Aquaculture

Freddie, are these beautiful marine species also infected by the coronavirus? No Lou but these animals have their own troubles.

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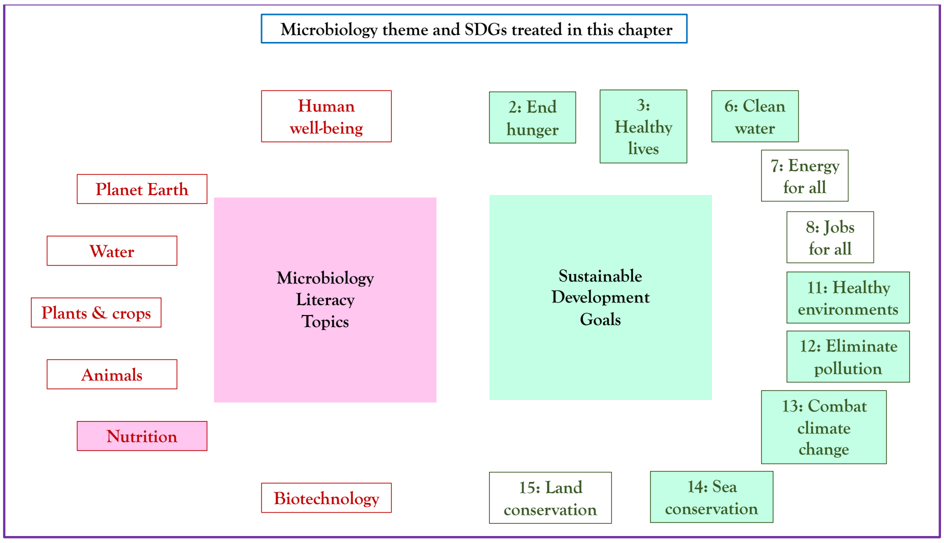
Storyline

Infectious diseases threaten the long-term survival of commercial and natural stocks of marine species. Our understanding and management of diseases are of critical importance as aquaculture is an important aspect of dealing with the approaching worldwide food shortage. The management of disease must take into account the fragility of the environment and maintain stable ecosystems at all scales of life. In particular, the intensive use of antibiotics in animal husbandry poses a major risk not only to public health but also to biodiversity. Antibiotics, which have no effect on viruses, target a wide range of bacteria, those that are harmful but also those that are necessary for biological equilibrium. The use of antibiotics promotes the emergence of resistant bacteria, which may be responsible for epidemics or even **pandemics** in the near future. Research is therefore focusing on "eco-friendly" alternatives to antibiotics, such as the use of bacteriophages, which are very abundant viruses in aquatic environments capable of infecting only bacteria.

The Microbiology and Societal Context

The microbiology: infectious agents associated with disease of marine species; virus, bacteria, protozoan; good and bad microbes; pollution; prophylactic and therapeutic approaches; vaccination; antibiotic; probiotic, prebiotic; phage therapy. *Sustainibility issues:* aquaculture; food support, omega-3 fatty acids, overfishing prevention; species re-introduction; eco-friendly alternatives; job creation; gastronomy; non endemic species invasion; degradation of ecosystems; eutrophication.



* **Note from Frederique Le Roux**: The coronavirus pandemic and the obligation of containment, gave the authors (from 7 to 15 years old) the opportunity to work remotely on a subject dealing with non-human infectious diseases related to the quality of the environment. We first discussed a general outline in four topics: aquaculture, infectious diseases, antibiotics and eco-responsible alternatives. Each of the authors sought information on these topics, definitions, advantages and disadvantages. This information was exchanged in writing and then discussed during weekly video conferences. A synthesis was written and criticized by all the authors. Words that were difficult to understand were defined in a glossary to enable young people to understand the article. The artists expressed themselves in the illustrations. During these weeks, I was impressed by the seriousness of the authors, their motivation, their creativity, their criticism and their autonomy in the work. Aren't these all the qualities required to be a scientist?

Aquaculture: the Microbiology

1. What is aquaculture? Aquaculture is a source of wealth, and rightly so. The word aquaculture comes from the Latin terms "aqua" and "cultura" which mean "water" and "to cultivate" respectively. "Cultura" refers to the care given to the land but also to the attention given to the spirit. Aquaculture can therefore be defined as the care given to the farming of species living in an aquatic environment (fresh, **brackish** or salt water), whether animals, algae or plants (Figure 1). Aquaculture includes fish farming (finfish farming), shellfish farming (shellfish), seaweed farming (macro and micro-algae), carcinoculture (crustaceans), and coral farming (corals). Aquatic species of various sizes are farmed for food, **pharmacopoeia** and aquariums

Fig. 1 The different species raised in aquatic environments, including introduced species

2. Aquaculture has advantages. Animal **proteins** are an essential source of food for humans. Intensive rearing of terrestrial animals for meat or milk production (cattle, sheep) has deep environmental impacts. These include, for example, the emission of greenhouse gases, or deforestation caused by the cultivation of crops that feed animals. The production of animal proteins from aquaculture species could therefore appear as an ecological alternative, especially as it helps to preserve marine species threatened by overfishing. It also allows the reintroduction into the environment of animals that have disappeared due to overfishing, pollution or disease. Fatty fish (e.g. salmon), crustaceans and mollusks provide a large amount of **omega-3** fatty acids that are essential for humans. Aquaculture creates jobs (for both men and women) and for some regions of the world is a large component of the food processing industry. Asia, the most populated continent on earth, is the largest consumer of aquatic species. Fish production is estimated at 80 million tons for fishing and 52 million tons for farming, and growing. Finally, aquaculture aims not only at satisfying the need for food but also for enjoyment, whether it be gastronomic, decorative in an aquarium, or even dedicated to the design of jewelry in the case of cultured pearls.

3. Aquaculture has its drawbacks. Fish also feed on animal protein. The production of 1 kg of fish requires 3 to 7 kg of animal meal, which is itself prepared from wild fish. This raises questions about the positive impact of fish farming in the fight against overfishing. Animals (e.g. oysters) can escape from the farming area and grow in the natural environment to the detriment of other species. The same is also true for algae introduced by man, which can invade the environment beyond their area of cultivation. If these animals are introduced from other regions or countries, they may facilitate the emergence of new diseases. As in agriculture, intensive aquaculture practice can lead to the degradation of **ecosystems**. On the one hand, the animals produce excrement that is deposited on the bottom. This **organic matter** is used as food by microbes to **proliferate**, using available oxygen and suffocating aquatic organisms living near the bottom. The excrement also contains and releases nitrogen and phosphorus, which allows photosynthetic microalgae to "bloom" – to grow in large amounts – a process named eutrophication. And when these microalgae die, they are also used as food by microbes, thereby further depleting the water of oxygen and suffocating more aquatic organisms. On the other hand, the establishment of rearing areas can lead to the destruction of natural habitats, as is already the case with **mangroves**. Finally, intensive farming, whether aquaculture or land-based, is associated with the emergence of diseases. Animals are very numerous for little space. When they move around they can injure themselves through contact. The confined environment, rich in organic matter and microbes, favors infections, which are transmitted all the more rapidly as contact between animals is frequent. The massive use of medicines such as antibiotics to reduce disease causes profound damage to the surrounding ecosystem.

4. Microbes are the cause of infectious diseases in farmed species. The word microbe comes from the Greek terms "mikros" and "bios" which mean "small" and "life" respectively. These organisms invisible to the naked eye that can only be observed under a microscope (Figure 2) are fully described in section 1, so we will focus here on microbes that cause infection in aquaculture. Infectious diseases caused by microbes affect many wildlife and livestock species with economic consequences for fisheries or aquaculture. Among the best-described examples of diseases, 25% are caused by viruses, 34% by bacteria, and 19% by protozoa. Most of these microbes induce mortalities of the species. For example, in the 1970s, a virus (iridovirus) decimated oysters (*Crassostreae angulata* or Portuguese oysters) in France. Oyster farmers then imported en masse another species of oyster from Japan (*Crassostreae gigas*), which was resistant to this virus. Another virus (a herpes virus) and bacteria (vibrios) now threatened the sustainability of oyster production worldwide. In the US, the protozoan *Perkinsus marinus* causes disease and mortalities in adult eastern oysters (*Crassostrea virginica*). Other microbes only affect species growth or marketing. For example, a bacterium named *Vibrio tapetis* affects the growth of clam in Europe. A microscopic parasite called Kudoa (the scientific name for this type of parasite, myxosporean) infects marine fish. This parasite causes a post-mortem "myoliquefaction", i.e. a softening of the flesh to such an extent that the fish becomes unmarketable. Most microbes that cause damage to marine species are not capable of infecting humans.

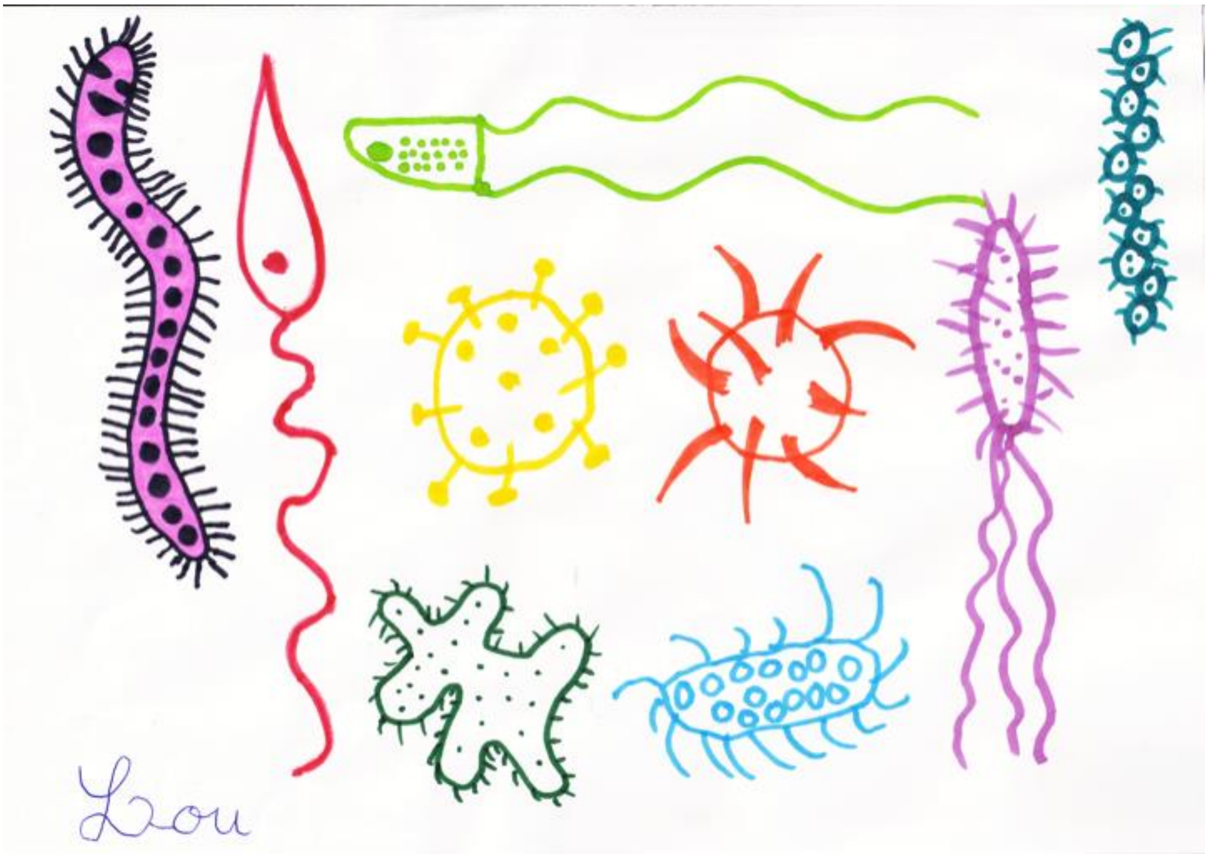


Fig. 2 Microbes are very diverse in shapes.

5. Some infectious diseases can be passed from fish and shellfish species to people. Microbes infecting marine animals can also cause disease in humans, known as zoonosis. Zoonoses are mainly infections associated with bacteria. These infections often do not make animals sick, but can cause serious illness in humans, especially if the human is weakened (immunosuppression, chronic illness, pregnancy). For example, various species of *Mycobacterium* infect a wide variety of fish species. In some cases these bacteria cause disease in fish. Most often the fish are asymptomatic, i.e. they are healthy despite the presence of the bacteria. Transmission to humans occurs through contact with a skin lesion when immersed in contaminated water: aquariums, more rarely water from rivers or lakes. People infected with this bacterium can develop " granulomas" which appear as skin sores or nodules usually on the hands. Immune-compromised people can develop a lung disease similar to tuberculosis. *Vibrio* and *Salmonella* are pathogenic bacteria that can be transmitted by contact with a wound but also by ingestion of water or consumption of raw marine animals (e.g. oysters). These bacteria can cause gastroenteritis with vomiting and diarrhea. A more serious and potentially fatal infection, septicemia, can occur in immune-compromised people. We can protect ourselves from most of these diseases by using basic hygiene procedures such as protecting our hands with gloves (especially if we have sores) when handling aquarium water. It is important to become familiar with the animals we come into contact with and the potential zoonotic diseases associated with each species. You should also avoid eating raw animals that are not under animal health surveillance. This is why shore fishing is sometimes prohibited. Finally, it is advisable to freeze certain fish eaten as sushi or tartar 7 days before eating them raw. This is to avoid the presence of another type of parasite, bigger than microbes, called Anisakidae. It is in fact a worm. Although cases of human infection by this parasite are quite rare in France - about 10 cases per year - they can however be very serious (perforation of the stomach).

6. Disease controls depend on the species reared and the infectious agent. There are two main means of controlling infectious diseases: prophylaxis and therapy. Prophylaxis is the prevention of infection and the spread of the infectious agent. It involves improving husbandry practices to prevent the species from being in a weakened state, for example by reducing the number of animals in the farm. It is also a question of preventing the environment from being conducive to the development of infectious agents, for example by cleaning and disinfecting facilities. Animals can also be protected by stimulating their immune system or by vaccinating them. In humans, the consumption of fruit and its supply of vitamin C stimulate the **immune defense**. The same could be true for "grandmother's remedies" such as essential oil of oregano, grapefruit seed or coconut, cider vinegar, honey, garlic, fermented foods. In farm animals, certain compounds, particularly sugars extracted from algae, can be added to the feed to stimulate the immune defense.

Vaccination consists of inoculating an inactivated microbe (or part of the microbe) to induce an immune response in the animal, which persists over time, known as immune memory. This immunity is based on the activity of white blood cells called lymphocytes. In particular, these cells control the production of antibodies, molecules that recognize particles of the "non-self". The absence of lymphocytes in invertebrates suggests that these animals do not have a memory immune system and therefore cannot be vaccinated. However, some form of immune memory also exists in invertebrates, although the mechanisms involved are only partially known. This immune memory makes it possible, for example, to prevent certain infectious diseases in shrimp. A final means of prophylaxis, applicable to vertebrates and invertebrates, consists of selecting animals that are resistant to infectious agents. When this resistance is transferred to subsequent generations, we talk about genetic selection. This genetic selection is not without risk. On the one hand it goes against natural diversity, on the other hand it can be associated with disadvantages such as lower growth or susceptibility to another disease.

Therapeutics is the use of a treatment (medication) to cure a disease or relieve its symptoms. In the field of aquaculture, therapeutics is aimed exclusively at controlling bacterial infections. In particular, this involves the use of antibiotics.

7. Antibiotics aren't automatic! The word antibiotic comes from the Greek terms "anti" and "bios" which mean respectively "against" and "life". Alexander Fleming discovered the first antibiotic in 1928. It was by chance that he observed that a fungus that had contaminated his bacterial cultures (staphylococcus) secreted an antimicrobial substance, penicillin (Figure 3). In the context of World War II, this discovery was the starting point of the antibiotic era (1942-2000). It also illustrates a famous quotation from Louis Pasteur, a pioneer in microbiology, that "chance favors only the prepared mind" (1854).

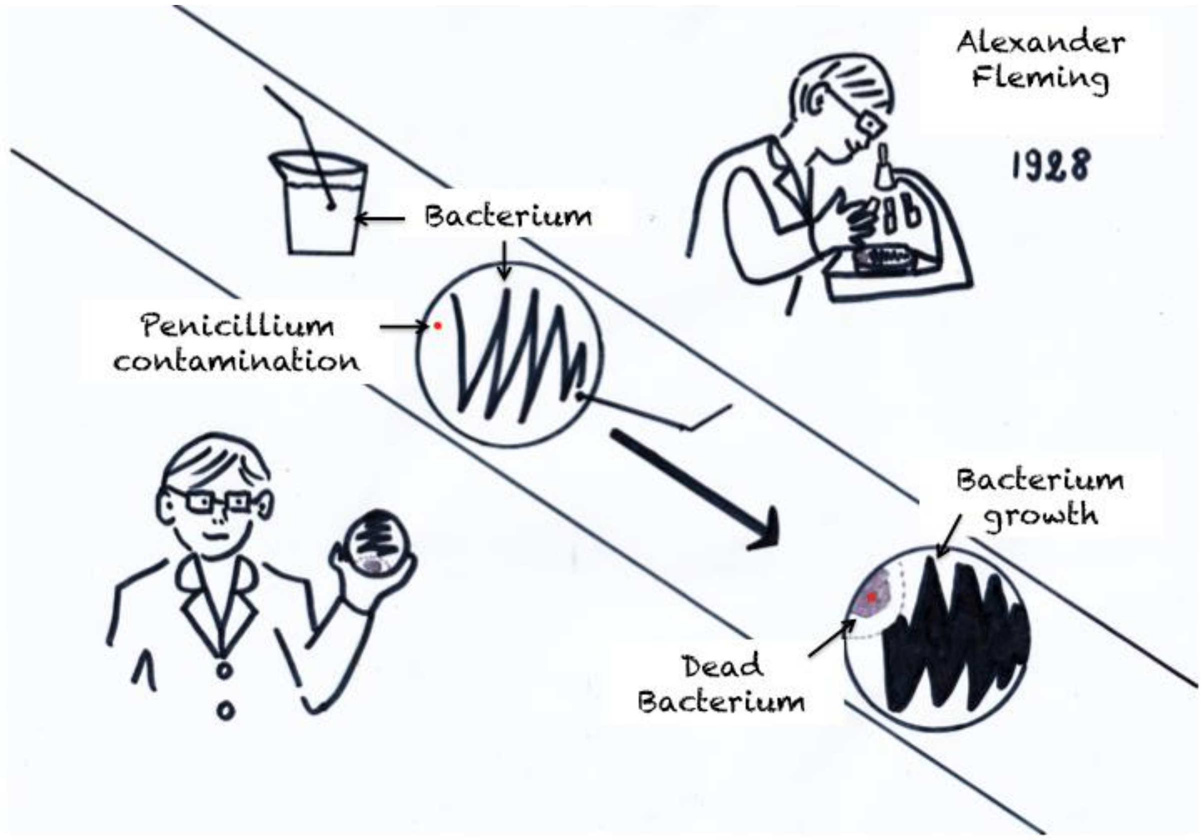


Fig. 3 Discovery of penicillin by Alexander Fleming in 1928. On his return from vacation, Fleming discovered that the petri dish on which a bacterium was growing (staphylococcus) had been contaminated by a microscopic fungus, Penicillium. His bench neighbour was working on this fungus... But he then observed that the bacteria did not grow when in contact with the mold, so he hypothesizes that the fungus secretes an anti-bacterial molecule.

Antibiotics are natural (produced by micro-organisms) or synthetic (created by man) molecules. Bactericidal antibiotics kill bacteria. Bacteriostatic antibiotics block bacterial growth. These molecules can act on different enzymes and stages of cell life such as bacterial wall synthesis, DNA replication, RNA transcription or protein synthesis. Antibiotics are not effective against viruses.

While it is obvious that antibiotics have saved millions of lives, they have the disadvantage of harming useful bacteria in organisms. These are the bacteria involved in digestion or in the immune response. These bacteria are present on the skin, in the intestine of human and fish and even in the blood of invertebrates. Another disadvantage of antibiotics is the appearance of bacteria that are resistant to these drugs. This is because the DNA of bacteria can undergo mutations, which can alter the target of the antibiotic (for example, an enzyme). The enzyme becomes insensitive to the molecule. The antibiotic will attack all susceptible bacteria and only bacteria that have acquired resistance will be able to survive and proliferate, they are selected (Figure 4). Finally, even more worrying is the appearance of bacteria that are multi-resistant to antibiotics or "superbug". They emerge because of the ability of bacteria to transfer DNA fragments to each other. Some of these fragments contain antibiotic-resistant genes, such as those encoding enzymes that destroy the drug. If a DNA fragment carries three resistance genes, treatment with a single antibiotic will select resistant bacteria for three different antibiotics. The emergence of the superbugs is now a therapeutic dead end for antibiotics. It is associated with 700,000 deaths per year worldwide and some scientists predict that by 2050 it will be associated with 10 million deaths, more than cancer (8 million). Superbugs are therefore likely to cause future pandemics. It will be impossible to treat currently unproblematic infections such as skin, dental or urinary tract infections.

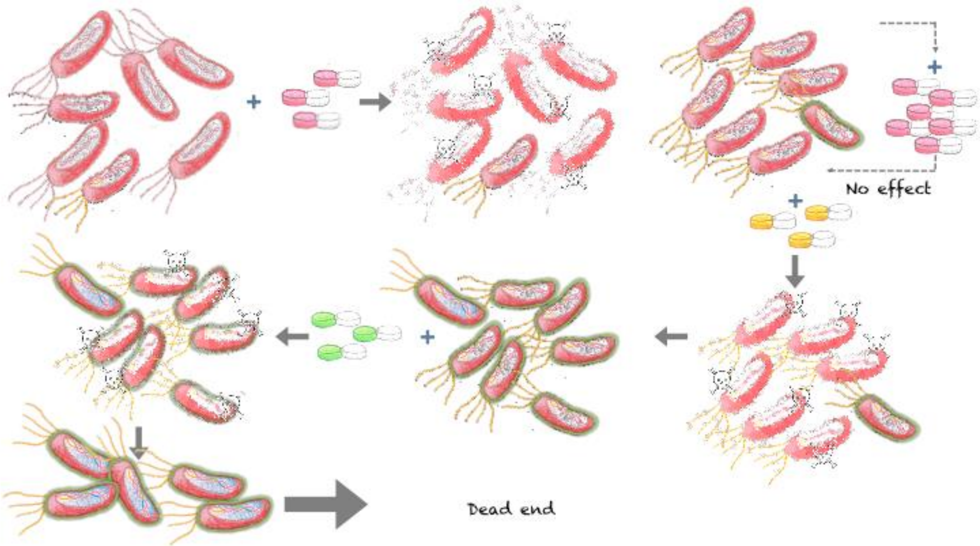


Figure 4. Multiple antibiotic resistance selection leads to a therapeutic dead end. Bacteria can undergo mutations in their DNA, and some can alter antibiotic sensitivity. In the presence of this drug, resistant bacteria are selected. If the antibiotic is changed, a new resistance can be selected.

Antibiotics are not automatic, but they are still necessary to treat human bacterial infections. They must therefore be saved in order to preserve their usefulness. Faced with this public health priority, agronomy, aquaculture and veterinary sciences must consider the risk of the mass use of antibiotics on farms, their dispersal in the environment, the emergence of multiple resistances and the spread of resistance genes. This is especially true since the origin (or reservoir) of antibiotic resistance genes is the environment. Indeed, as explained above, microorganisms produce natural antibiotics to fight competitors. These competitors in turn can acquire resistance to counterattack. This is called the evolution of resistance. This is why antibiotic resistance precedes the discovery and clinical use of antibiotics. For example, multi-resistant bacteria have been isolated in antibiotic-free environments. We have so much to learn from nature. What if the key to new antimicrobials came from observing what happens in the environment?

8. Alternatives to antibiotics. Human and animal health is intimately connected to the quality of the environment and the maintenance of biodiversity. For example, a coral disease called bleaching is associated with global warming, ocean acidification and overfishing. In some areas of the ocean, the abundance and diversity of fish has decreased so much that jellyfish, which are no longer threatened by their competitors, are invading the environment. On a microscopic scale, biodiversity is also synonymous with the quality of the environment. Competitors and predators control the abundance of bad bacteria (or pathogenic bacteria). Identifying the actors and understanding the mechanisms of this control in nature could help to develop alternatives to antibiotics.

Competitive bacteria can replace **pathogens** in the ecological niche (e.g. a fish tank or fish gut) because they are better adapted to this environment without harming the animal. Useful bacteria that are used to fight disease are called probiotics. Prebiotics (including some grandmother's remedies) are molecules that stimulate the growth of good bacteria. Some bacteria produce natural antibiotics to win the battle. In oyster blood (or hemolymph), some bacteria produce small molecules called antimicrobial peptides, which lodge in the membrane of the bacteria and kill it. Finally, some bacteria produce molecules that prevent the bacteria from communicating and taking concerted action to cause disease.

Predators are defined as organisms that kill their prey for food. This phenomenon therefore plays a major role in biological and microbiological balances. The predators of bacteria are generally slightly larger cellular organisms, **unicellular** eukaryotes (or protists). They are generally not very specific and therefore attack useful and pathogenic bacteria. In addition, some protists (such as amoebae) are also pathogenic, and therefore do not constitute a preferred alternative to antibiotics to date.

Bacteriophages are also predators of bacteria. They were described and named by Felix d'Hérelle (1917) as very small bacteria-eating organisms (phage), and it was not until the discovery of the electron microscope in the 1940s that they were observed (Figure 5A). They are in fact viruses capable of infecting only bacteria. Like other viruses, phages attach to the bacterial cell at a very specific receptor (Figure 5B).

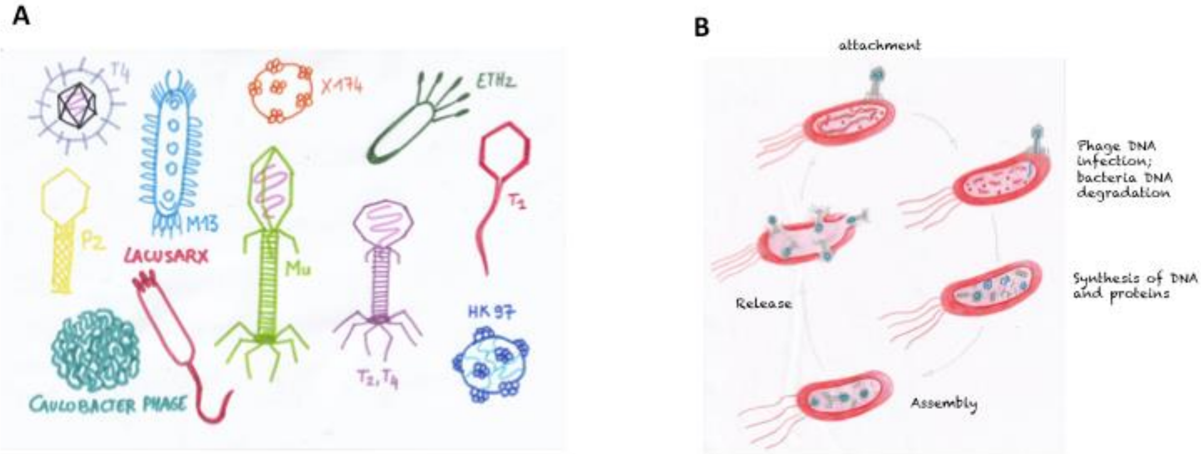


Figure 5. Bacteriophages (or phages) **A.** Phages can be observed using an electron microscope. They show a wide variety of shapes. **B.** Phages specifically infect bacteria by injecting their genome into the cell, hijacking the cell machinery to replicate and killing the cell to be released (adapted from Sawakinome).

They inject their genome into the cell and hijack the cellular machinery to multiply. This hijacking only works for the machinery of the bacterium; that is why phages are not able to infect other single-cell organisms, animals, plants or algae. The phages complete their life cycle by expressing enzymes that puncture the wall to release about 100 new phages. The equation is simple, if a phage encounters a bacterium that carries its receptor, the death of the infected bacterium leads to the production of 100 times more phages. One says phages are capable of self-amplifying. If all sensitive bacteria are killed, the phage can no longer multiply and is eliminated. Self-amplification and self-elimination are major advantages of phages over antibiotics. Another advantage is their extreme specificity. They are able to infect only certain bacteria, so phages can be searched for infecting only pathogenic bacteria and not useful bacteria. This specificity can also be a limit, it is sometimes necessary to use different phages (a cocktail) to kill all pathogenic bacteria, either because the phage only infects a part of the pathogenic bacteria, or because the latter are able to develop a resistance just like with antibiotics. However, while the development of phage resistance is often observed in the laboratory, it seems that in nature it is not so simple. In an "arms race" game, the bacterium develops mechanisms to resist phages, which then counterattack by developing new infection mechanisms. This coevolution of the phage and the bacterium can be to the detriment of other capacities. It can have a cost, just like the genetic selection previously described. For example, it can result in a lower growth of the bacterium and the phage.

Despite these limitations, phages are extremely abundant (10 to 100 times more than their bacterial host) in the environment, particularly in water, where they play a major role in regulating the abundance of bacteria, their evolution and therefore microbial biodiversity. An alternative to antibiotics would therefore be to understand how in nature phages control pathogenic bacteria and to assess whether it is possible to use them as therapeutic or prophylactic tools. High throughput phage production can be carried out in the laboratory at low cost. Numerous research teams are now working on the development of phage therapy for many fields of application, including aquaculture. Researchers can draw on the experience of their colleagues in the former Soviet Union, particularly those at the Eliava Institute in Georgia, which has been practicing phage therapy in human medicine since the 1930s.

In parallel and in the context of a new scientific revolution, that of synthetic biology, another approach consists in recreating life in the laboratory by making it more "intelligent". This can be considered illusory because laboratory conditions considerably simplify nature, the functioning of which is still poorly understood. However, in the case of the search for alternatives to antibiotics, researchers are working on the creation of phages capable of specifically infecting pathogenic or antibiotic-resistant bacteria. For example, eligobiotics are phage-inspired biological robots that have a system for recognizing a specific DNA sequence (for example an antibiotic resistance gene) coupled with a system for mass destruction of the bacteria's DNA (scientific name: CRISPRcas system). The eligobiotic infects the bacterial cell and, if it carries the resistance gene, destroys its DNA and kills it.

Relevance for Sustainable Development Goals and Grand Challenges

The microbial dimension of aquaculture relates to several SDGs (*microbial aspects in italics*), including

- **Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture** (*end hunger and malnutrition, increase agricultural productivity).* Aquaculture is a major contributor to the production of food and essential nutrients, and hence central to ending hunger and malnutrition. Microbial diseases reduce aquaculture food yields, whereas environmentally friendly treatments, like microbial probiotics, prebiotics and phages, can increase aquaculture food yields, and hence sustainability of aquaculture operations.
- **Goal 3. Ensure healthy lives and promote well-being for all at all ages** (*improve health, reduce preventable disease and premature deaths).* Raw fish and shellfish (including sushi, sashimi, ceviche) can transmit pathogenic microbes – most often bacteria, but also viruses and toxic flagellates – some of which, like neurotoxin-producing flagellates and *Vibrio vulnificus*, can result in lethal disease. On the other hand, the products of aquaculture are health-giving, so pathogenic microbe reduction in yields and probiotic-mediated increases in yields are key microbial activities affecting this SDG.
- **Goal 6. Ensure availability and sustainable management of water and sanitation for all** (*assure safe drinking water, improve water quality, reduce pollution, protect water-related ecosystems,*

improve water and sanitation management). Aquaculture enclosures are point sources of water pollution: feed and faeces contribute to eutrophication and the creation of oxygen minimum zones that suffocate aquatic animals; growth promoter additions, like antibiotics select and enrich antibiotic resistant microbes, and pathogens are enriched by high density monocultures, so are important challenges for sustainability.

- **Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all** (*promote economic growth, productivity and innovation, enterprise and employment creation).* Aquaculture is a significant industry and employer, and a key contributor to food supply. Appropriate actions to increase the positive contribution of microbes and ameliorate the negative ones will contribute significantly to the sustainability of aquaculture as a contributor to economies and employment.
- **Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development** *(reduce pollution of marine systems by toxic chemicals/agricultural nutrients/wastes like plastics, develop mitigation measures for acidification, enhance sustainable use of oceans and their resources).* Current aquaculture practices, involving the overcrowding of food animals, and the use of growth promoters and disease-reducing compounds, are polluting and not sustainable. The application of sustainable practices like microbial probiotics can ameliorate the problem.

Potential Implications for Decisions

1. ***Individual***
   a. should I eat farmed or wild fish/seafood?

2. ***Community policies***
   a. Given the local environmental consequences (pollution of public spaces and local water bodies with faeces, antibiotic residues, antibiotic resistance spread, including to human infecting microbes), but positive economic consequences, should aquaculture be encouraged locally?
   b. If so, how should it be regulated to minimize negative consequences?
   c. How should a local aquaculture facility be monitored for safety, polluting activities?
   d. What contingency plans need to be put in place in an aquaculture facility and by local authorities, to respond to potential problems that may arise?

3. ***National policies relating to aquaculture***
   a. Should the development of aquaculture as source of food for humans be encouraged politically?
   b. Should the use of antibiotics be allowed and, if so, should they be subject to oversight and control?
   c. What guidelines/regulations are needed to ensure food and water, including recreational waters, safety?
   d. What guidelines/regulations are needed to ensure that the environmental consequences of aquaculture conform to national and international environmental policies?
   e. Should "Fallow Land" practices be mandated to prevent long-term degradation of coastal waters?
   f. What policies are needed to prevent/minimize the escape of invasive species into non-target environments?

g. What research programs should be developed to promote the discovery of new ways to make aquaculture more sustainable?

h. Develop in parallel research to prevent or decrease the use of antibiotic (with clear impact for environment)

Pupil Participation

1. ***Class discussion of the issues associated with aquaculture***

2. ***Pupil stakeholder awareness***
   a. Aquaculture has positive and negative consequences for the SDGs. Which of these are most important to you personally/as a class?
   b. Can you think of anything that might be done to reduce the negative consequences, especially in the food supply chain?
   c. Can you think of anything you might personally do to reduce the environmental footprint of aquaculture?

3. ***Exercises (could be made at any level, but these are probably secondary education level)***
   a. The production of animal proteins from aquaculture has consequences for the environment, but fishing too. What other alternatives can you envision?
   b. Therapeutic, in particular with antibiotic appears as dead end. What sustainable options are there? How might you formulate a sustainable aquaculture for your region?
   c. Do we need to understand how nature controls microbes and use this knowledge to create new antimicrobials (e.g. through the use of phages) or use synthetic biology (e.g. eligobiotics). What are the advantages and disadvantages of these two approaches?

The Evidence Base, Further Reading and Teaching Aids

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Glossary

Pharmacopoeia: collection of medicines
Brackish water: water with low salt content, e.g. water in marine estuaries.
Omega-3: fatty acid (also called lipid) very important for our health, found in large quantities in fish or shellfish, but also in nuts or soybeans.
Ecosystem: a community of living beings in interrelation (biocenosis) with its environment (biotope).
Proliferate: multiply
Mangrove: a forest of trees that live in the water, their roots form galleries that create shelters for many species of all sizes.
Organic matter: corresponds to what composes living beings as well as what results from their degradation or excretion.
Protozoa: a small living organism, usually consisting of a single cell.
Unicellular: made up of a single cell, this is the smallest unit of life.
Membrane: assembly of molecules separating the inside from the outside of the cell.
Cytoplasm: content of the cell
Enzymes: proteins that are responsible for cell chemistry (synthesis of sugars, lipids and other proteins) and energy production.
Nucleus: a membrane in the cell that contains the DNA
DNA: deoxyribonucleic acid
RNA: ribonucleic acid
Flagellum: cell locomotion apparatus
Pathogen: which leads to diseases
Altruists: which give to others (the opposite of selfishness)
Obligate parasite: an organism that can only multiply to the detriment of another organism.
Immune defense, immunity: the body's ability to defend itself against infectious agents, the "non-self".
Pandemic: infectious diseases, epidemic affecting organisms worldwide
Globalization: free movement of goods, capital, services, people, technology and information