Rift Valley fever virus (RVFV) is a mosquito-borne Bunyavirus that currently affects livestock and humans, causing a wide spectrum of symptoms. RVFV was confined to the African continent for many decades and spread to the Arabian Peninsula in recent history. The potential for widespread emergence into new regions and populations is possible and likely, as many outbreaks are driven by human behaviour and livestock trade. While many imported human cases have been detected, establishment of the virus in new geographic areas will depend on amplification in dense animal populations. Western and European countries have identified a substantial risk for the emergence of RVFV, as agricultural industries constitute a large percentage of the global economy.

Recent emergence

Throughout the last decade, the unanticipated emergence of viruses has caused significant immediate and long-term hardships for people worldwide. West Nile virus emerged in the Americas in the early 2000s and was marked by the onset of severe neurological symptoms in thousands of patients. The rapid spread of chikungunya virus to populations throughout South America, the Caribbean and the Mediterranean in 2013 and 2014 led to the infection of hundreds of thousands of individuals, some of which are still suffering from long-term sequelae. By 2015, South America and territories in the Caribbean were experiencing an explosive outbreak of Zika virus that was presenting with previously unreported symptoms and consequences, such as severe congenital effects and neurological complications. There are many viruses which have been isolated to specific regions or ecosystems for decades, such as RVFV, that, with the right conditions, may emerge in larger sections of the world and cause extensive disease burden. The development of this disconcerting trend of sudden and broad emergence of viruses is due to a number of human-related factors, and is not anticipated to slow in the future.

Emergent history of Rift Valley fever virus

The first report of RVFV was published in 1931, and documented disease in humans and livestock in the Great Rift Valley region of Kenya. Cases of RVFV were limited to the African continent, primarily affecting sub-Saharan Africa, until the early 2000s, when outbreaks were detected in Saudi Arabia and Yemen. Madagascar has been endemic for RVFV since its introduction to the island in 1979, followed by significant outbreaks with devastating loss in livestock populations in 1990 and 2008.

Imported cases have been reported in the UK, Europe and more recently in China. It is thought that the recent Zika virus outbreak in Brazil that spread throughout the Americas was caused by imported cases tied to large sporting events.

One Health and factors influencing disease transmission

There are four major categories of factors that influence local and widespread transmission of a virus. The first category is the vector, or a living organism that physically transmits the infection from one individual to the next. In many of the more recent outbreaks, mosquitoes are responsible for transmission. In many cases of mosquito-borne disease, the vector is species specific, meaning that only one or a few species of mosquitoes are able to carry and transmit the virus, and that the virus is dependent on the presence of the vector to continue the cycle of infection to new populations. RVFV is transmitted by many species of mosquitoes, and conserved in populations by vertical transmission, wherein a female mosquito transmits the virus to her offspring during egg laying.

The second category is the possible host, which is also species specific. For viruses that infect humans, factors that may contribute to the risk of infection...
can include biological sex, age, socioeconomic status (SES), occupation, behaviour and the type of access to fundamental resources, such as water, nutrition and sustenance, and sanitation. Mobility and ease of travel, specifically with air travel, has had a significant impact on disease transmission and viral emergence because humans can carry the pathogens in their blood to a new place where the vectors exist. Additionally, human proximity to animals, through human encroachment into forest or natural areas for personal or industrial use, increases risk of exposure, as many viruses are zoonotic, and have evolved to infect both humans and certain species of animals. RVFV infects both humans and domesticated livestock, and occupational exposure, especially for individuals who work in abattoirs and handle a large amount of animal carcasses and blood products, has been proven to increase the risk of infection.

The third category is climate and environmental conditions, which directly impact where and how humans, animals and vectors live and thrive. The impact of our immense human population on the planet has reduced the availability of natural resources, and promoted irreversible changes to climate conditions. Gradual changes to climate contribute to overlaps in vector environment and human environments. Past outbreaks of RVFV have been linked to periods of heavy rainfall. Fluctuations between drought and heavy rains leads to water collection near homesteads, whether for specific use in cooking or bathing, or as passive water collection in structures and man-made containers around the home. Water collection near the home provides mosquitoes with new places to breed within close proximity to humans, making it easier to feed without flying too far from their breeding sites.

The fourth category is comprised of the molecular elements of the virus. Mutations in the viral genome drives the evolution of viruses into new vectors, reservoirs and hosts, and thus increases the chance of outward spread. The viral genome of RVFV has been mostly conserved, despite its prominent history throughout Africa and movement to the Arabian Peninsula.

These four categories impact disease transmission on a personal level, and are directly related to the health of the planet, or the 'One Health' concept. The interconnected nature of these four categories is built on dependence, in such that changes to one category drives a response or an adaptation in another. For example, vertical transmission in mosquitoes preserves new generations of mosquito populations with RVFV intact. Heavy rains can reanimate eggs preserved during a drought or dry season, not only increasing the mosquito population as larvae hatch and develop, but also increasing the likelihood of an outbreak.

These images illustrate how native Kenyan and NASA-funded scientist Assaf Anyamba and a team of collaborators from NASA Goddard Space Flight Center, the Walter Reed Army Institute of Research, the World Health Organization, the United States Army Medical Research Unit-Kenya, and the United States Department of Agriculture used satellite data to predict an outbreak of Rift Valley fever in late 2006. The top image shows vegetation growth in December 2006 compared to average growth in previous Decembers from 1998 through 2006 as seen by France’s SPOT satellite. Areas where plants were growing far more than average are dark green, while less-than-average growth is represented in brown. This information served as a proxy for the conditions that accompany an outbreak of Rift Valley fever. The lower image shows the risk map Anyamba and his colleagues created based on satellite data of rainfall and vegetation. Regions where an outbreak of Rift Valley fever might be expected based on high rainfall and higher-than-average plant growth are red. Adjoining regions, where the disease was less likely to appear based on satellite data, are green. The locations of reported human cases between September 2006 and May 2007 are marked with circles on the risk map. Those cases that fell into the risk area are yellow, while those that fell outside the risk area are blue. Credit: NASA images created by Jesse Allen, using provided by the United State Department of Agriculture Foreign Agriculture Service and processed by Jennifer Small and Assaf Anyamba, NASA GIMMS Group at Goddard Space Flight Center. Caption by Holli Riebeek. Source: https://earthobservatory.nasa.gov/
**The effects of emergence**

Human RVFV infections may present with a wide range of symptoms and sequelae. Many patients report mild fever and non-specific flu-like symptoms, joint and muscle pain, diarrhoea, jaundice and delirium. Mild forms of Rift Valley fever (RVF) are often misdiagnosed as meningitis, as muscle pain and stiffness concentrated in the neck with delirium are too general to differentiate without differential diagnosis. Approximately 8–10% of cases experience severe disease, which can include ocular lesions and partial or complete loss of vision, meningoencephalitis and significant neurological complications, and haemorrhagic fever. RVF has also more recently been linked to spontaneous abortion.

While the mortality rate of RVFV infection is only 1% overall, experience of severe disease can increase the risk of death to 50% if proper monitoring and symptomatic treatment is not received. Asymptomatic cases are common with RVFV infection, yet are an important factor in disease transmission, as mosquitoes can pick up RVFV from an infected person who is not experiencing disease symptoms, and spread the virus to other individuals. Some theorize that asymptomatic cases of infections are often the most dangerous, as asymptomatic individuals are the least likely to access treatment or enforce precautions to limit further spread of the infection, due to the lack of diagnosis.

Animals experience sudden and widespread RVF disease, making livestock populations ideal amplifying hosts, and increasing risk for transmission to humans. RVF cases in animals, especially common in species of sheep, goats, camels and cattle raised as livestock, appear rapidly with distinct symptoms. Spontaneous abortion is the most significant and indicative experience of RVFV infection in animals. Sudden deaths and large population die-offs are common, with younger animals extremely susceptible to death because of infection. Febrile disease and prostration are more common in adult animals, with a possibility of acute hepatitis and jaundice. The loss of livestock may be devastating for families that are dependent on their stock for sources of food and milk.

RVFV outbreaks in both humans and animals have devastating impacts on economies dependent on livestock. The loss of yield of *in utero* animals and younger generations of animals can be difficult to recover from, causing decreased income for years. Cases in adult animals introduce a high risk for humans, as many of these animals are sent to slaughter, and infected products, such as meats, milk and blood, can be distributed widely through trade and sales. Livestock trade between regions has been a driving force for past RVFV outbreaks, assisting the virus in travelling to new regions to infect naïve populations of animals and humans without immunity to RVFV.

One of the best measures used to control the spread of RVFV has been the enactment of trade restrictions and sanctions when infected animals are detected. The duration of limitations and temporary bans after the detection of an infected animal or stock depends on the local restrictions associated with import and export. Strict limitations and fines can decrease the spread...
of RVFV through animal trade and other livestock economies, but has devastating consequences on local economies leading to illegal trade and use of products from infected animals.

**Rising risks in the West**

With the unanticipated spread to the Arabian Peninsula in 2000, Europe and the United States have increased livestock importation restrictions with regulated surveillance checkpoints and bans on imports from countries with reported cases of RVFV. Establishment of RFVF in the United States or Europe would require considerable populations of amplifying hosts (livestock), and environmental conditions to support thriving populations of the vector. The United States already has several mosquito species that could support autochthonous, or local transmission of RVFV.

While the spread of RVFV doesn’t pose a huge threat of infection in the human population, it would have explosive impacts on animals in the United States. The USDA has identified RVFV as a significant threat to the expansive agricultural industry in the United States, as introduction of RVFV to the United States could cause catastrophic damage to individual farmers and the country’s economy. As seen with prior outbreaks, RVFV is difficult to control and contain once livestock populations are exposed. Additionally, the livestock industry in the United States has been designed for high volume population rearing, for the maximization of product and economic benefit leading to decreased resistance to diseases. Many industrial farming facilities also confine animals in restricted pens, which increases the risk for extensive disease spread within a facility. The common use of prophylactic antibiotics in factory and industrial housing facilities to reduce the risk of exposure to bacterial infections in animal populations illustrates the emphasis on product volume.

An animal vaccine is currently available in Africa, yet the efficacy and ultimate pay off of vaccinating is not widely recognized. Vaccine boosters are required regularly, and can be costly and hard to justify if the perceived risk is low. Additionally, side effects of the vaccine mimic symptoms of the disease and spontaneous abortion can still occur. Often, perceptions of the risks of administering the vaccine outweigh the perceived risk of disease in a healthy herd.

Given the recent increase in disease emergence, many reports have warned of the risk of RVFV emergence. RVFV is a potential candidate for more frequent outbreaks and movement into naïve populations. The imported case identified in China earlier this year highlights the vast distance that viruses can travel with ease, and suggests that further spread is imminent. We all need to be on high alert for emergence of this significant One Health threat.

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**Further reading**