are not locally available.  
215

### 216 ***Case study #1: Highly Pathogenic Avian Influenza (HPAI) H5N1***

217 As of 2006, Jordan and most of its neighbors have remained free of human HPAI H5N1 cases,  
218 with the exception of Egypt (which reported 48 deaths and 165 cases between November 2014  
219 and April 2015) (23-25). Jordan's geography puts it at low risk for the introduction of HPAI  
220 from migratory waterfowl due to its lack of surface water; key migratory bird habitats in the  
221 Jordan Valley and around the Gulf of Aqaba are distant from major poultry production facilities.  
222 A majority of Jordan's poultry farms are commercial with backyard flocks comprising only 2%  
223 of the sector (22). The commercial sector is advanced for the region; including biosecurity into  
224 its best practices (26).  
225

### 226 ***Existing networks***

227 Following devastating outbreaks of HPAI H5N1 in 2006, Jordan established the National  
228 Committees on Avian and Pandemic Influenza, including the National Steering Committee, the  
229 National Technical Committee, and the National Center for Security and Crisis Management  
230 (previously the Disaster Management Committee) each playing a role in detection, reporting, and  
231 response to highly pathogenic and pandemic influenza. Jordan has both an Animal Health



232 National Preparedness Plan and National Contingency Plan for Avian Influenza, which are  
233 utilized by various ministries, including Ministries of Health, Agriculture, Planning, Foreign  
234 Affairs, Transport and Communication, Interior, Industry and Trade, Education,  
235 Communications and IT among others. At the regional level, the Middle East Consortium on  
236 Infectious Disease Surveillance (MECIDS) network developed an Avian and Pandemic Influenza  
237 Sub-Regional Common Plan of Action for Palestine, Jordan, and Israel (27). The plan defines the  
238 protection zone (3km radius from affected farm designated for culling), surveillance zone (10km  
239 radius from affected farm where enhanced surveillance and control measures must be taken), and  
240 case definitions for avian and human influenza cases (suspected, probable, and confirmed). It  
241 also outlines principles, procedures, and protocols for MOA and MOH officials in the case of  
242 H5N1 in poultry (notification of suspected case, protection and surveillance zone established, lab  
243 confirmation of H5, follow-up) and in the event of H5N1 in humans (notification of suspected  
244 case, epidemiological investigation, lab diagnosis of H5 and follow-up). In 2008, 32  
245 representatives from multiple sectors (health, transportation, education, interior, laboratory, and  
246 media) in Jordan, Palestine, and Israel participated in a regional pandemic influenza tabletop  
247 exercise to develop action items based on various influenza case scenarios, including human-to-  
248 human transmission of HPAI H5N1. This body is active in disease surveillance and response  
249 across a number of priority diseases for the region and is able to activate and respond in the event  
250 of HPAI if necessary. The 2006 HPAI H5N1 outbreak in poultry is a good example of how and  
251 when MOH and MOA communicate, particularly when there was an immediate need and  
252 financial resources.

253

#### 254 *Detection, notification, and response*

255 If a patient presents at a health facility or hospital and the clinician suspects HPAI based on  
256 clinical symptoms or due to reports of contact with sick poultry, the patient is isolated and  
257 samples are sent to the Central Public Health Laboratory (CPHL) for diagnostic confirmation.  
258 The isolated patient is treated with antivirals and health care staff involved in patient care  
259 receives preventative treatment. HPAI is an immediate reportable Group A disease; the primary  
260 health care unit or hospital reports directly to the Health Directorate, which then reports to the  
261 Directorate of Communicable Diseases (DCD). MOH also communicates with MOA that there is  
262 a suspect human case of HPAI. Likewise, if there are reports of poultry deaths and/or an animal  
263 presents and is characterized as suspect HPAI, veterinary services will notify MOA, MOH, and  
264 collect samples for confirmation testing at the Central Veterinary Laboratory (CVL). A positive  
265 rapid diagnostic test for type A influenza may result in quarantine or culling of affected farms  
266 while confirmation testing is performed at CVL. MOA reports positive cases to OIE on a  
267 monthly basis whereas MOH would immediately report a positive human case as outlined under  
268 IHR (2005). If the CVL confirms HPAI, Rapid Response Teams (RRTs) assist in providing  
269 personal protective equipment (PPE) and restricting contact to affected farms/flocks to determine  
270 proper culling procedures. In addition, a poultry vaccination team will be deployed to  
271 farms/flocks within a 7km radius. In the event of a confirmed human case public health RRTs  
272 will conduct in-depth reports and follow up with possible suspect cases and contacts. If the  
273 patient's symptoms persist with unconfirmed diagnosis, treatment with Tamiflu continues for 7  
274 days and care is provided per physician recommendations. During an outbreak MOH and MOA  
275 will communicate laboratory confirmed cases to each other on a daily basis. Jordan has both an  
276 Animal Health National Preparedness Plan and National Contingency Plan for Avian Influenza,  
277 which are utilized by various ministries including MOA and MOH. Figure 3 depicts a flow chart

278 schematic of surveillance and laboratory channels. Mechanisms for communication and  
279 coordination among laboratory, public health, and veterinary officials at the governorate and  
280 national level are strong in the event of a suspect case of HPAI H5N1. Frameworks and plans  
281 exist and function well; however, they are only activated in the case of emergencies.  
282

### 283 ***Case study #2: Rabies***

284 Rabies is a zoonotic viral disease that causes acute inflammation of the brain in animals. The  
285 disease is spread to humans from another animal (e.g. dogs, camels, donkeys), commonly by a  
286 bite or scratch, although exposure of mucous membranes to infected saliva is also a risk.  
287 Globally, most cases are the result of a dog bite: exposure to rabid dogs is the cause of over 90%  
288 of human exposures to rabies and of over 99% of human deaths worldwide. Rabies is a  
289 completely preventable disease in the human population with effective veterinary vaccine  
290 campaigns and effective reporting and rapid post-exposure treatment following animal bites.  
291 More than 50,000 people die annually from rabies worldwide, despite the fact that the tools to  
292 prevent and manage the disease are readily available. (28) Once clinical signs of rabies appear,  
293 the disease is nearly always fatal, and treatment is typically supportive.  
294

### 295 *Existing networks*

296 Human rabies cases are rather rare in Jordan. Dog bites account for the vast majority of suspect  
297 human rabies cases in Jordan (29). According to MOH, 4,753 patients were treated for rabies  
298 exposure in 2013, but no human rabies cases were reported (or have been for the last 3 years).  
299 MOA reported a total of 7 cases and 7 deaths to OIE in 2013 (30). MOA provides free vaccines  
300 to vaccinate animals for prevention and control of rabies; however, there is a limited vaccine  
301 supply and an inability to cover the entire susceptible population. Currently, vaccine campaigns  
302 focus on the companion animal population, covering stray dogs only as supplies allow. There is  
303 no policy to vaccinate any potential wildlife reservoir. Key to the control of rabies in Jordan is  
304 the containment and vaccination of the stray dog population nationwide.  
305

### 306 *Detection, notification, and response*

307 Any human bitten by stray or wild dogs is considered a probable rabies case and the responsible  
308 health official uses the case definition for determination. All suspect patients are treated post-  
309 exposure with the rabies vaccination and MOH covers all costs for post-exposure prophylaxis  
310 and supportive care. Patient samples are collected and sent to the Department of Sera and  
311 Vaccines for confirmation however testing of samples is not routine which can lead to  
312 unnecessary costs of patient care from post-exposure prophylaxis for unconfirmed rabies cases.  
313 Rabies is an immediately notifiable disease, MOH notifies MOA of suspect cases however  
314 animal bites are reported to MOA on a weekly basis and to OIE annually. The Surveillance Unit  
315 within MOH conducts investigations into suspect cases and submit final reports to DCD.  
316 Occasionally the RRT includes veterinarians and subject matter experts from MOA. In the event  
317 of suspect rabies case(s) in domesticated or wild animals, the local veterinary services is notified  
318 and if based on case definition the animal is labeled suspect, MOA is immediately notified for  
319 investigation. If the suspect case is in feral or otherwise non-domesticated individuals, the animal  
320 is immediately culled without quarantine. If the animal(s) are domesticated, they are quarantined  
321 for 10 days under the observation of MOA; if the animal develops symptoms or succumbs to  
322 infection, samples are sent to MOH-Department of Sera and Vaccines for diagnostic  
323 confirmation. There is currently no public veterinary laboratory in Jordan that has capacity to

324 diagnose rabies in animals. MOA will conduct an investigation of neighboring areas for  
325 additional cases and quarantine when necessary. Figure 4 shows a flow chart schematic of  
326 surveillance and laboratory channels. Key to the control of rabies in Jordan is the containment  
327 and vaccination of the stray dog population nationwide and timely confirmation of suspect  
328 human cases in order to prevent unnecessary extensive health care costs for post-exposure  
329 treatments on negative patients.

330

### 331 ***Case study #3: Brucellosis***

332 Brucellosis is an important zoonotic disease of livestock, notifiable to OIE (31). Globally,  
333 human brucellosis is a re-emerging zoonotic disease with an estimated 2% case fatality rate, even  
334 though successful eradication and control programs for domestic animals effectively and  
335 significantly decrease disease incidence in humans, and have been established in many at-risk  
336 countries. Symptoms of brucellosis in humans include fever with multiple non-specific clinical  
337 signs and symptoms. Delayed diagnosis, chronic disease, failure of primary antibiotic treatment,  
338 and relapses are common. Brucellosis is transmitted through exposure to infected animal  
339 products (most commonly raw dairy products) or, less frequently, through direct contact with  
340 infected camels, cattle, sheep or goats. More than 500,000 human cases are reported worldwide  
341 each year, (32) but the number of undetected cases is believed to be considerably higher.  
342 *Brucella* spp. are also categorized as potential biological agents for deliberate use in many US  
343 and international frameworks due to their high contagiousness and their impact on human and  
344 animal health.

345

#### 346 *Existing networks*

347 In 1985, an official system for reporting human cases of brucellosis was established by MOH,  
348 under the supervision of the Communicable Diseases Control Program Division. Spurred by a  
349 large brucellosis outbreak in Jordan roughly 10 years ago, the MOH's Division of Zoonotic  
350 Diseases and veterinary public health actors at the MOA developed a cooperative relationship in  
351 reporting and response to brucellosis. However, there is no national plan. According to OIE  
352 reporting, brucellosis continues to be in the top 3 zoonotic diseases reported in Jordan (30). In  
353 collaboration with CDC, the MOH and others conducted a burden of illness study in 2003 including  
354 population, animal vaccinations, and laboratory surveys and validation study. However, outbreaks  
355 are still prevalent in Ma'an and Mafraq governorates on a seasonal basis and for various reasons,  
356 including the lack of clear clinical symptoms and misdiagnosis, human brucellosis is  
357 significantly under-reported and under-diagnosed, particularly by the private health sector (33,  
358 34). In Jordan, ruminants, particularly sheep and goats, are vaccinated at all ages, at any time  
359 during the year, and annual revaccination is recommended. On average, about 18% to 25% of the  
360 sheep and goats in Jordan were vaccinated through 2000, although unofficial estimations on  
361 vaccine coverage is increasing and can be estimated at times to be as high as 50% recently  
362 published data indicates that only 1.5% of the small ruminant population is vaccinated leading  
363 to regional endemicity, particularly in the north (35, 36). Starting in 2015 a new project will  
364 begin, a partnership between EMPHNET and CDC with Jordan MOH as lead implementer will  
365 estimate disease burden in the human population (37).

366

367

#### 368 *Detection, notification, and response*

369 When a patient presents with symptoms consistent with brucellosis and has ingested raw milk or  
370 other potentially infected dairy products, the health official will use the case definition to

371 determine whether to classify the case as suspect brucellosis. Suspect human cases are reported  
372 to MOH and the Occupational Health and the Food and Drug Agency of Jordan. Patients may be  
373 admitted to a fever hospital to confirm diagnosis and initiate treatment. Clinical samples are sent  
374 to the governorate level laboratory for initial diagnostic testing, and to CPHL for confirmatory  
375 testing as indicated. The lab results are not shared with MOA. When possible, health education  
376 is provided to at-risk occupational groups (farmers, meat packers, dairies) working with animals  
377 or animal products; however, there is no clear guidance for surveillance and outbreak response  
378 for MOH. In the event of a suspect case or farm(s), the local veterinary services will quarantine  
379 the suspect farm(s) and collect samples for diagnostic testing at the CVL, at times and when  
380 possible governorate level labs will perform diagnostics. A team is sent to each suspect farm to  
381 conduct an investigation, which includes an imposed quarantine, provision of herd vaccination  
382 history, sample collection and testing. A farm must test negative three consecutive times before  
383 being cleared. Any animals testing positive must be culled. It should be noted that this is the  
384 recommended procedure however we do not country-wide data as to whether this is implemented.  
385 MOA reports all positive cases to OIE. Individual animal cases of brucellosis are not reported to  
386 MOH due to the endemicity of brucellosis in Jordan, however outbreaks are reported directly to  
387 DCD. Please see Figure 5 for a flow chart schematic of surveillance and laboratory channels.  
388 As noted above, effective livestock vaccine campaigns can significantly reduce the burden of  
389 human brucellosis. There are clear seasonal patterns associated with human cases and outreach  
390 and education on zoonotic transmission will be key in containing human outbreaks.

## 391 392 **Discussion**

393 Mapping of zoonoses and the burden of such diseases can help identify vulnerabilities where  
394 zoonoses pose significant health threats, but also where efforts can be focused to improve  
395 prevention, communication, and coordination across veterinary and human health. These study  
396 findings describe existing systems that can be strengthened or applied by stakeholders to address  
397 current needs within Jordan, and offer case studies that can be applied in other contexts.  
398 Although the findings may appear predictable to those already deeply familiar with Jordan's  
399 surveillance and response systems, the formal linkages within and across sectors may not be  
400 immediately obvious to the increasingly diverse stakeholder and partner networks engaged in  
401 long-term capacity-building for global health security.

402  
403 We found many similarities in surveillance and response capacities across local, governorate,  
404 and national public and veterinary health networks regardless of the pathogen mapped, indicating  
405 that improvement in response to one specific pathogen would most likely improve the ability to  
406 respond to other zoonoses (Figure 6). The results of our mapping highlighted three main areas  
407 for improvement towards building national One Health capacities: (1) a national zoonotic  
408 reporting and communication framework, (2) a national zoonotic preparedness and response  
409 plan, and (3) increased laboratory diagnostic capacity across governorate level laboratories.

### 410 411 ***National zoonotic reporting and communication framework***

412 There are strong informal mechanisms for communication and coordination within and across  
413 local public health and veterinary services with consistent reporting up to governorate and  
414 national levels. However, the local facilities are not always involved in outreach and  
415 communication strategies for local response. There is no standardized structure for  
416 communication and information sharing across and within surveillance sectors and laboratories.  
417 There is no formal mechanism or protocol for reporting laboratory confirmation beyond CPHL

418 and CVL obligations to report back to their relevant ministry departments. There is little, if any,  
419 cross-talk between CPHL and CVL in both surveillance reports and laboratory confirmation.  
420 This node of cross-sector communication is of particular importance when considering sentinel  
421 and early warning systems for zoonotic disease outbreaks in the veterinary sector and in  
422 investigations and response during simultaneous outbreaks of zoonoses in humans and animals.  
423 We recommend establishing a framework for reporting and communication to and from ministry  
424 department focal points to their local and governorate counterparts as well as across sectors at  
425 each level of reporting.

426

#### 427 ***National zoonotic preparedness and response plans***

428 Rapid response teams, both locally and nationally deployed, are effective in outbreak  
429 investigation within their respective sectors; however, organization and deployment of multi-  
430 disciplinary RRTs are extremely pathogen-dependent. This inconsistency can lead to duplication  
431 of efforts during critical phases of outbreak response and containment. While there are disease  
432 specific plans, such as the Animal Health National Preparedness Plan and National Contingency  
433 Plan for Avian Influenza, no national framework for preparedness and response to priority  
434 zoonotic diseases exists. We recommend that RRTs should be multi-disciplinary at the national  
435 level, using the FETP as resource to link governorate level epidemiologists available for rapid  
436 response.

437

#### 438 ***Laboratory capacity***

439 Local and governorate level public health and veterinary laboratory capacity is inconsistent.  
440 Some labs lack the ability to perform routine diagnostics, due either to constraints in  
441 infrastructure, equipment, human resources and/or funding. This inconsistency leads to delays in  
442 time to pathogen confirmation and response as well as increased diagnostic burdens on the  
443 national level laboratories, and at times, outsourcing to private laboratories for diagnostic  
444 confirmation. We propose that Jordan develop a national laboratory network, modeled after their  
445 experience as a member of the Network for the Control of Public Health Threats in the  
446 Mediterranean Regional and South East Europe (EpiSouth) Laboratory Network, to provide a  
447 formalized, standard protocol for private and public laboratory partnership for diagnostic testing  
448 or priority pathogens in the event of public and veterinary health events and those for routine  
449 testing for sentinel surveillance efforts.

450

451 Although this project focused on three priority zoonotic diseases in Jordan the challenges  
452 identified from both public health and veterinary surveillance and laboratory sectors are  
453 challenges faced by many middle income countries. Our analysis indicates that the HPAI  
454 networks in Jordan are well developed, coordinated, and effective in event identification,  
455 diagnosis and response which suggests that these existing resources can and should be leveraged  
456 to develop a comprehensive laboratory and surveillance One Health network.

457

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463

464 **Author Contributions**

465 EMS, SK, JEF, RK conceived of the research; MEA, NM, SK, CJS, EMS, IB conducted the  
466 research; MEA, NM, SK, EMS, IB, JEF wrote the manuscript; CJS, RK provided technical  
467 review and input to the manuscript.

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564 **Figure Legends**

565 **Figure 1. Model Joint Assessment and Response.** In collaboration with the Jordan Ministry of  
566 Health, Field Epidemiology Training Program, and Ministry of Agriculture, we examined  
567 coordination and communications from the index case to notification at the national and  
568 international levels in order to identify priorities and gaps that limit information sharing for  
569 actions. Efforts in surveillance and response lead by Ministry of Health are represented in blue  
570 while those lead by Ministry of Agriculture are in green.  
571

572 **Figure 2. Identifying Priority Zoonoses and Identification and Networks for Case**  
573 **Management.** In order to select three priority zoonotic diseases for analysis, we considered  
574 MOH and MOA notifiable disease lists as well as global priority zoonoses. For the three  
575 selected priority zoonoses, we developed case studies outlined in a five-step process: 1) Case  
576 Reporting; 2) Reporting and Sample Submission; 3) Laboratory Testing; 4) Case Management;  
577 and 5) Outbreak Investigation. The resulting analysis is a systems map that identified the nodes  
578 of communication, coordination, and decision-making where the health and veterinary sectors  
579 intersect, highlighting both areas of strength and gaps that would benefit from capacity-building  
580 resources.  
581

582 **Figure 3. Surveillance and Laboratory Mapping of Highly Pathogenic Avian Influenza**  
583 **(HPAI) H5N1.** Surveillance and laboratory networks for HPAI H5N1 including nodes of  
584 communication and response were mapped across human health and veterinary sectors. Systems  
585 were analyzed beginning from report of a suspect case to diagnostic confirmation including  
586 evaluation: case reporting; reporting and sample submission; laboratory testing; case  
587 management; and outbreak investigation. Efforts in surveillance and response lead by Ministry  
588 of Health are represented in blue while those lead by Ministry of Agriculture are in green.  
589 Positive cases are noted in orange while unknown/unconfirmed cases are represented in purple.  
590 Abbreviations: Ministry of Health (MOH), Central Public Health Laboratory (CPHL),  
591 Directorate of Communicable Diseases (DCD), Ministry of Agriculture (MOA), Central  
592 Veterinary Laboratory (CVL).  
593

594 **Figure 4. Surveillance and Laboratory Mapping of Rabies.** Surveillance and laboratory  
595 networks for rabies including nodes of communication and response were mapped across human  
596 health and veterinary sectors. Systems were analyzed beginning from report of a suspect case to  
597 diagnostic confirmation including evaluation: case reporting; reporting and sample submission;  
598 laboratory testing; case management; and outbreak investigation. Efforts in surveillance and  
599 response lead by Ministry of Health are represented in blue while those lead by Ministry of  
600 Agriculture are in green. Positive cases are noted in orange while unknown/unconfirmed cases  
601 are represented in purple. Abbreviations: Ministry of Health (MOH), Central Public Health  
602 Laboratory (CPHL), Directorate of Communicable Diseases (DCD), Ministry of Agriculture  
603 (MOA), Central Veterinary Laboratory (CVL).  
604

605 **Figure 5. Surveillance and Laboratory Mapping of Brucellosis.** Surveillance and laboratory  
606 networks for brucellosis including nodes of communication and response were mapped across  
607 human health and veterinary sectors. Systems were analyzed beginning from report of a suspect  
608 case to diagnostic confirmation including evaluation: case reporting; reporting and sample  
609 submission; laboratory testing; case management; and outbreak investigation. Efforts in

610 surveillance and response lead by Ministry of Health are represented in blue while those lead by  
611 Ministry of Agriculture are in green. Positive cases are noted in orange while  
612 unknown/unconfirmed cases are represented in purple. Abbreviations: Ministry of Health  
613 (MOH), Central Public Health Laboratory (CPHL), Directorate of Communicable Diseases  
614 (DCD), Ministry of Agriculture (MOA), Central Veterinary Laboratory (CVL).

615

616 **Figure 6. Mapping Public Health and Veterinary Surveillance and Laboratory Networks.**

617 An overall analysis of existing surveillance and laboratory networks for zoonotic diseases  
618 including nodes of communication and response were mapped across human health and  
619 veterinary sectors to indicate areas of strength and those requiring strengthening. Efforts in  
620 surveillance and response lead by Ministry of Health are represented in blue while those lead by  
621 Ministry of Agriculture are in green. Strengths within and across sectors are represented by solid  
622 blue and green lines. Major gaps are represented in red while minor gaps are represented in  
623 orange. Abbreviations: Ministry of Health (MOH), Central Public Health Laboratory (CPHL),  
624 Directorate of Communicable Diseases (DCD), Ministry of Agriculture (MOA), World Health  
625 Organization (WHO), World Organisation for Animal Health (OIE), Rapid Response Teams  
626 (RRTs).

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Figure 1.TIF

Sorrell et al Figure 1

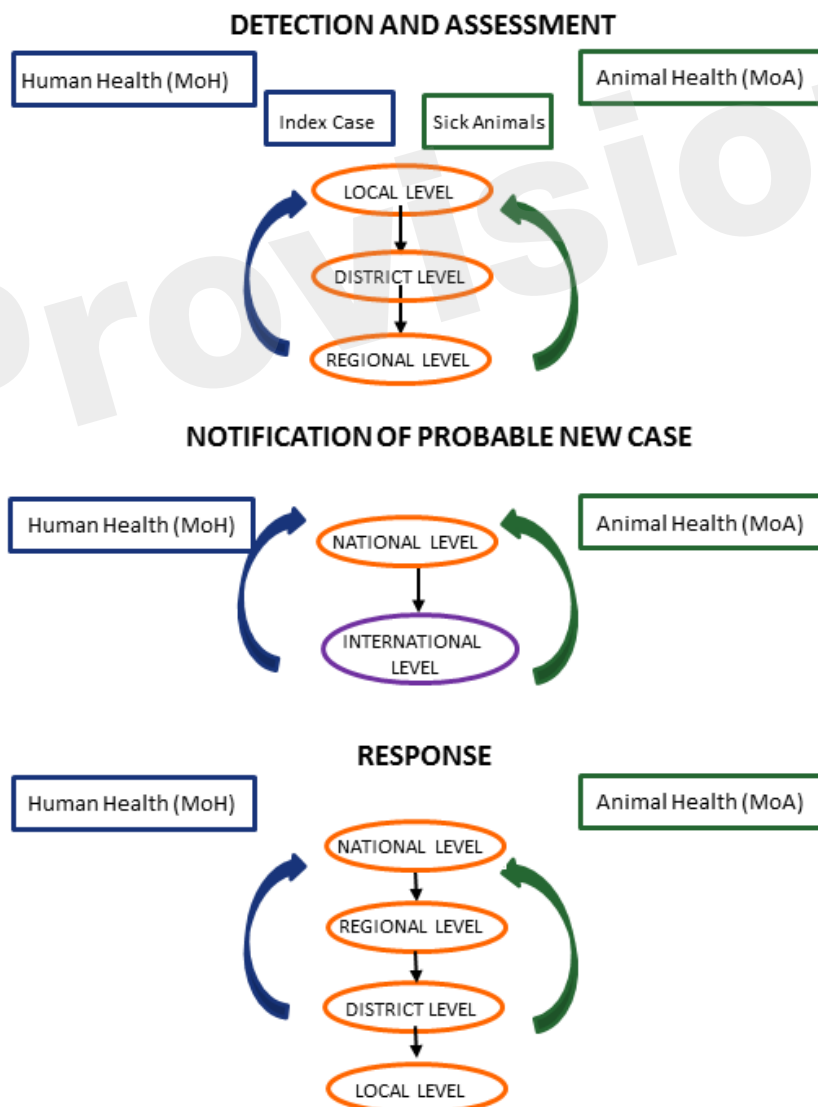


Figure 2.TIF

Sorrell et al Figure 2

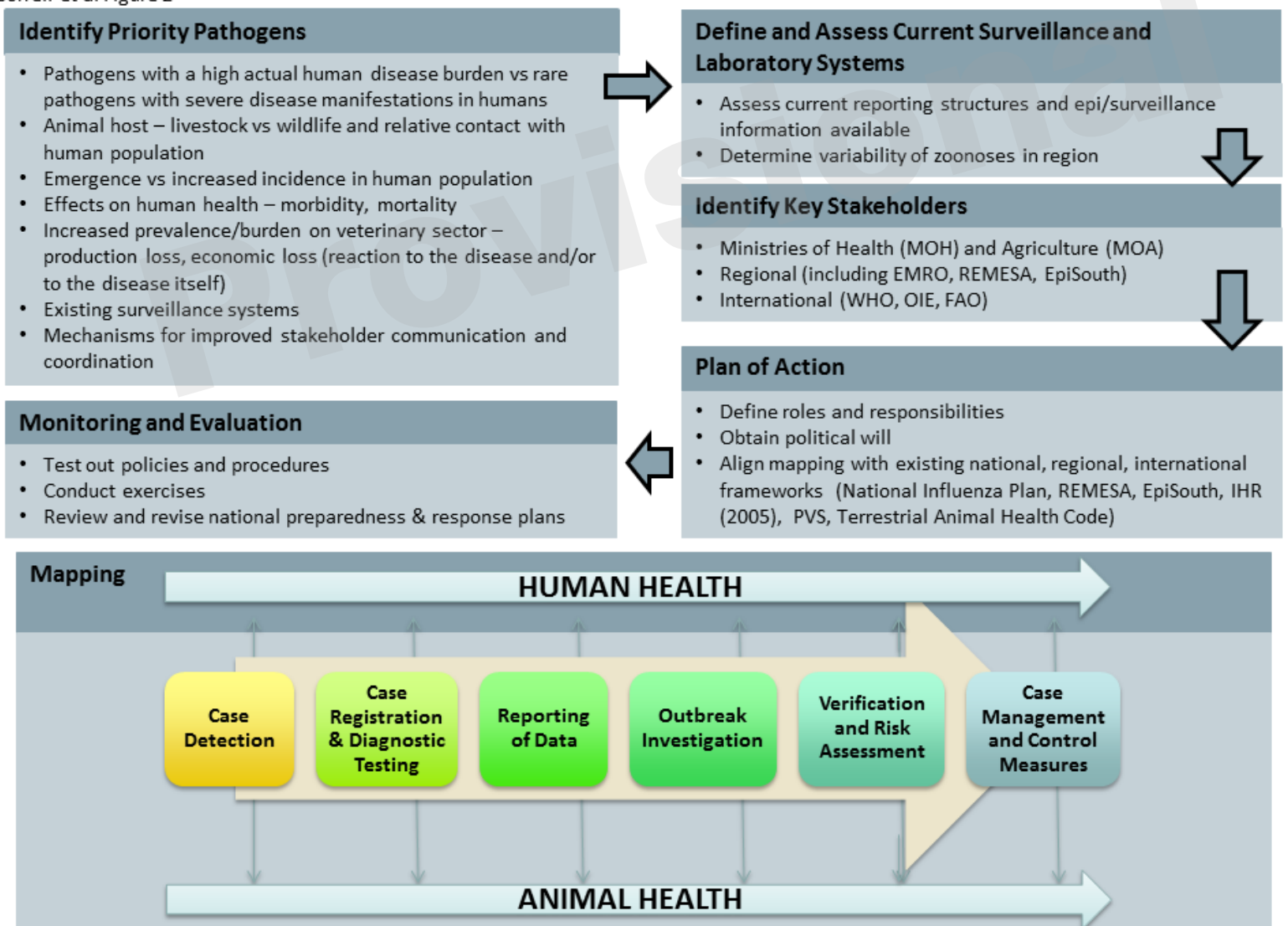


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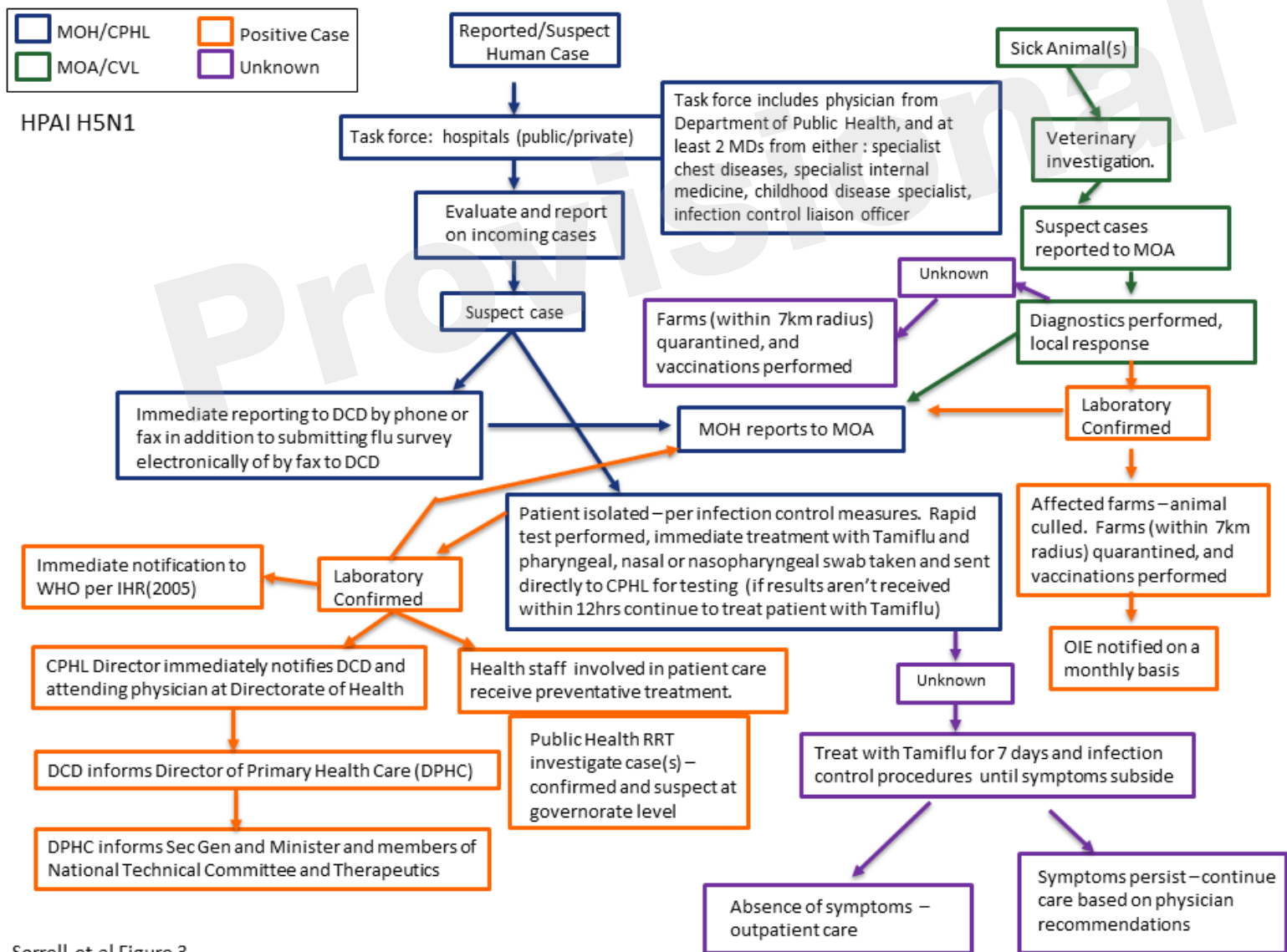


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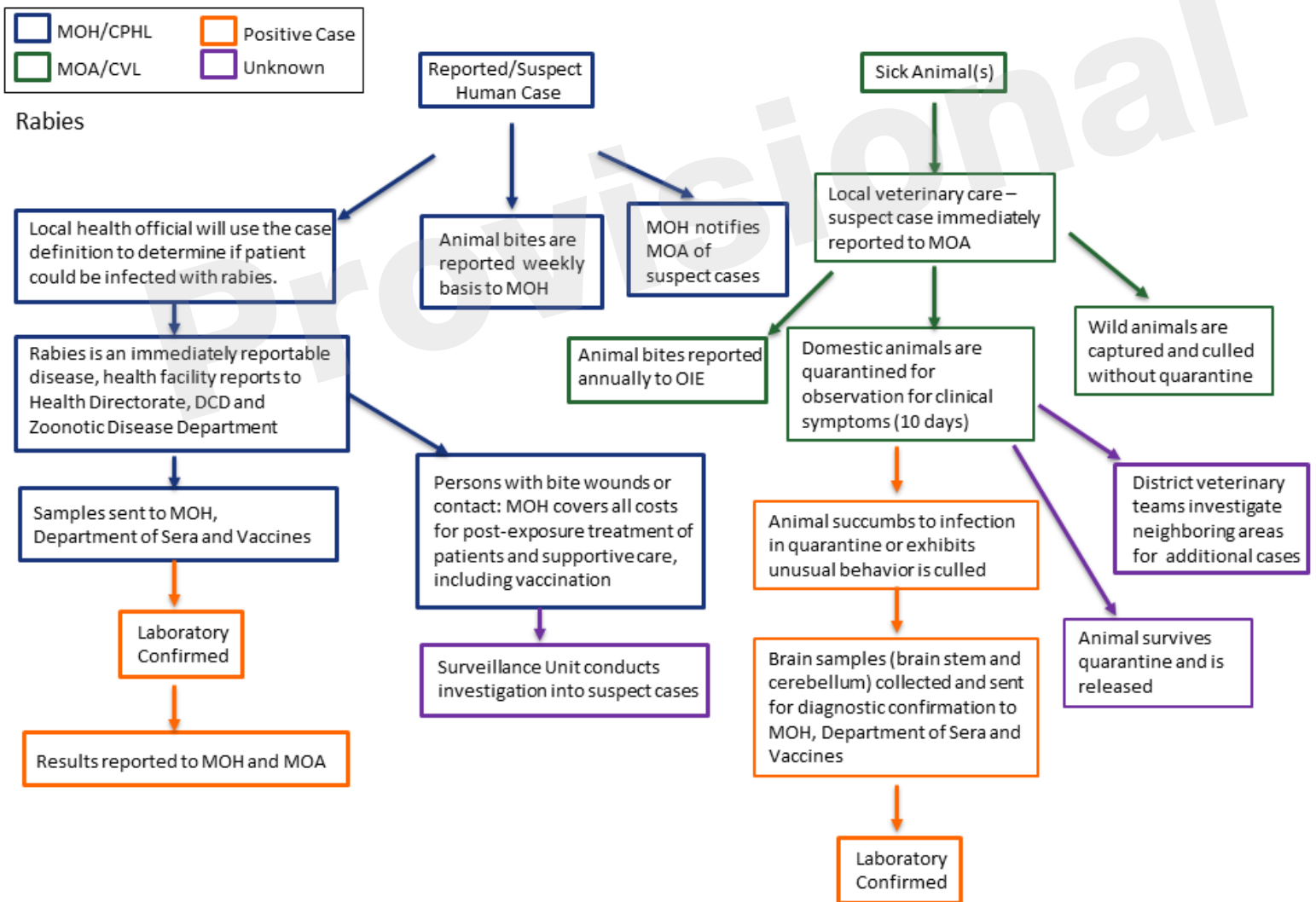


Figure 5.TIF

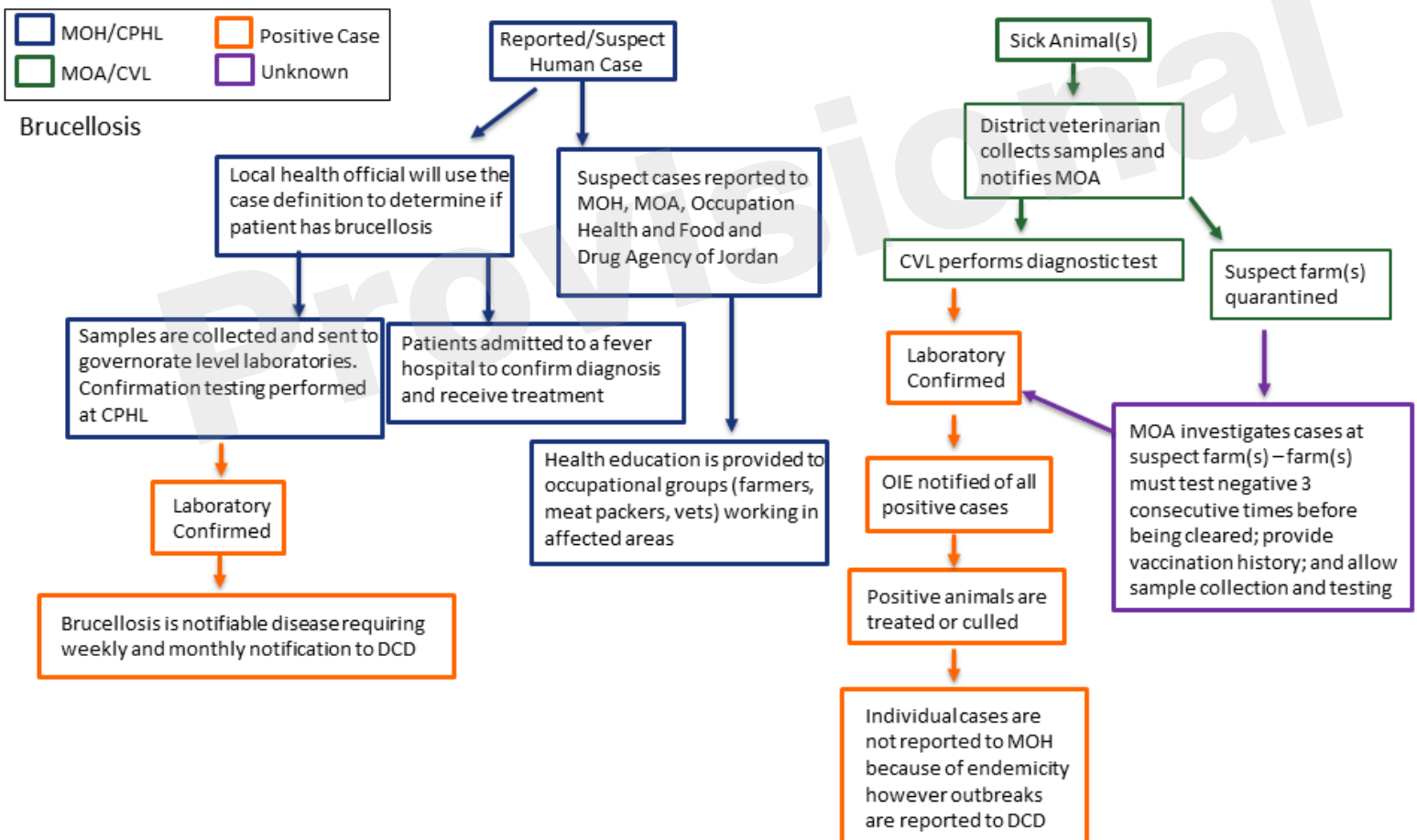




Figure 6.TIF

