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QUESTION AND ANSWER Open Access

Q&A: What are pathogens, and what have they done to and for us?

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Abstract

Microbes are found on us, within us and around us. They inhabit virtually every environment on the planet and the bacteria carried by an average human, mostly in their gut, outnumber human cells. The vast majority of microbes are harmless to us, and many play essential roles in plant, animal and human health. Others, however, are either obligate or facultative pathogens exerting a spectrum of deleterious effects on their hosts. Infectious diseases have historically represented the most common cause of death in humans until recently, exceeding by far the toll taken by wars or famines. From the dawn of humanity and throughout history, infectious diseases have shaped human evolution, demography, migrations and history.

What is a pathogen?

A pathogen is defined as an organism causing disease to its host, with the severity of the disease symptoms referred to as virulence. Pathogens are taxonomically widely diverse and comprise viruses and bacteria as well as unicellular and multicellular eukaryotes. Every living organism is affected by pathogens, including bacteria, which are targeted by specialized viruses called phages.

The number of viruses and bacteria on earth is staggering and they occupy essentially every environment. A liter of surface seawater typically contains in excess of ten billion bacteria and 100 billion viruses. The number of viruses on Earth is estimated to be around 10^{31}, which corresponds to roughly ten billion times the number of stars in the universe [1]. An average human is made up of about 30 trillion cells but carries a similar number of bacteria, mostly in the gut [2].

The vast majority of viruses and bacteria we are exposed to have no negative effect and some can even be beneficial, though a tiny fraction of these can severely affect our health. Specifically, about one in a billion microbial species is a human pathogen. Indeed, approximately 1400 human pathogens have been described, whereas it has been estimated that there are one trillion microbial species on Earth, the vast majority of which remain uncharacterized [1].

What is the relationship between pathogens and hosts?

Pathogens can be divided into two main categories, namely facultative and obligate pathogens, reflecting how intimately their life cycle is tied to their host.

Facultative pathogens are organisms for which the host is only one of the niches they can exploit to reproduce. Facultative pathogens are primarily environmental bacteria and fungi that can occasionally cause infection. They include many of the most problematic hospital-acquired bacteria involved in the antimicrobial resistance pandemic. A distinction is sometimes made between facultative and accidental pathogens, with the latter representing those which only occasionally infect weakened or immunocompromised hosts. Typical examples of 'accidental' pathogens include *Neisseria meningitidis* or *Escherichia coli*.

Obligate pathogens require a host to fulfil their life cycle. All viruses are obligate pathogens as they are dependent on the cellular machinery of their host for their reproduction. Obligate pathogens are found among bacteria, including the agents of tuberculosis and syphilis, as well as protozoans (such as those causing malaria) and macroparasites.

Some obligate pathogens require multiple different hosts to fulfil their life cycle. The definite host, which supports the adult form of the pathogen, is often a vertebrate and the intermediate host (referred to as a vector) is generally an arthropod or a mollusc. This alternation of vertebrate and invertebrate hosts is found in viruses (for example the Zika virus), bacteria (for example Lyme disease) and protozoa (malaria). Trematodes (parasitic flatworms) go even further and some exhibit among the

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