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As the World Warms - Diseases will Spread:
How climate change affects distribution of infectious diseases

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Humans have, for a very long time, been aware of the effect that the climate has upon the spread of infectious diseases. In ancient Rome, the higher class of society escaped to their homes in the mountains during summer to avoid the bite of malaria-carrying mosquitoes and, in the United States, a terrible yellow fever outbreak was heralded by one of the worst episodes ever recorded[1] of El Niño, the abnormal warming of the Pacific Ocean.

We, as a world, are also now fully aware of the destructive effect that human habitation has had upon our planet. We are witnessing an increase in global temperatures, melting ice caps, rising sea levels and the increase in pollutants in our atmosphere. Another serious effect that develops alongside the damage to our native environment is the increase of infectious diseases, through migration of animal vectors which transmit these diseases and the increasing temperatures of contaminated food and water sources. Neglected tropical diseases, such as leishmaniasis, dengue and schistosomiasis, affect 2 million, 400 million and 240 million people respectively per year - wreaking havoc on the communities in which they are endemic. If increasing global temperatures causes migration of the vectors that transmit these diseases, it could be seriously detrimental to the health and wellbeing of areas of the world hitherto unaffected.

Vector-Borne Disease

Many vector-borne diseases require an arthropod species to spread[2]. Examples of some arthropod vectors and the infectious diseases that they can transmit are represented in Figure 1, including neglected tropical diseases such as African Sleeping Sickness, Leishmaniasis and Dengue fever. Arthropods are a type of invertebrate animal which are so small that they lack effective mechanisms to regulate their body temperatures (thermoregulation) and can only live where the environment is warm enough for them[1,3]. This dependence on climate is extremely important to consider when studying the spread of infectious diseases.

Vector-borne neglected tropical diseases such as dengue are detrimental to the health of people living in the global south, such as countries throughout Africa and South-East Asia. Dengue, which is spread through the bite of an infected mosquito, can cause serious illness and 1 in 4 people infected will become sick. Severe infection can become life-threatening in just a few hours, although most cases will improve within a week. Over 4 billion people currently live in risk areas for dengue virus infection. However, if the mosquito that carries this infection spreads into other new areas, this number will inevitably rise[4].

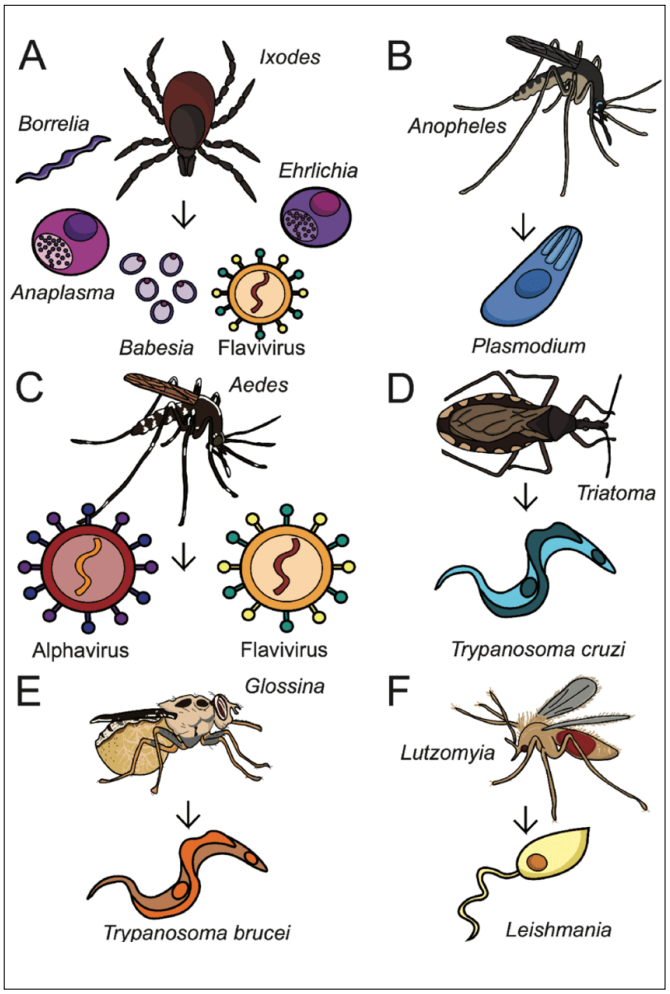

Figure 1: ***Examples of arthropod insect vectors and their associated infectious agents.***

A: The tick *Ixodes* can carry three bacteria: *Borrelia* (which causes Lyme disease), *Anaplasma* (causing anaplasmosis) and *Ehrlichia* (causing ehrlichiosis). In addition, the tick can transmit the parasite *Babesia* (the causative agent of babesiosis), and also the family of Flaviviruses (causing Yellow fever, Dengue fever, Japanese encephalitis, West Nile disease and Zika). B: The *Anopheles* mosquito can carry the parasite *Plasmodium* (which causes malaria). C: The *Aedes* mosquito can carry the families of Alphaviruses (causing various diseases that attack the brain) and Flaviviruses. D: *Triatoma,* also known as the Kissing Bug, can carry the parasite *Trypanosoma cruzi* (causing Chagas disease). E: The *Glossina* Tsetse fly can carry the parasite *Trypanosoma brucei* (causing African Sleeping Sickness). F: The sandfly *Lutzomyia* can carry the parasite *Leishmania* (the causative agent of leishmaniasis).
Source: O'Neal, Anya & Butler, L. & Rolandelli, Agustin & Gilk, Stacey & Pedra, Joao. (2020). Lipid hijacking: A unifying theme in vector-borne diseases. eLife Sciences. 9. 10.7554/eLife.61675.

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High minimum temperatures during heatwaves speed up the reproduction of vectors and can be linked to outbreaks of disease[5], as was observed during the heatwaves in Romania and Israel in 1996-1997 and 2000 respectively, causing a spike in cases of West Nile disease[6]. Different vectors favour different climates and conditions - such as temperature, rainfall and day-length[7] which affect their breeding, hatching and biting seasons. Understanding how climate drives the life cycle of these vectors can guide public health policy through timed spraying of insecticides to kill larvae before they develop into biting adults[5]. Modelling the effect of climate on the breeding and migration patterns of vectors will also prove extremely useful as temperatures increase, allowing health officials and scientists to predict the potential areas where infection will become a serious problem.

Europe has always been home to many vector-borne diseases. As the continent has become more urbanised, however, the conditions suitable for vectors to develop have reduced. Dengue, which is one of the most devastating viral diseases in the world, is nearly absent from Europe because of the standardized use of piped water systems[8]. Colder climates also restrict the opportunity for vectors to breed but, as can be seen in Figure 2, the average temperature throughout Europe has increased in the last century and shows no sign of slowing down. In July 2022, the United Kingdom recorded its highest ever temperature of 40.3 °C [9], compared to an average temperature of 15.5 °C in July in 2000[10] .

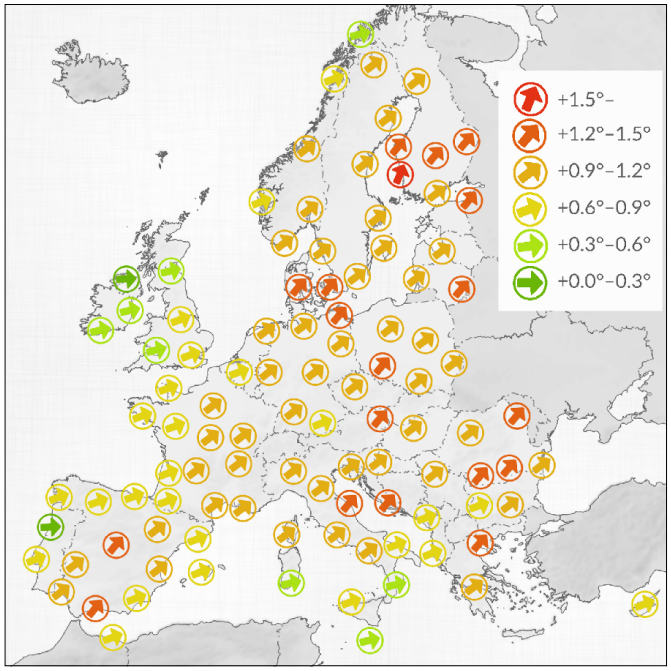

Figure 2: Average temperature increases over the continent of Europe from 1900 – 2017.

Source: Kayser-Bril, Nicolas (24 September 2018). "Europe is getting warmer, and it's not looking like it's going to cool down anytime soon". EDJNet. Retrieved 25 September 2018.

The freshwater snail is a mollusc vector which transmits the disease schistosomiasis (Figure 3). These snails are very sensitive to temperature, as are the parasites that infect them. This limits the bodies of water in which this parasitic disease can thrive[11]. The infection rates for this parasite increase along with temperature, and the optimum temperature range for transmission in most parts of Africa is between 22-27°C[12]. Currently, lochs and lakes in the United Kingdom are nowhere near that temperature year-round. Monitoring of Scottish loch water temperatures during 2015-2019 has, however, shown an increase in the average temperature of 97% of the bodies of water tested. The temperature of 88% of lochs rose between 0.25-1°C per year, while 9% increased by 1.3°C[13]. With this trend, it is possible that, in the next 50 years, all lochs and lakes throughout the UK could be warm enough to be an attractive home to the freshwater snails that carry the schistosome parasite.

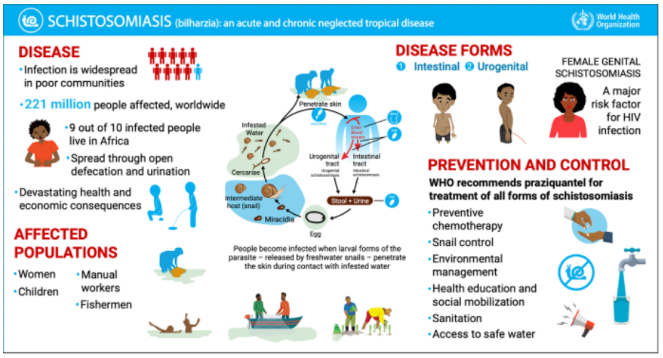

Figure 3: General Information about the Neglected Tropical Disease Schistosomiasis.

Source: https://www.who.int/health-topics/schistosomiasis

Food- & Water-Borne Disease

Higher temperatures can also affect the transmission of food- and water-borne illnesses by reducing incubation times for food-borne illnesses, such as that caused by *Campylobacter jejuni*, the main cause of gastrointestinal bacterial disease worldwide, and *Salmonella* spp, the second-leading cause of food-borne illness worldwide[2]. Both infections cause diarrhoea, fever, stomach cramps and nausea. Fresh meat and meat produced by intensive farming account for almost 50% of all *Campylobacter jejuni* infections and, as temperatures rise, the susceptibility of mass-farmed chickens to infection rises as well. An increase in ambient temperature has a proven association with an increase of salmonellosis of 5-10% for each degree increase in the weekly temperature[14].

A temperature increase has also been linked to an increase in some water-borne illnesses such as cholera, caused by the bacterium *Vibrio cholerae*. This bacterium is transmitted indirectly through the water by attaching itself to zooplankton which feed on phytoplankton. A rise in water temperature increases the phytoplankton food supply which in turn increases the abundance of zooplankton and, by association, the cholera bacteria. As temperatures rise, cholera outbreaks are more likely to occur[15]. Human impact on the planet, causing changes in climate patterns with more intense monsoons and flooding, will increase the access this bacterium has to human populations[16]. Extreme climate events such as droughts can also have an effect on the potential for some water-borne infections. From a recent study in the UK, it was found that 20% of water-borne outbreaks of *Cryptosporidium*, which is a parasite that causes diarrhoeal disease, were associated with an extended period of low rainfall[17]. Drought conditions cause river levels to drop, increasing the concentration of the pathogen that water treatment plants need to filter out, something they cannot always do successfully[18,19].

Changes in climate will have a continual and significant impact on the transmission and abundance of infectious disease. Continuous monitoring and analysis of infectious disease outbreaks will reveal the effect that increasing temperatures and changing weather patterns are having on the distribution of disease. This will allow scientists and public health officials to be better prepared to combat serious outbreaks and epidemics in the future.

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