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Opinion

Integrating One Health into Systems Science

Pamela A. Burger *

University of Veterinary Medicine Vienna, Research Institute of Wildlife Ecology, Savoyenstrasse 1, 1160 Vienna, Austria

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1. General context: One Health and Systems Science in the anthropocene

Most of the major challenges we are facing in the Anthropocene are systemic and demand innovative, holistic and efficacious problem-solving strategies. One Health and Systems Science are transdisciplinary approaches that deal with the complexity of natural, social and other systems. While One Health aims to sustainably balance and optimize the health of ecosystems, people and animals [1], the concept of Systems Science is rather multidimensional comprising many different fields spanning cognitive, physical, social and technological systems. In its simplest form, a system is an arrangement of interacting parts that together exhibit properties that the individual constituents do not. In a more complex form, an adaptive system has many interrelated subsystems, components or agents, that interact with a dynamic environment that itself is a system of systems [2] (Fig. 1). This Opinion article shows the One Health concept integrated into Systems Science and illustrates how Systems Thinking and Systems Dynamics can help to design interventions, e. g., ecosystem conservation and health management actions, for a sustainable change in One Health outcomes.

2. What exactly is One Health Systems Science

One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent [1]. Systems Science is a transdisciplinary approach that deals with the complexity of natural, social and other systems [3]. Treating One Health together with its subsystems (ecosystem, people and animal health) as a complex system within the Systems Science concept opens doors for finding answers on how interventions (Systems Design) can generate a sustainable change in One Health outcomes (Fig. 1). To fulfil the ambition of the One Health concept, it will need sound theoretical underpinnings for its problem solving and action planning, and Systems Science provides the right source for that foundation.

3. The theoretical concepts behind Systems Science

The Systems Sciences are relevant to a multitude of fields including Cognitive Systems, Living Systems, Physical Systems, Social Systems and Technological Systems, but the most fundamental theoretical concepts are:

General Systems Theory. The complexity and importance of General Systems principles was first developed in 1956 by von Bertalanffy, who recognized that principles like organization, wholeness, directiveness, teleology, control, self-regulation and differentiation are intrinsic in biological, behavioural and social systems, and indispensable in living organisms or social groups [3]. This led to a scientific paradigm shift from seeing the world comprised of independent objects towards an understanding of adaptive systems with components and agents (Fig. 1).

* Corresponding author.
E-mail address: pamela.burger@vetmeduni.ac.at.

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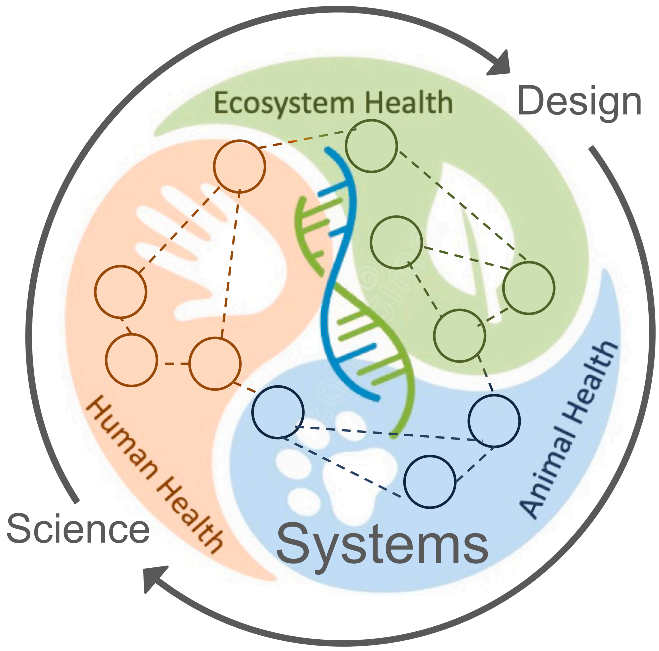

Fig. 1. One Health Systems Science. The three subsystems of One Health (ecosystem, human and animal health) are integrated in the Systems Science concept, where objects or adaptive agents (circles) interact with a dynamic environment, and Systems Thinking can lead to interventions (Systems Design) generating a change in One Health outcomes. Real-time genomic data retrieved from the three subsystems provide information for Systems Thinking and Systems Design.

The attributes and performances of those interdependent units are influenced by their internal organization as well as by ongoing and circular interactions between them and their environments. General Systems Theory was seen as a way to open up and overcome divisions between scientific disciplines, and to find answers to challenges of social inequity and existential risks of the modern world [4]. To achieve the One Health vision, the specialized disciplines have to find ways to communicate effectively and cooperate constructively. General Systems Theory can provide a toolkit for supporting this via a common ground of concepts and principles.

Systems Thinking aims to identify and understand the elements, components and agents of a system, e. g., the factors that influence health and disease in a population within its ecosystem (One Health). Putting together Big Data information from a multitude of fields, a broader picture can be achieved on how individuals and other agents of a system are interconnected in scenarios in which researchers cannot control the environment, but can thus influence how events further unfold [5].

Systems Dynamics recognizes the connections between subsystems and characterizes the interactions between their changing attributes and internal system behaviour. Systems dynamics models aim to describe the structure of a system that reflects the key characteristics of a dynamic problem independent of exogenous factors. A Systems Dynamics approach allows transdisciplinary research of complex social, managerial, economic, and ecological systems, ultimately One Health systems, which are characterized by interdependent components, mutual interaction, information feedback loops, and circular causalities [6]. *Systems Design* represents a multitude of general methods, practices and applied fields that focus on finding solutions or interventions that can generate a change in the outcomes of complex (One Health) systems. As such, Systems Design acts as a bridge between descriptive research and putting scientific solutions into practice [2]. Methodological approaches within Systems Science include Big Data techniques (e. g., real-time genomics), classical thermodynamics, chaos theory, complexity theory, cybernetics, information theory, network science, micro-simulations, multi-agent modelling, and theory of autopoiesis [2].

4. How big data like real-time genomics contribute to One Health Systems Science

Big Data techniques include, amongst other large data sets, real-time genomic analyses employing DNA sequencing with nanopore technology. Nanopores are tiny protein pores that enable the sequencing of nucleotides in "real-time" by rapidly translating characteristic disruptions of the ionic current of the DNA or RNA passing through the nanopore into genomic data [7]. The latest tools for providing such sequencing (e. g., the instruments from Oxford Nanopore Technology) could be crucial for One Health genomic surveillance as time critical information like pathogen identification is provided immediately through real-time data streaming. By retrieving simultaneously the genomic information of environmental, plant and animal samples, we can capture not only the host (species-specific) DNA but also (zoonotic) pathogens that can influence animal and human health (Fig. 1). At the same time, complete haplotypes of the immune response genes and microbiomes together with antimicrobial resistance genes can be identified. Combining the host genomic data with geographic records allows to model opportunistically expanding species distribution under different climate scenarios. Adding vector presence, climate and landscape data facilitates early risk factor assessment for potentially zoonotic pathogen spread and transmission routes. This accelerates the development and implementation of more locally, specific disease control strategies, medical response and vaccine development to safeguard ecosystems and alleviate future pressures on animal and human health. As such, One Health (real-time) genomic surveillance can help inform public health management. Considering global food security as linked to many One Health-related problems, portable nanopore sequencing can be used to generate genome reference data for indigenous or local crop species within the countries or by detecting plant diseases and pests rapidly, reducing harvest loss and increasing economic stability. In-situ real-time genomics further has been applied in wild-life forensics and illegal wildlife trade for rapid species identification and determining the potential geographic origin of confiscated samples [7]. Finally, metagenomic surveillance of non-invasive air, water and soil samples can be used to describe the natural environmental microbiome, and to recognize the relationship between anthropogenic, climatic and ecological change, completing the One Health Systems Science circle.

5. Future challenges of One Health Systems Science

Most of the challenges we are facing in the Anthropocene are systemic and rooted in the close connection between humans, animals and the shared environment. Multiple sectors at different levels of the society need to cooperate under important key principles like (i) equity between sectors and disciplines, (ii) socio-political and multicultural parity, (iii) socioeconomical equilibrium acknowledging the importance of biodiversity and the intrinsic value of all life within an ecosystem, (iv) stewardship to adopt sustainable solutions for securing the well-being of future generations, and (v) transdisciplinarity and multisectoral collaboration [1]. One Health Systems Science can address complex challenges via *Systems Thinking* – identifying interdependent components and adaptive agents, *Systems Dynamics* – understanding the structure and connectivity within and between components, and *Systems Design* – finding solutions for a sustainable change. Consequently, Systems Thinking and Systems Design are interconnected with One Health and can meaningfully contribute to achieving many of the 17 sustainable development goals (SDGs) adopted by the United Nations in 2015 (https://sdgs.un.org/goals), particularly SDG 1 | No Poverty, SDG 2 | Zero Hunger, SDG3 | Good Health and Well-Being, SDG 14| Life Below Water, SDG 15 | Life on Land, and SDG 17| Partnerships for the goals.

CRediT authorship contribution statement

Pamela A. Burger: Conceptualization, Funding acquisition, Visualization, Writing – original draft.

Declaration of competing interest

The author declares that there is no conflict of interest.

Data availability

No data was used for the research described in the article.

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