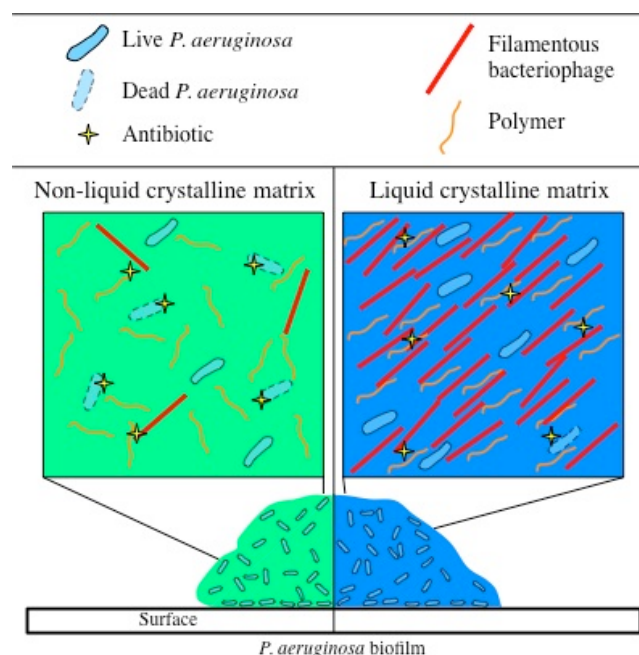


Filamentous bacteriophage organize bacterial biofilms into liquid crystals

At sites of chronic infection, bacteria form biofilms, clusters of bacteria encased within a slimy, polymer-rich coating called the matrix. Biofilms are of concern because bacteria within biofilms become tolerant not only to environmental stresses, but also antibiotic treatment.

The opportunistic pathogen *Pseudomonas aeruginosa* forms biofilms in many types of chronic infections, including long-term infections of the airways of people with cystic fibrosis (CF). Despite rigorous antibiotic treatment, CF airway infections can persist for decades and airway damage caused by long-term infection is the leading cause of death for people with CF.



Scientists noticed that when *P. aeruginosa* is grown as a biofilm in the laboratory, large amounts of filamentous bacteriophage are produced. Bacteriophage are viruses that infect bacterial cells – they are typically considered parasites – they infect a bacterial cell, replicate within, and burst out of their microbial host, killing it. However, filamentous bacteriophage produced by *P. aeruginosa* biofilms only kill a small subset of the bacterial population. In addition, clinical isolates of *P. aeruginosa* often carry filamentous bacteriophage. These observations lead us to hypothesize that the production of filamentous bacteriophage by *P. aeruginosa* could be beneficial to the bacterial population.

Filamentous bacteriophage are long, slender filaments. Since they are easily produced in large quantities and are all the exact same size, filamentous bacteriophage have been an invaluable tool for studying the physics that drive liquid crystal assembly. A common example of a liquid crystal,

which is a state of matter in between a solid and a liquid, are the liquid crystal displays (LCDs) used in computer monitors. At high concentrations, filamentous bacteriophage spontaneously assemble liquid crystals. With this in mind, we hypothesized that the production of filamentous bacteriophage by *P. aeruginosa* biofilms would organize the biofilm matrix into a liquid crystalline structure and this liquid crystalline organization would promote key features of the biofilm.

To determine if the production of filamentous bacteriophage resulted in the organization of the biofilm matrix into a liquid crystal, we took advantage of the unique optical properties of liquid crystals. Liquid crystals can interact with and change the polarization of light. It is this property that makes liquid crystals ideal for use in LCDs. Using a form of polarized microscopy, we were able to show that biofilms producing filamentous bacteriophage significantly changed the polarization of light, as would be expected for a liquid crystal.

Next, we wondered how the liquid crystalline biofilm matrix might affect bacterial traits important for pathogenesis. For example, for bacteria to be transmitted from the environment to the lungs of a CF patient, the bacteria must be able to survive on dry surfaces for prolonged periods of time. Therefore, we tested how well liquid crystalline biofilms survived desiccation. We found that liquid crystalline biofilms were better able to survive desiccation compared to biofilms within a non-liquid crystalline biofilm matrix.

We also wondered if the liquid crystalline matrix could promote antibiotic tolerance. When exposed to tobramycin, an antibiotic used routinely to treat CF patients infected with *P. aeruginosa*, we found that the liquid crystalline matrix did indeed provide more protection from this antibiotic than non-liquid crystalline biofilms. This may be due to the ability of liquid crystals composed of filamentous bacteriophage to efficiently bind these antibiotics, keeping the drug away from the bacterial cells within the liquid crystalline biofilm, reducing the efficacy of the antibiotic.

Targeting filamentous bacteriophage production or the liquid crystal organization of the biofilm matrix may provide alternative therapeutic strategies to combat chronic biofilm infections.

Publication

[Filamentous Bacteriophage Promote Biofilm Assembly and Function.](#)

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