Even viruses can be beneficial microbes

Although viruses are almost always thought of as pathogens, most viruses probably do not cause disease, and some provide essential benefits to their hosts. Beneficial viruses are found in a wide variety of hosts including bacteria, insects, plants, fungi and other microbial eukaryotes, and humans and other animals. Beneficial viruses can confer tolerance to stress such as heat, cold and drought; they can prevent or attenuate infection by pathogenic microbes; they can act as bio-weapons to allow their hosts access to new territory; and they have been critical in the evolution of their hosts. In spite of their bad reputation, viruses could be used to benefit humans and their food sources in novel ways.

Almost everything we know about viruses is related to their ability to cause disease in humans and their domesticated plants and animals. Recent metagenomics studies demonstrate the abundance of viruses in many different environments, and suggest that causing disease is not the normal lifestyle of viruses, and that most are probably benign1-3. Some are clearly beneficial4.

Why do we have such a bias in the scientific literature? The first described virus, Tobacco mosaic virus, caused disease in plants5. Perhaps this set the stage for viruses as malevolent agents, but listening to the news shows us that humans are inherently fascinated with the bad rather than the good. In addition, because viruses have been responsible for some very serious human diseases, such as polio, influenza, and AIDS, almost everyone is aware of their potential for devastating effects.

The most well known beneficial viruses are insect viruses. The polydnaviruses (from poly, many, DNA segments) are found in thousands of species of parasitoid wasps. The wasps lay their eggs in caterpillars, and deposit virus particles along with the

Figure 1. Drought tolerance in rice. Rice plants were subjected to several days of water withdrawal. The plant on the left is infected with Cucumber mosaic virus, the plant on the right is uninfected. Photo courtesy Ping Xu.
eggs. The viruses encode genes that suppress the immune system of the caterpillars, and this allows the wasp eggs to develop. This relationship between wasp, virus and caterpillar has been going on for so long that some of the virus genes are incorporated into the wasp genome.

Other insect viruses have similarly amazing stories. For example, some aphids can be infected with a virus that changes them from rapidly reproducing wingless morphs to winged morphs with lower reproduction rates. The virus is vertically transmitted at a low rate, and uses the plant as a vector for transmission to uninfected aphids. How does this benefit the aphids? When a plant becomes very crowded with uninfected wingless aphids the odds of one of them acquiring the virus from plant sap increases, and when one does the winged morph can move to a new plant to start the cycle over again.

Beneficial viruses are not limited to insects. Plant viruses confer tolerance to drought and cold stress. In this study, four different acute plant viruses were used to infect a variety of plants, including the water intensive plant rice (Figure 1). In all cases tested virus infection increased the plants’ tolerance to drought stress. One plant used in this study, Chenopodium amaranticolor was infected with Cucumber mosaic virus, which causes only a local infection. This localised infection was sufficient to provide drought tolerance, suggesting that the effect does not require the virus to be actively replicating in affected cells.

Viruses of fungal endophytes (fungi that live inside plants) can be required for mutualistic plant–fungal interactions that allow plants to live in extreme environments such as geothermal soils. In plants growing in geothermal soils in Yellowstone National Park, USA, an endophyte is required for thermotolerance. A virus that infects the fungal endophyte is also required: fungi cured of the virus do not confer thermotolerance, but this can be restored if the fungi are re-infected.

Mycoviruses are also found in some plant pathogenic fungi, where they can attenuate the pathogen. The most well studied example is the hypovirus of Chryphonectria parasitica, the causal agent of chestnut blight. When the fungus is infected with the virus the fungally colonised trees recover and survive. This has had limited success in the recovery of chestnut forests in the US because the virus is not easily transmitted to uninfected fungi.

Bacteriophage provide a number of beneficial effects for their hosts. They can produce toxins that allow expansion of the bacterial territory, either by killing off competitors or by allowing infection of host tissues, such as the phage of Corynebacterium diphtheriae that produces the toxin allowing the bacteria to invade the human throat tissue.

Mammalian viruses, including human viruses also may provide benefits. In some cases virus infection prevents super infection by a more serious pathogen. In other examples, viruses protect against other diseases. Mice infected with lymphotropic viruses do not get type I diabetes, and mice infected with latent herpesviruses are protected from serious bacterial infections. Mammalian endogenous retroviruses have a number of potential benefits including effects on development, and almost certainly have contributed to the evolution of human and other mammalian genomes.

The world of beneficial viruses is largely unexplored. With more study, many human, plant and animal diseases may be prevented or attenuated using beneficial viruses. Perhaps the biggest hurdle will be in changing people’s thinking. Imagine going to your doctor and being told that your cure will be infection by a virus!

References


Biography

Marilyn Roossinck is a professor of Plant Pathology and Environmental Microbiology, and Biology at the Pennsylvania State University, and an Adjunct Professor at Murdoch University. She studies virus ecology and evolution using plant and fungal viruses.