SYMMETRY IN BACTERIOPHAGES

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ABSTRACT - Understanding the basic anatomical structure of bacteriophages can reveal the importance of symmetry in the functions carried out by bacteriophages. Various parts of the phage structure, such as the capsid head and tail components, contain symmetry that supports the infection process from the virus to the bacteria, including the transfer of genetic material, stabilization, and protection.

Keywords: Symmetry, bacteriophages, capsid head, hexagons

1. INTRODUCTION

A bacteriophage (or phage) is a bacterial virus that invade and kill bacterial host cells. Phages are abundant in nature, from soil and water, to the guts of animals. The process by which they infect bacterial host cells is through injecting their viral DNA into the bacterium. This can be achieved through either lysis (host cell is killed) or lysogeny (host cell is not killed). The research of bacteriophages is important, as they have the potential to treat bacterial diseases. The basic composition (Figure 1) of the bacteriophage includes the head (capsid protein structure encapsulating genetic material) and the tail (collar, sheath, baseplate, tail fibers).

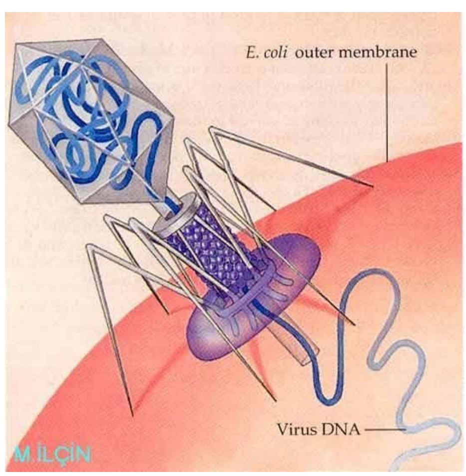

Figure 1

2. DISCUSSION

2.1 Capsid Head Symmetry

The head of a bacteriophage averages 55 nm in diameter and takes on the 3D symmetry of the Straight Icosahedron (I_h or Y_h). The icosahedron (Figure 2) has 5-fold symmetry at each vertex, meaning that if it were held by a string at one vertex and rotated by the axis of the string, it will return back onto its original position after 5 rotational clicks. Each face is an equilateral triangle with D3 symmetry, and there is 2-fold symmetry at each edge. There are 20 faces and 30 edges in total.

The icosahedral symmetry is extremely stable for the infection process. The capsid head contains densely packed DNA, which allows for high-energy states that prime the phage for infection and help facilitate the delivery of the viral genomes into the host cell. Thus, the protein structure must be able to sustain high internal pressure (10–60 atm) exerted by their tightly packed genomes.

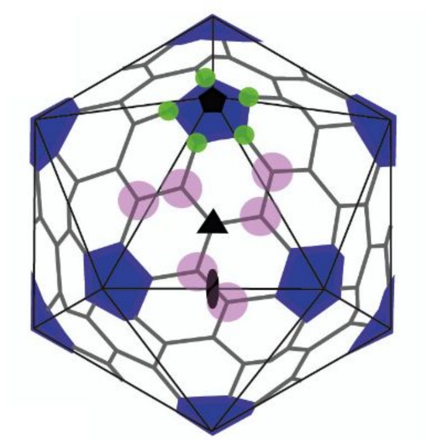

Figure 2

2.2 Protein Coat Symmetry

Some phage heads may encode an additional outer layer, where “decoration” proteins bind to form a protein coat. This is to help stabilize the bacteriophage and to withstand environmental stresses and the internal pressure of genome packaging. However, it is unknown how various decoration proteins recognize and bind to specific sites on capsids with different icosahedral geometries. In Figure 3, the outer protein layer has been flattened out from the capsid in Figure 2. The magenta lines indicate 8 mirror lines of symmetry and the dots represent the 2 rotation centers.

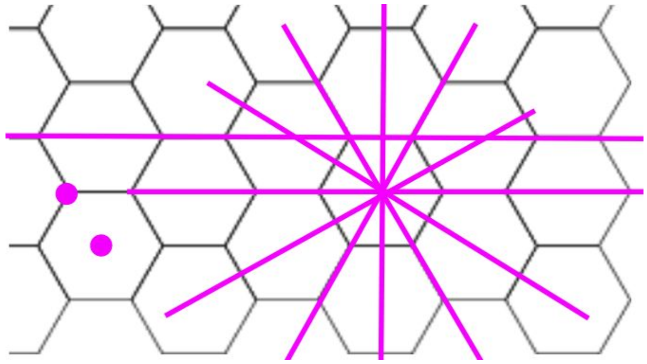

Figure 3

2.2 Tail Symmetry

The collar and base plate of the bacteriophage have symmetry as well. Observing the phage from a bottom-up view, the collar and base plate line up to overlap onto the sheath axis. From this perspective, they can be seen to be both hexagonal shapes with C6 symmetry, meaning that they have a 6-fold rotational axis (Figure 4).

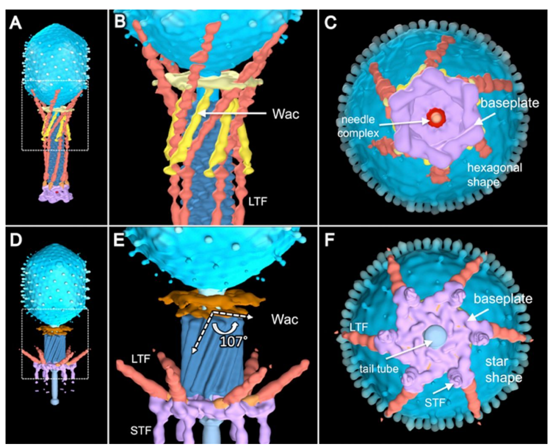

Figure 4

3. CONCLUSION

The ubiquitous presence of hexagonal figures in bacteriophages and nature, such as honeycombs, insect eyeballs, soap bubble clusters, and molecular structures, demonstrates the significance and importance of symmetry in nature. Being the closest regular shape to the circle (2D) and a sphere (3D), the shape of the hexagon provides stability, balance, and efficiency, achieving the minimum surface area with the maximum volume.

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