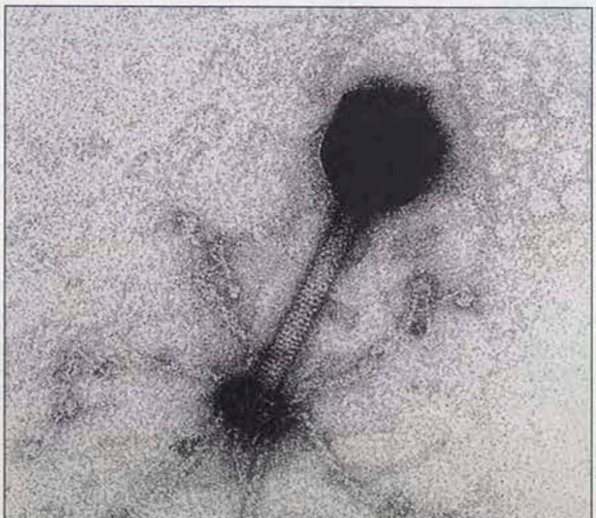
Viruses of Marine Bacteria

John B. Waterbury

Viruses are among the smallest and most numerous creatures in the sea. Strictly speaking, they are neither living nor nonliving, but lie on the borderline between. Viruses are parasites of cellular organisms including plants, animals, and bacteria. Individual virus species are very host specific, usually able to attack only a single host species or even single clones within a species.

Viruses occur in two states: one outside of cells and the other inside. Outside cells they exist as tiny particles that contain one or several molecules of nucleic acid, either DNA or RNA, that are usually but not always surrounded by a protein "coat." Viruses are smaller than cells, varying from 20 to 200 nanometers (a nanometer is one millionth of a millimeter) and their architecture ranges from roughly spherical bodies to complex structures like the ones illustrated. Outside cells, they are incapable of replication or metabolism. To replicate, a virus attaches to a host cell at a specific site and introduces its own nucleic acid into the cell. The virus's genetic material then commandeers the host cell, inducing it to produce the components required to make more viruses.

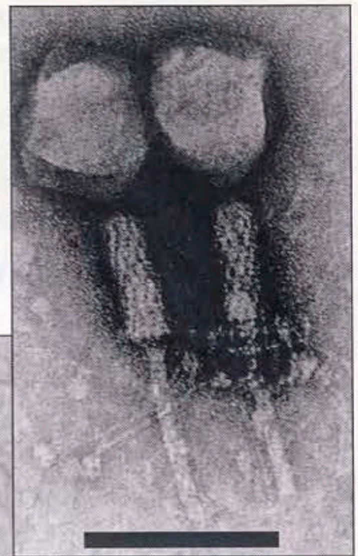
Viruses have long been known to exist in seawater, but in the last few years their role in marine microbial ecology became controversial as it was discovered how abundant they actually are. Using electron microscopy, it is not uncommon to find between 10,000 and 10,000,000 viruses per milliliter of seawater, many of them recognizable as tailed, bacterial viruses. In light of their abundance, it has been suggested that viral infection might be a significant cause of marine bacteria and phytoplankton mortalities. At least for bacteria, this has not proven to be the case. Bacteria have developed highly effective lines of defense to prevent viral attack, principally resistance. This is usually acquired through a single genetic mutation that alters the virus attachment site on the bacterial cell wall, preventing the virus from attaching.

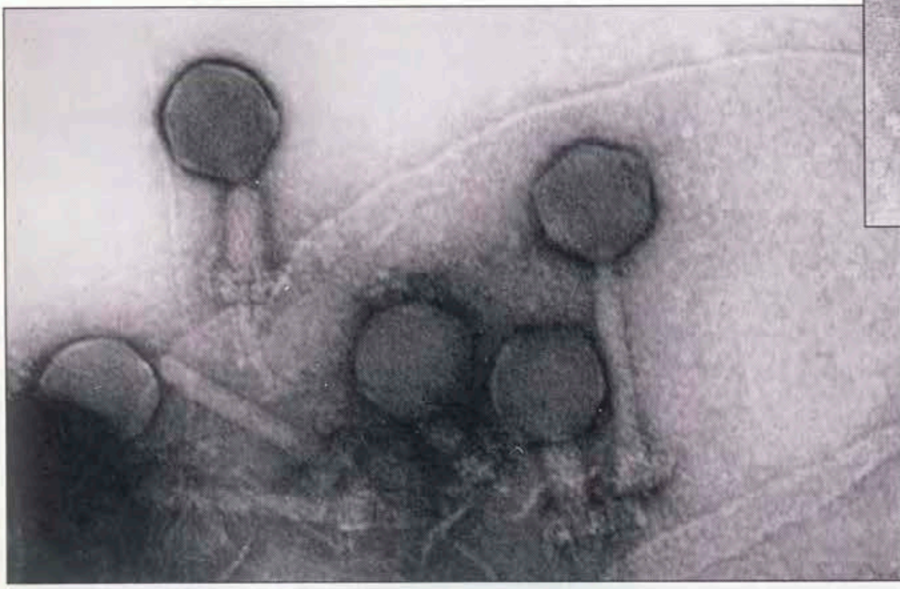


A bacterial virus, as seen by electron microscopy, is a very small (the bar represents 100 nanometers) but complex structure. The major components are the head, the contractile tail, and six radiating tail fibers.

Thus when a bacterium and its specific viruses are isolated from a single seawater sample, almost all the bacterial isolates are found to be resistant to their co-occuring

The tails of these two bacterial viruses (right) have contracted, revealing the central core that transmits the nucleic acid from the head of the virus into the cell of the bacterial host. The bar in this image represents 100 nanometers. Numerous viral particles are adsorbed to the surface of one end of a ruptured bacterial cell (below). The tail of the viral particle in the upper left corner of this electron micrograph has contracted, and the central core has penetrated the bacterial cell wall.





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viruses. However, some sensitive host cells persist, and these are responsible for releasing viruses at concentrations that typically result in a viral population about an order of magnitude lower than its host population. The virus-sensitive bacteria persist because they possess a subtle ecological advantage over their resistant counterparts. The viral attachment sites on their cell surfaces have other specific cellular functions. For example, their viral attachment sites may be proteins also involved in nutrient transport. Upon modification to confer resistance, nutrient transport may become less effective. Despite this and other possible ecological costs, the rapid acquisition of resistance is crucial for the stable co-existence of bacteria and their viruses, and prevents substantial bacterial mortality from viral attack.

There is a certain sense of deja vu associated with marine microbial ecologists' recent suggestion that viruses might be responsible for a large fraction of bacterial mortality in the oceans. For several decades following their discovery early in this century, viruses were advanced as agents to treat diseases caused by bacteria. Viruses were isolated that infected the bacteria causing a variety of diseases including cholera, diphtheria, dysentery, gonorrhea, and the plague. However, in each case, virus therapy failed, mainly because of the bacteria's ability to defend themselves against viral attack by rapidly acquiring resistance.

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