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BACTERIAL BIOFILMS: DID YOU KNOW THEY CAN HELP US?

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YOUNG REVIEWER:

UMBERTO

AGE: 12

Bacteria are tiny organisms that we cannot see with our naked eye. In nature they live in social groups called biofilms. To build biofilms bacteria produce a sticky material that works like a glue, called the biofilm matrix, that helps the bacteria stick to each other and to surfaces. Although some types of biofilms can be harmful, a lot of biofilms are very useful for humans. In this article we will give you examples of the amazing things biofilms can do for us, from helping remove oil spills in the oceans to helping our plants and crops stay healthy! There is an animation you can watch and an illustration you can explore. We hope you enjoy learning about beneficial biofilms.

WHAT ARE BIOFILMS?

Bacteria are small, single cell organisms. In nature, bacteria live in social groups called "biofilms." If a biofilm grows big enough, we can even see it with our naked eye. Examples of biofilms you might have

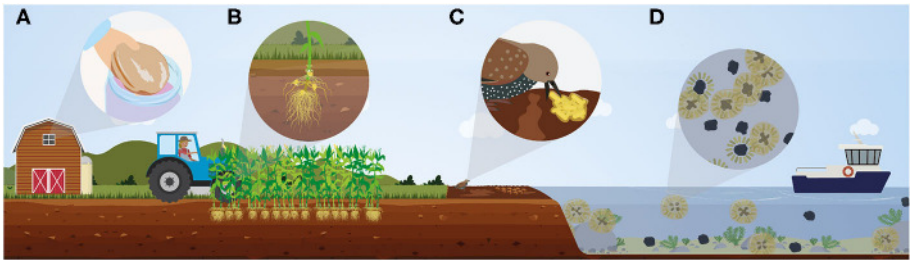

Figure 1

Figure 1

Beneficial biofilms. Beneficial biofilms are found all around us. From **(A)** in our homes where they can be used to make food and drinks including kombucha, **(B)** in fields where biofilms on plant roots help plants to grow and be protected from harmful disease-causing microbes, **(C)** in mud flats where they provide essential food for migratory birds and **(D)** in our oceans where they help to keep the water clean and remove toxic oil spills. The illustration was commission from Science Animated (`https://sciani.com/`).

BIOFILM MATRIX

Slimy material produced by members of the biofilm community.

seen include plaque that grows on our teeth, slime that forms on shower tiles, and the slippery coating on pond rocks. In a biofilm, bacteria stick to surfaces and to each other. To build the biofilm and spread out over the surface, bacteria make materials to cover both themselves and their neighbors. The slimy protective coating the bacteria make is the "**biofilm matrix**." The biofilm matrix acts like cement between bricks when building a wall. It gives structure to the bacterial community. The matrix also protects bacteria in the biofilm from the environment, which can include antibiotics. The matrix also acts like a glue sticking bacteria to surfaces, which makes the biofilm hard to remove.

You can think of a biofilm like a busy crowded city. A city starts with few people settling in an area. The settlers build houses and overtime a large and diverse community can establish. The same is true for biofilm formation. Bacteria choose the places they want to settle and build a biofilm. This is according to their needs, which can vary depending on what food they need to grow. In a biofilm you can find different types of bacteria living and working together. The cooperation lets the bacteria survive in many environments. The environments can include the soil, deep in the sea, in food we eat, and even in our own bodies!

For humans, bacterial biofilms can be both harmful and helpful. The impact depends on which bacteria live in them and where the biofilm grows. Sometimes bacteria form biofilms that can cause harm to us, or our surroundings [1]. For example, if the bacterium *Clostridium difficile* forms a biofilm inside our intestines we get ill. Other bacteria can form biofilms inside pipes causing blockages and can sometimes contaminate the food we eat. Due to the sticky and protective nature of the biofilm matrix, getting rid of these biofilms is a difficult job. Despite biofilms playing an important role in infection and spoiling food and surfaced, there is more to it. Most microbes are helpful and without them life on this planet would not be possible. Here we focus on the beneficial actions of biofilms for both us and the environment.

NOT ALL BIOFILMS ARE HARMFUL!

Marine Life in Danger? Biofilms to the Rescue!

An example of a helpful biofilm can be found when cleaning up accidental toxic oil spills from our oceans and seas. Oil spills can happen when the machinery in ships breaks down or when oil tankers sink. The leak of oil into waterbodies is a major disaster for our environment, causing pollution and the deaths of sea animals and birds. There are various methods to clean-up oil spills. One method involves the use of bacteria which form biofilms around the oil droplets! One of these beneficial bacteria is *Alcanivorax borkumensis.* This bacterium is found in many of our oceans and uses an oily chemical compound—hydrocarbon—as a food source [2].

A. borkumensis creates a specialized biofilm matrix that works like a glue to allow it to attach to oils in the water. When there is an accidental oil spill, *A. borkumensis* senses the oily chemical droplets and attaches to their surfaces to eventually form biofilms. *A. borkumensis* produces compounds called **biosurfactants**, that make the oil easier for other bacteria to use a food source. In this way, *A. borkumensis* attracts more helpful bacteria, such as *Cycloclasticus* species to join the biofilm community and help to clean up toxic chemicals, by eating them and using them for energy [3]. In a biofilm community, *A. borkumensis* grows quickly and produces **enzymes**, which are tiny machines made from protein that can be used to break down food and other compounds into smaller parts. The enzymes produced by bacterial biofilms help to break down the toxic oil spill droplets into smaller carbon compounds. The broken-down oils are used as food by *A. borkumensis* and its biofilm neighbors [3]. Scientists are working on ways to save the environment during oil spills and bacterial biofilms may be one way to help!

BIOSURFACTANTS

Surface-active compounds produced by various microorganisms which have several unique properties.

ENZYMES

Biological machines that can make or break chemicals.

Healthier Soil Makes Healthier Food

Another arena where biofilms are useful for humans is in agriculture—the growth of plants for food. Soil is home for many types of bacteria and other microbes. One of the beneficial bacteria found in the soil is the bacterium *Bacillus subtilis,* which attaches to plant roots and forms biofilms. *B. subtilis* biofilms and the host plant work together to keep the plant healthy. The plant supplies sugars and other foods into the soil for *B. subtilis*. In return, the biofilm protects the plant from potentially harmful microbes, called phytopathogens, by producing compounds that act as antibiotics or antifungals that kill invading bacteria or fungi [4]. *B. subtilis* also makes enzymes that change nutrients in the soil to make them more accessible to plants, including the key minerals nitrogen and phosphorus. The bacteria live happily in the soil surrounding the root system and improve the growth of crops and other plants [4] (Figure 1, Movie 1). Think of *B. subtilis* biofilms as natural fertilizers, if you add a mixture of these helpful bacteria close to the roots of corn plants for example, it increases the chances of having healthier plants [4]. Therefore, bacterial biofilms can be an

MOVIE 1

This animation will take you through the benefits of the biofilms discussed in this article. The animation was created by Science Animated (`https://sciani.com/`).

eco-friendly alternative to chemical fertilizers, that often pollute the air and water and release greenhouse gases, bringing hazards to our health and the environment.

Biofilms in the Home

KOMBUCHA

A fermented drink made from sweetened tea and a microbial culture known as a "scoby."

Did you know biofilms are used in food production? Have you ever tasted a fermented tea drink called "**kombucha**?" To make this drink, a community of bacteria and yeast (another type of microbe) work together to achieve the tasty flavors of the final product (Figure 1, Movie 1). The exact bacteria used to make kombucha varies greatly but often includes *Acetobacter*, *Lactobacillus*, and *Gluconobacter* species. Over-time, the bacteria and yeast form a pancake-like layer on the surface of the drink called "scoby." This is a "pellicle biofilm." Pellicle biofilms develop on top of the liquid near the air, floating on the surface. When making kombucha, some members of the microbial community use the sugar added to the tea to grow. As the bacteria grow, they make waste compounds that they release into the surrounding environment. Next, other members of the microbial community use the newly made (waste) compounds as food. The biofilm forms because bacteria and yeast live in harmony, feeding on the sugary tea and each other's leftovers! Over time the biofilm produces carbon dioxide (a gas that we breathe out and is used to make drinks fizzy) and acids that give kombucha its tangy flavors [5].

DIATOMS

A group of microalgae, found in the oceans, waterways, and soils around the world.

It is not just humans who use biofilms for food production. Biofilms can also be food for animals and provide an important source of nutrition for migrating birds, such as Western Sandpiper. A collection of bacteria and **diatoms** (type of marine algae) form microalgal biofilms in wet sand along the seashores. The biofilm looks like a green slime upon sunlight reflection. The microbes in the biofilm release molecules called lipids, which serve as excellent food for birds, crabs, or worms [6]! (Figure 1, Movie 1).

CONCLUSION

Biofilms are all around us. Although we often think of bacteria as being the cause of disease, we now know that they work for us in many helpful ways to make our lives better. These tiny organisms and the matrix they produce can have several useful applications and scientists are working hard to understand more about how we can put biofilms to good use. We should say "Thank you biofilms!"

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REFERENCES

1. Poilvache, H., and Van Bambeke, F. 2020. Dangerous slimes: how bacterial biofilms make you sick and how to combat them. *Front. Young Minds* 8:62. doi: 10.3389/frym.2020.00062
2. Timmis, K. N., McGenity, T., van der Meer, J. R., and de Lorenzo, V. 2009. *Handbook of Hydrocarbon and Lipid Microbiology.* Berlin: Springer.
3. McGenity, T. J., Folwell, B. D., McKew, B. A., and Sanni, G. O. 2012. Marine crude-oil biodegradation: a central role for interspecies interactions. *Aquat. Biosyst*. 8:10. doi: 10.1186/2046-9063-8-10
4. Hashem, A., Tabassum, B., and Abd Allah, E. F. 2019. *Bacillus subtilis*: a plant-growth promoting rhizobacterium that also impacts biotic stress. *Saudi J. Biol. Sci.* 26:1291–7. doi: 10.1016/j.sjbs.2019.05.004
5. Dufresne, C., and Farnworth, E. 2000. Tea, kombucha, and health: a review. *Food Res. Int.* 33:409–21. doi: 10.1016/S0963-9969(00)00067-3
6. Embry, P. 2020. Slimy mudflat biofilms feed migratory birds—and could be threatened. *Sci. Am.* Available online at: `https://www.scientificamerican.com/article/slimy-mudflat-biofilms-feed-migratory-birds-and-could-be-threatened/`

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWER

UMBERTO, AGE: 12

Hi, my name is Umberto. I like to study science, read epic stories, play with my skateboard and going to the beach. In the future I would like to become a physicist. I am very excited to be working with Frontiers for Young Minds!

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Diana Gudynaite (M.Sc.) is a research assistant at the molecular microbiology department, University of Dundee, UK. Her research project involves growing *Bacillus subtilis* bacteria in different stressful conditions and trying to figure out how they manage to survive and grow. When not in the lab, she enjoys playing guitar and reading psychological books.

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Sofia Arnaouteli is a Postdoctoral Research Assistant working at the Molecular Microbiology Division at the University of Dundee in Scotland, UK. Her projects are focused on understanding how the soil bacterium *Bacillus subtilis* forms biofilms and its physiology while being part of a biofilm community. Apart from studying the exciting world of bacteria, she is a dedicated yoga student and enjoys eating nice food and especially cakes!

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Natalie Bamford is a Postdoctoral Research Assistant working at the Molecular Microbiology Division at the University of Dundee in Scotland, UK. Her research focuses on understanding the materials in the biofilm matrix and how they are made by bacteria. Outside the lab, Natalie enjoys cycling, walks, crosswords, and tasty food.

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