LETTER

The next chapter of human–plague science

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In PNAS, Jones et al. (1) provide an expert history of human–plague interactions across central Asia, and we support their thesis that zoonotic systems are best regulated using "control" rather than "eradication" strategies. Nonetheless, a control strategy is incomplete if it fails to acknowledge the critical role that modern biospecimen infrastructure plays in revealing historic and ongoing oscillations of host–pathogen systems. Recent environmental changes unique to central Asia (2), coupled with intensification of cultural and economic exchange in the region (i.e., China's Belt and Road Initiative; ref. 3) demand approaches to pathogen control that are informed by the historic and modern material contained in biorepositories.

Dealing with Zoonotic Systems

Dynamics of most zoonoses largely are driven by complex interactions among climate, environment, and population biology of reservoir hosts and vectors. Jones et al. (ref. 1, p. 2) review the complexities inherent to forecasting and control of plague at the landscape level. Control rather than eradication is sound strategy, but meaningful response to emergent zoonoses increasingly relies on our ability to explore an even broader range of host–species interfaces and to anticipate pathogen adaptive capacity within stochastic and changing natural systems. In an era of both heightened ecosystem modification and human interconnectedness, this task requires baseline information mined from the spatially, temporally, and taxonomically broad data resources held in biorepositories.

A Specimen-Based Approach to Pathogen Response

Specimen collections minimize gaps in the global knowledge base of zoonoses that emerge from changing "political configurations, technologies, and priorities" [Jones et al. (1), p. 3; also ref. 4]. Historic specimens offer definitive records of pathogen occurrence and attributes, informing our understanding of natural and anthropogenically altered disease dynamics in powerful ways, e.g., by revealing host affinities of both well-described (5) and completely novel (6) pathogens. This can shift human response from reactive to proactive and guide deployment of new technologies at multiple spatial scales (i.e., landscape to global; ref. 7). Now-emerging digital networks of specimen-based biodiversity data (e.g., GIBF, iDigBio) serve as a backbone for integrating information about reservoirs, vectors, and pathogens in a spatiotemporally explicit and globally accessible way (8). Extension of these links to archaeological specimens (9) may also help to enrich our understanding of landscape-level plague dynamics on deeper timescales.

Zoonosis Control in a Digital Biodiversity Era

The promise of a biocollections-based approach to zoonosis control depends on collaboration among natural historians, disease ecologists, and biodiversity-oriented data scientists. Because infrastructure and funding are limited in many zoonosis hot spots, we must coordinate the core work of developing spatially and temporally representative specimen collections, including hosts and associated parasites sampled systematically at the global scale (7). These materials must assume a permanent digital presence and remain durably linked to environmental data, host taxonomy, trait and molecular datasets derived from these zoological and archaeological specimens, and public health monitoring and outcomes (10). In these ways, biorepositories can refine future control of zoonoses as we write a new historiography of humans, their pathogens, and effective disease mitigation.

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1 S. D. Jones *et al.*, Living with plague: Lessons from the Soviet Union's antiplague system. *Proc. Natl. Acad. Sci. U.S.A.* **116**, 9155–9163 (2019).
2 E. Lioubimtseva, G. M. Henebry, Climate and environmental change in arid Central Asia: Impacts, vulnerability, and adaptations. *J. Arid Environ.* **73**, 963–977 (2009).
3 J. Xi *et al.*, "Belt and road cooperation: Shaping a brighter shared future" in *Joint Communique of the Leaders' Roundtable of the Second Belt and Road Forum for International Cooperation* (2019). https://eng.yidaiyilu.gov.cn/brficpc.htm. Accessed 6 May 2019.
4 S. Davis *et al.*, Predictive thresholds for plague in Kazakhstan. *Science* **304**, 736–738 (2004).
5 M. J. Hubbard, A. S. Baker, K. J. Cann, Distribution of *Borrelia burgdorferi* s.l. spirochaete DNA in British ticks (Argasidae and Ixodidae) since the 19th century, assessed by PCR. *Med. Vet. Entomol.* **12**, 89–97 (1998).
6 T. L. Yates *et al.*, The ecology and evolutionary history of an emergent disease: Hantavirus pulmonary syndrome. *Bioscience* **52**, 989–998 (2002).
7 D. R. Brooks *et al.*, Finding them before they find us: Informatics, parasites, and environments in accelerating climate change. *Comp. Parasitol.* **81**, 155–164 (2014).
8 D. E. Schindel, J. A. Cook, The next generation of natural history collections. *PLoS Biol.* **16**, e2006125 (2018).
9 M. J. LeFebvre *et al.*, ZooArchNet: Connecting zooarchaeological specimens to the biodiversity and archaeology data networks. *PLoS One* **14**, e0215369 (2019).
10 J. L. Dunnum *et al.*, Biospecimen repositories and integrated databases as critical infrastructure for pathogen discovery and pathobiology research. *PLoS Negl. Trop. Dis.* **11**, e0005133 (2017).