Prokaryote interactions & ecology

Cooperation and "multi-cellularity" in prokaryotes. Mutualisms, commensalisms, parasitism’s. Carbon and nitrogen cycles.

Key points:

Bacteria can be highly cooperative. Some even form organized structures a lot like a multicellular tissue.

Biofilms are surface-attached collections of microorganisms that stick together and exchange nutrients.

Some prokaryotes form close associations with plants, animals, or fungi. These may be mutualisms (+/+), commensalisms (+/0), or parasitism’s (+/-). proving to be social and cooperative, much more so than biologists first thought.

Some bacteria cooperate in groups, dividing up metabolic tasks and sharing the products. Others form cooperative associations with a host organism (though some also form neutral or harmful associations).
In this article, we will first explore how bacteria cooperate with each other and form organized groups (sometimes almost seeming “multicellular”). Then, we’ll look at some of the ways they interact with other species.

Cooperation and “multi-cellularity” in bacteria

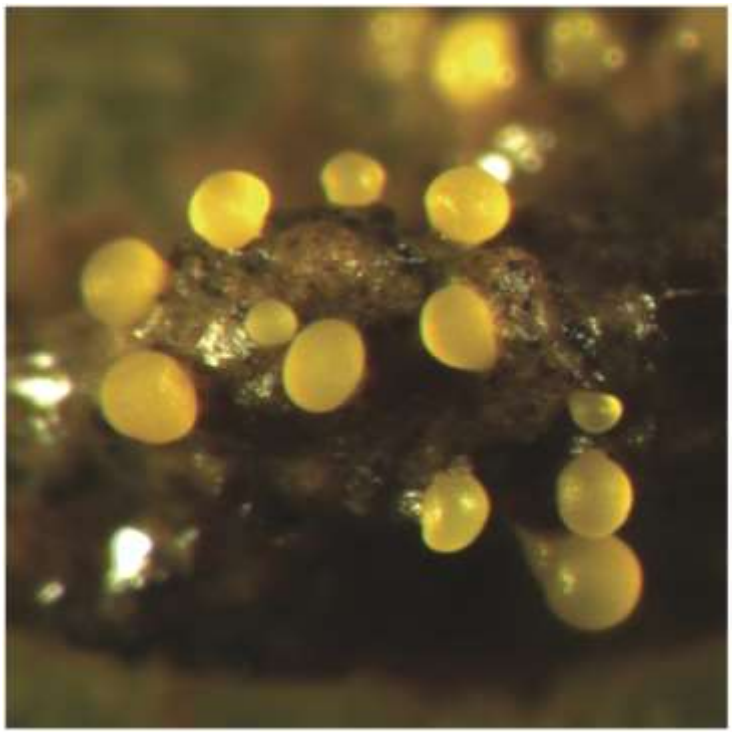
Bacteria often benefit from cooperating with each

other. This cooperation can be loose, or it can be coordinated to the point where it starts to look very much like eukaryotic multi-cellularity!

Here are some examples of bacterial cooperation – you can judge for yourself whether they really count as multicellular or not (an ongoing and controversial question in biology).

Myxobacteria

Myxobacteria are soil bacteria that interact to form coordinated groups (and even complex structures with specialized cells). When lots of resources are available, myxobacteria form groups called swarms. A swarm moves in a coordinated way and feeds by secreting digestive enzymes into the soil and absorbing the digested material.

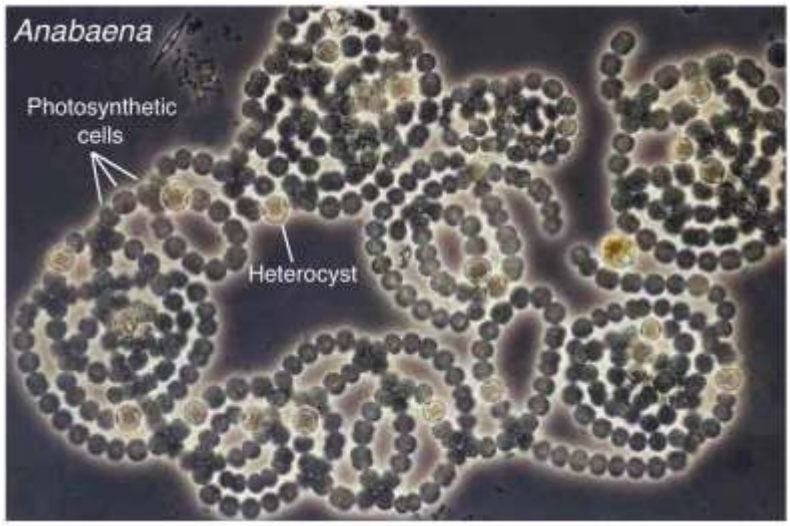


If resources become scarce, the myxobacteria join together to form multicellular-like structures called fruiting bodies (see the image above). Within fruiting

bodies, cells mature into spore-like structures called myxospores. Each myxospore has a thick cell wall than enables it to persist over a long period of time. When resources become available, the myxospores germinate and a new swarm is produced.

Chain-forming cyanobacteria

Cyanobacteria in the genus Anabaena don't split off on their own when they're produced by binary fission (bacterial cell division). Instead, they stick together in chains of connected cells, as shown in the image below.



The cyanobacteria cells have the capacity to both photosynthesize and fix nitrogen. However, a single cell can't do both at once, because the oxygen released in photosynthesis blocks nitrogen fixation (impairs the nitrogen-fixing enzymes).

To get around this issue, when nitrogen availability in the environment is low, some of the cells in the chain will become cells called heterocyst’s. The heterocyst’s specialize in fixing nitrogen, unlike the rest of the cells in the chain, which carry out photosynthesis.

Biofilms

A biofilm is a surface-attached collection of microorganisms held together by a gooey substance (mostly carbohydrate) that they secrete themselves. In many cases, biofilms form via quorum sensing. In quorum sensing, bacteria continually exchange signals that allow them to detect population density, and they change their behaviour when density exceeds a certain threshold.

Biofilms often contain multiple types of bacteria or other microorganisms. In some cases, the different members of the biofilm are metabolically complementary, with one producing molecules the other can use. Biofilms typically have water-permeable channels for exchange of nutrients and wastes, and some biologists compare them to a "primitive circulatory system."

Most bacteria in nature probably live on surfaces, rather than being free-floating, and biofilms are all quite literally everywhere. They form on household surfaces, such as kitchen counters, cutting boards, sinks, and toilets. Even plaque scraped off your teeth by dentists is a biofilm!

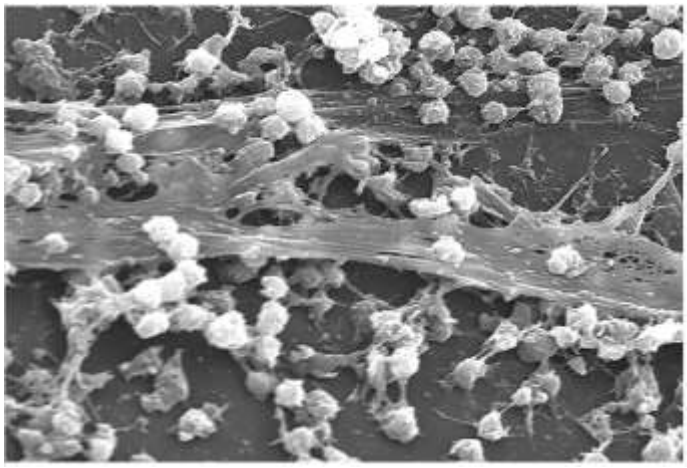


Image credit: "Staphylococcus aureus biofilm" by the Centres for Disease Control and Prevention (public domain).

Biofilms often get the most attention when they're causing problems. Pathogenic (disease-causing) biofilms, such as the Staphylococcus biofilm pictured above, can be a serious problem in hospitals. They are often hard to kill with antibiotics, and they can cause persistent infections if they contaminate medical equipment, such as catheters. Other biofilms corrode metal pipes and damage industrial equipment.

Some biofilms, however, have beneficial applications. For example, biofilms are used in water treatment plants to remove organic matter from sewage.

Multicellular or not?

In the examples above, bacteria interact cooperatively. To some degree, the social behaviour of cells in a biofilm is analogous to the cooperation of cells in a multicellular organism. Anabaena and myxobacteria are, in my opinion at least, even closer to multicellular. Some scientists argue that these cooperative bacteria qualify as multicellular organisms. Others, however, say that prokaryotes can't really be multicellular, and that these are just groups of individuals cooperating (for example, like ants in an anthill). The jury is still out, so you get to be the judge!

Mutualistic, commensal, and parasitic bacteria

We just saw some special cases where bacteria interact to form organized (dare we say multicellular?) associations. However, many types of bacteria also form close relationships with eukaryotic species such as humans, often living inside them.

Three important types of ecological interactions between species are mutualism, commensalism, and parasitism. Bacteria can participate in all three types of

interactions. In fact, we humans encounter lots of bacteria in each category!

Mutualism

Some bacteria form mutualisms, mutually beneficial (+/+) relationships between two organisms.

For example, Ruminococcus bacteria live in the gut of a cow and break down cellulose, a carbohydrate from grass, into a form usable by the cow. Without these bacteria, cows could not digest the grass they eat! In return, the bacteria get nutrients and a safe place to live (the gut of the cow).

Commensalism

Bacteria can also form commensalisms, relationships where one partner benefits and the other is not affected (+/0).

For example, we humans have millions of bacteria living in and on our bodies, many of which are thought to have a commensal relationship with us (for instance, feeding on dead cells or metabolic by-products). However, it's often the case that these commensal relationships actually turn out to be slightly mutualistic or parasitic (see below) when they are examined carefully.

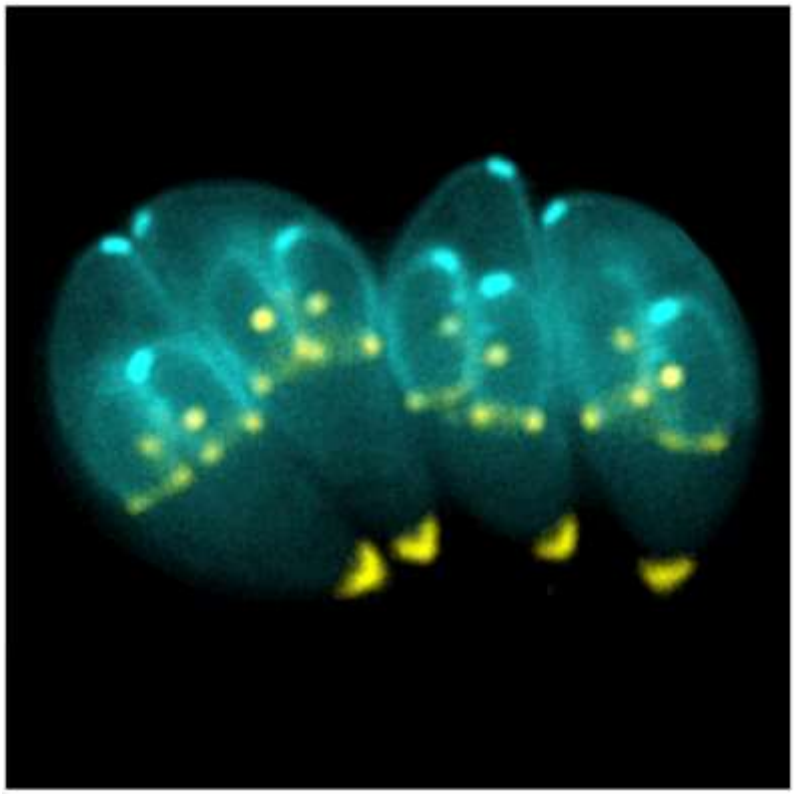
Parasitism

A parasitism is a relationship where one organism benefits and the other is hurt (+/-). Parasitic bacteria are the ones that we humans are most familiar with, and the ones that give bacteria their bad reputation as nasty "bugs."

The bacteria that cause human diseases take

resources from the human body and also attack the host in other ways, producing the nasty symptoms of a bacterial infection.

Disease-causing bacteria may harm their host in a variety of ways, such as invading tissues, producing toxins, or causing direct damage to host cells. Some bacteria, such as the Toxoplasma Gondi that cause toxoplasmosis, even get directly inside the cells of their host.



Dividing Toxoplasma Gondi bacteria marked with glowing tags. Image credit: "Toxoplasma Gondi", by Ke Hu and John M. Murray (CC BY 4.0).