

Science & Society

The Burden of Livestock Parasites on the Poor

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Parasitic diseases of humans and livestock are ubiquitous in the developing world and have substantial impacts on human wellbeing. For the estimated one billion people living in poverty who rely on livestock for their livelihoods, parasites steal valuable nutritional resources through multiple pathways. This diversion of nutrients ultimately contributes to chronic malnutrition, greater human disease burdens, and decreased productivity of both humans and livestock.

The past 15 years have borne witness to unprecedented improvements in health conditions among developing countries. Catalyzed partly by the HIV pandemic around the turn of the 21st century, the global health agenda has evolved from narrowly focused 'vertical' initiatives, such as the Global Fund to Fight AIDS, TB, and Malaria, to a more integrated agenda for improving health systems, as codified by the WHO's six 'building blocks' of health-system strengthening. Support for these efforts was critically bolstered by a growing understanding of their role in broader strategies for economic development, advanced by the Millennium Development Goals. However, even as the global health movement becomes integrated with systems of healthcare in developing countries, there remain substantial blind spots on how these systems of healthcare

interface with complex systems of disease.

Over two billion people still live in poverty (<US\$2 per day) and 800 million experience chronic undernutrition (<http://r4d.dfid.gov.uk/Output/190314/>) [1]. Physical and economic barriers to food access and availability, and the resulting hunger and malnourishment, can have a profound impact on human health and economic productivity. Protein-energy malnutrition, or inadequate calorie and/or protein intake, inhibits long-term physical and cognitive development, and contributes to half of all deaths in children under the age of 5 years [2]. Deficiencies in micronutrients, such as iron and vitamin A, cause debilitating conditions, including anemia and blindness in millions of people, and increase the risk of preterm birth and maternal death [3]. These health outcomes ultimately affect income-generating potential of individuals and, therefore, the economic security of households and communities.

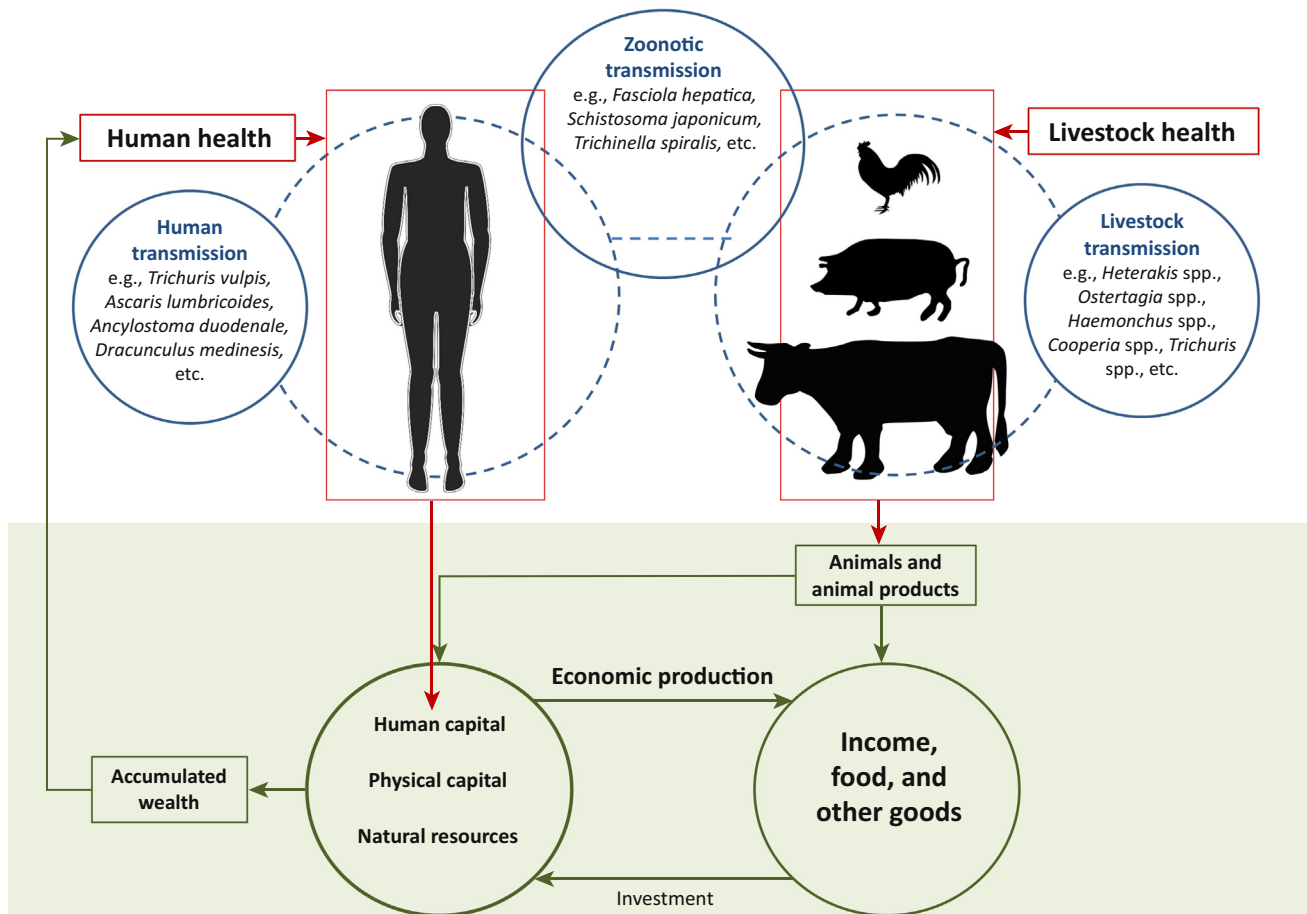
Malnutrition among the poor is generally caused by two forces: (i) inadequate acquisition of nutrients, often due to a lack of access to nutrient-dense foods; and (ii) inhibited uptake or depletion of nutrients due to disease, most often in the form of parasites [4]. While the global health community recognizes that human parasites have an important influence on human health, nutrition, and economic productivity, there is considerably less research on the pathways through which livestock parasites may induce similar outcomes. After all, nearly half of the world's poor rely on domestic livestock to support their economic and nutritional needs (<http://r4d.dfid.gov.uk/Output/190314/>). Livestock production is undermined by parasitic diseases, which inherently compete for scarce resources [5]. Thus, livestock parasites may reinforce traps of poverty, malnutrition, and disease in ways that are directly comparable to human diseases. A better understanding of these relationships can inform the important

work of livestock policy initiatives such as those advanced by the World Organisation for Animal Health (www.oie.int), the International Livestock Research Institute (www.ilri.org), and Vétérinaires sans Frontières (vsf-international.org), among others, to further develop integrated livestock health strategies targeted for poverty reduction.

To understand these relationships, Figure 1 presents a schematic of a coupled system of human health, livestock disease, and economic productivity, which corresponds to model results in Figure 2. In such systems, economists model income generation as a production process, where 'capital' is combined with labor to produce goods, such as food in a subsistence economy (Figure 1, green lines). Capital can be broadly defined as various forms of durable assets that are used to produce benefits over time; and includes physical capital (equipment), natural resources (land), and human capital (knowledge, skills, or health status) [6,7]. For the one billion poor livestock keepers in the world, livestock have a fundamental role in this production process (<http://r4d.dfid.gov.uk/Output/190314/>).

Animals and animal products (meat, eggs, and milk) are sold in local markets to generate income or are available as food for consumption [8]. Livestock can also serve as a direct form of physical capital when used for draught power or when manure is used to improve soil fertility and increase crop production [8].

Given that healthy humans are an important part of this production process (Figure 1, red lines) [6], parasitic diseases that impact human health lower economic productivity and reduce wealth accumulation, which further undermines health status. Livestock serve as another living form of capital in the system, and so the burden of livestock parasites is an extension of that of human parasitic disease. Given the multiple indirect pathways by which livestock contribute to economic production, nonzoonotic livestock parasites (which represent most livestock



Trends in Parasitology

Figure 1. The Impact of Parasites on Human and Livestock Health, and Economic Productivity. The health of humans and livestock (in red) directly impacts their capacity to contribute to economic production (in green). Economic production is the process by which inputs in the form of human capital, physical capital, and natural resources are used to generate outputs in the form of income, food, and other economic goods. These outputs can be re-invested to generate wealth when economic productivity is high. In these systems, human health and livestock are important forms of human and physical capital respectively. Animals and animal products contribute as both inputs and outputs of the production system. Parasitic diseases (in blue) impact human and animal health, and reduce economic production through multiple pathways. When economic production is severely affected, wealth cannot accumulate and the ultimate result is persistent poverty and disease.

parasites) may be even more important to human health than zoonotic parasites, such as echinococcosis, foodborne trematodiasis, cysticercosis, and zoonotic schistosomiasis [9], that contribute directly to human disease [10].

The system described by Figure 1 can be explicitly modeled by coupling existing models of disease, livestock, and economic dynamics, variations of which have been presented elsewhere [11,12]. For heuristic purposes, Figure 2 presents the results of a stylized version of this system where both zoonotic and

nonzoonotic livestock diseases are shown to influence human disease prevalence and income. The key features of such models are that the various forms of capital are used for generating income, and that income is in turn used to accumulate capital and reduce human disease (by decreasing exposure or increasing rates of recovery or treatment). As the transmission of livestock diseases rise (Figure 2, left-hand column), the prevalence of human disease increases in the presence of both zoonotic and nonzoonotic disease (Figure 2C), while income is lost (Figure 2E). Conversely, as rates of clearance (or

recovery) of livestock disease increase, the prevalence of human disease falls (Figure 2D) and income rises (Figure 2F). While these are only theoretical results, rather than empirical estimates, they provide a formal foundation for how livestock parasites influence such systems through multiple pathways that are comparable to human parasites. They also provide simple implications for policy interventions that reduce livestock disease transmission or increase rates of disease clearance.

Given the clear importance of livestock health on human wellbeing and economic

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