MICROBIOLOGY SOCIETY

BIOFILMS

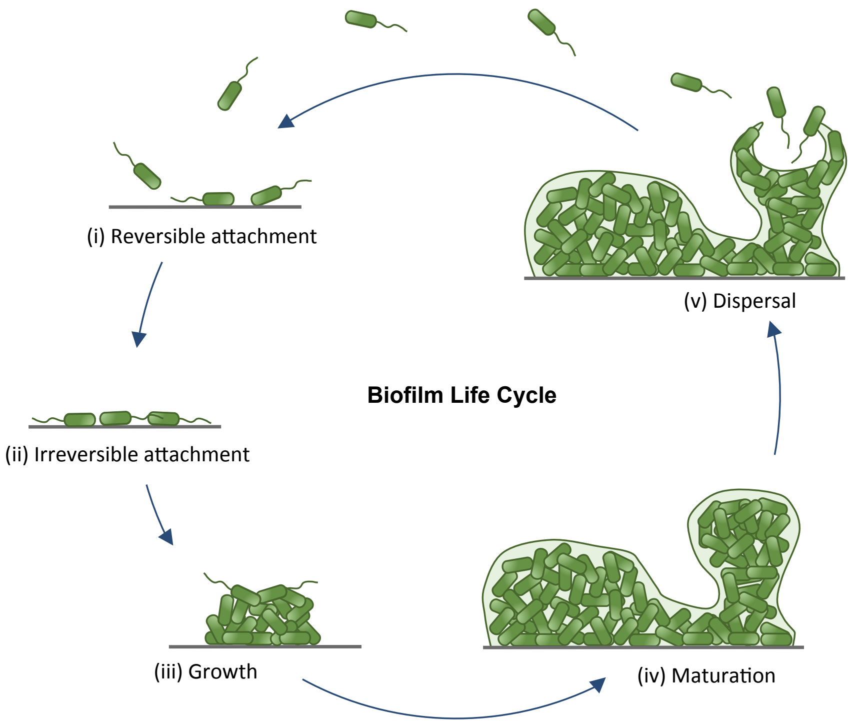
- Micro-organisms most commonly exist in nature as communities within biofilms rather than as single free-floating organisms. Biofilms are all around us, from the slime on rocks in streams (even in hot springs), to washing machines, to our own bodies, for example the dental plaque on our teeth.

- Detrimental biofilms can impact human and animal health as a cause of chronic antimicrobial-resistant infections, and exert economic costs to industry as a cause of water and food contamination, energy loss, and corrosion. However, there are also opportunities to exploit biofilms to our benefit, for example to generate electricity and to clean polluted environments.

- Gaining a greater understanding of how to prevent, detect, manage and engineer biofilms, as well as performing basic research to understand their composition, would present benefits across a range of sectors.

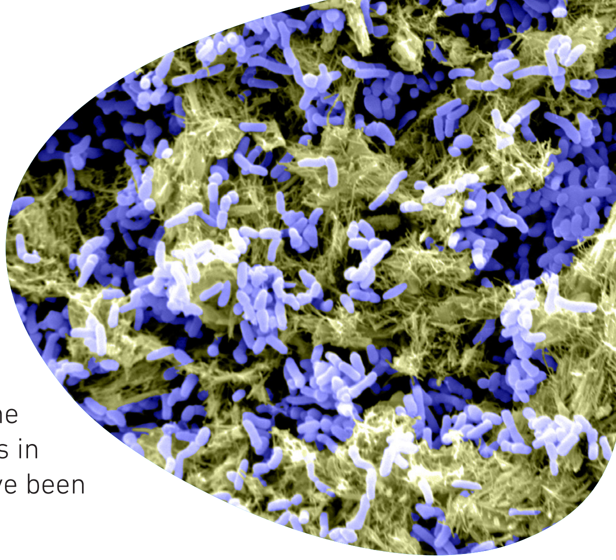
WHAT ARE BIOFILMS?

Biofilms are communities of micro-organisms that stick to each other and to surfaces. They form in aqueous environments when free-floating micro-organisms attach and adhere to surfaces in response to cues in the environment such as changes in pH and nutrient concentration. The biofilm matures as attached micro-organisms multiply, colonising the surface and recruiting new members which are embedded in self-secreted extracellular polymeric substance (EPS), a sticky slime-like material consisting of DNA, polysaccharides, and proteins, forming a structured 3D matrix.



The composition and architecture of biofilms are complex and diverse. They may consist of one microbial species or mixed species such as bacterial and fungal – although at present the majority of research focusses on single and multi-species bacterial biofilms – and these act as an organised community, sharing resources for growth and survival. For example, chemical gradients can form that allow for nutrient exchange and waste removal via a network of channels.

Biofilm formation greatly enhances the survival of micro-organisms, providing structural support as well as protection from surrounding threats such as antimicrobials, grazing predators, and the immune responses of a host as it fights infections. However, micro-organisms do not necessarily become permanent members of the biofilm community; they are actively able to disperse from biofilms, going on to colonise new surfaces. Alternatively, dispersal can occur passively due to the action of external mechanical forces such as scrubbing.



WHY ARE THEY IMPORTANT?

Biofilms were first discovered in the 17th Century by Antonie van Leeuwenhoek, who used a microscope to observe them on scrapings of plaque from his own teeth. Historically, microbes have been studied as single species in a pure culture, a state that rarely occurs in nature, rather than as members of biofilms. It is only since the late 20th Century that the ubiquity and importance of adherent biofilms in industrial processes, clinical settings, and the natural environment have been recognised.

Infections

Biofilm infections are estimated to be responsible for up to 80% of all infections in humans and animals, posing a major health challenge. These infections can occur on the body, delaying wound healing and causing gum disease (periodontitis); within the body, such as in urinary tract infections or in cystic fibrosis lung infections; attached to medical devices such as contact lenses, pacemakers and prostheses.
Furthermore, bacteria existing within pathogenic biofilms can be up to 1000 times more resistant to antibiotic treatment than free-floating bacteria, making them a significant cause of treatment failure for infectious disease. There are various mechanisms by which biofilms protect microbes from antimicrobial action. The development of novel treatment strategies to address these, including through the combined use of antimicrobials with therapeutic agents that disrupt biofilms, is an important area of research.

Biofouling

Biofouling describes the unwanted accumulation of organisms, initially biofilms, on wetted surfaces, which can degrade the material and cause corrosion. Biofouling is particularly problematic in the naval industry as larger marine animals such as mussels and barnacles can stick onto biofilms on ship hulls. This increases drag resistance, and thus causes greater fuel consumption and greenhouse gas emissions, and can cause the spread of invasive marine species. From the 1950s, paint containing organotin compounds was used to coat ship hulls due to its effective anti-fouling properties, but since 2008 it has been phased out due to its toxicity to non-target organisms and accumulation in the food chain. Scientists are still working to develop effective, environmentally-friendly anti-fouling paints.

Water quality and food safety

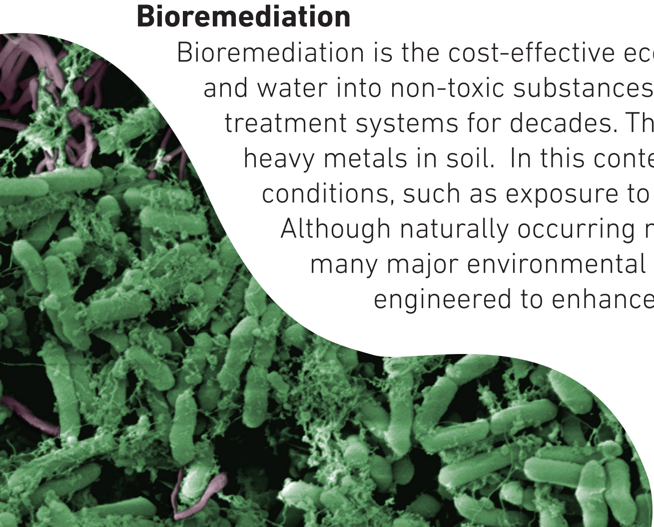
Biofilms can form on the inner surface of pipes, storage tanks and silos, and on food preparation surfaces. These can contain micro-organisms that can cause disease and food spoilage and are resistant to disinfection, and thus compromise the safety and quality of drinking water and food products. Research is ongoing to determine the best surface materials to use, and sanitation measures, to prevent biofilms or to remove them. For example, researchers at the University of Sheffield are examining factors such as biofilm composition and water flow and flushing strategies to remove biofilms from water distribution networks.

BENEFICIAL BIOFILMS

Although biofilms are often detrimental, beneficial applications in which biofilms can be exploited also exist.

Bioremediation

Bioremediation is the cost-effective eco-friendly process of degrading harmful pollutants from the air, soil and water into non-toxic substances using micro-organisms. Biofilms have been used in wastewater treatment systems for decades. They can also be used to clean up oil spills in the ocean and detoxify heavy metals in soil. In this context, the ability of biofilms to withstand harsh environmental conditions, such as exposure to toxic chemicals, and remain attached to surfaces is advantageous. Although naturally occurring micro-organisms have evolved bioremediation mechanisms for many major environmental pollutants, micro-organisms in biofilms can also be genetically engineered to enhance this process, or to degrade specific pollutants.



Microbial fuel cells (MFCs)

Biofilms are used in MFCs to convert chemical energy into electricity, generating clean energy. MFCs consist of an anode and a cathode separated by a semi-permeable membrane. Micro-organisms on the anode oxidise organic matter in the absence of oxygen, to produce protons and electrons. These electrons flow from the anode through an external circuit to the cathode, generating a current. Ongoing research aims to use MFCs in wastewater treatment, to generate electricity from waste material.

The gut microbiome

The highest concentration and diversity of microbes in the body occurs in the gut and these microbes are collectively referred to as the gut microbiome. This is increasingly understood to play a vital role in maintaining human health, for example in aiding digestion and promoting immune function. However, much research into the gut microbiome involves analysis of faecal samples, which have a different composition and structure to the intestinal microbiome, where biofilms can occur around food particles or possibly on the mucus layer that lines the digestive tract. Further research is required to determine how biofilms in the gut contribute to human health and how disturbances might cause disease.

PROGRESSING BIOFILMS RESEARCH

Over the past decade an understanding of the importance of biofilms has grown in the UK, with the BBSRC and Innovate UK working to identify priorities in biofilm research, investing millions in R&D and launching the National Biofilms Innovation Centre (NBIC) in 2017 as part of the UK Biofilms Programme. Biofilms pose different challenges in different settings and strategies to control them including methods of prevention, detection, management and engineering will vary across sectors. The aim of NBIC is to connect biofilms researchers with industrial partners, providing a platform for collaboration to provide solutions to the challenge of biofilm management. In addition, biofilm research spans several disciplines; microbiology, medicine, chemistry, physics, engineering and computer science, meaning researchers from different fields need to work together to better understand the complexity and diversity of biofilms.

FURTHER READING

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IMAGE CREDITS

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Pseudomonas aeruginosa biofilms on diseased human bronchial epithelial cells. Bhavik Bharochia.
Biofilms in Yellowstone National Park. Jo Slater-Jefferies.

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