Harnessing friendly bugs to chase away nasty ones in hospitals

Sir: could we fight the bad microbes that cause infections in the hospital by using good microbes, letting them struggle for us, like in a "Microbe War"?

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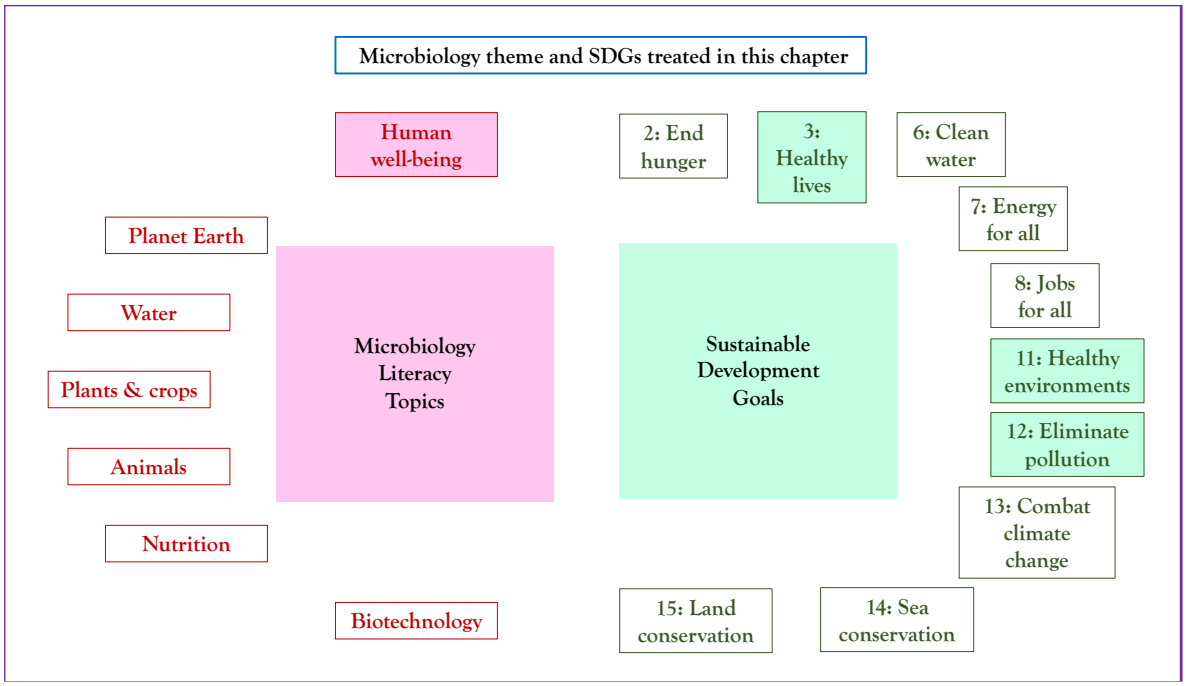
Storyline

The presence of good bugs – 'commensals' – in the bodies of children provides irreplaceable health benefits, as it is fundamental for the correct development and maturation of many body functions, including the immune response. 'Knowing by mouth' – the action of an infant putting everything it can pick up into its mouth – is considered important because it allows cognitive development through recognition of objects, shapes, consistencies, flavours, etc. But also, or perhaps primarily, this action is important because it introduces environmental bugs into the body that subsequently colonize the mouth, the skin, and the gastrointestinal tract, thus enriching the microbial diversity of the body and promoting development of a healthy immune system. Microbiome enrichment is generally recognized to be of critical importance for the capability to counteract invasion by bad bugs that cause disease, i.e. infections, by competing for living space on the body – the process of *competitive exclusion*. This principle of competitive exclusion may also be applied to the environment, and could lead to the construction of a healthier environment, where concentrations of bad microbes can be reduced by the applying good 'colonizers' able to stably replace them and discourage their growth. This concept, successfully applied in the hospital environment where it was shown to prevent many infections, could be applied to other built environments, for example schools, with important potential consequences for Sustainable Development Goals.

The Microbiology and Societal Context

The microbiology: survival and growth on surfaces; pathogens and non-pathogens, microbiology of the built environment; disinfection; competitive exclusion-environmental probiotics; reduction in hospital-acquired infections. *Sustainability issue:* health.

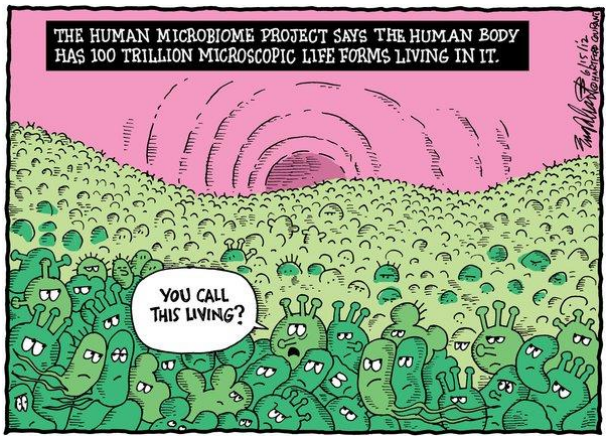


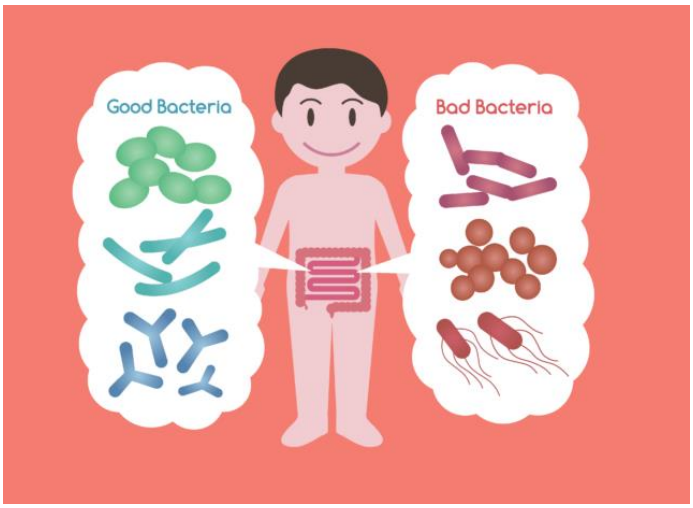
Harnessing friendly bugs to chase away nasty ones in hospitals: the Microbiology

1. ***Microbes colonize essentially the surfaces of every living and non-living entity in the biosphere.*** Diverse microbes grow on all the available surfaces and eat what they find on them. The entire microbial content of each organism or environment is called its "microbiota". Human beings, as well as other living organisms, each have their own, different microbiota, consisting of billions of tiny microbial cells that cover all the external surfaces of our body, plus all the internal surfaces that are connected with them. Thus, the skin, eyes, hair, but also the mouth, the entire gastrointestinal tract, bronchial cavities, and urinary tract are covered with microbes – our microbiome friends – living with us in peace. Indeed, the presence of our microbiome is essential for several vital functions which our body is unable to fulfill itself.

The first time some of our microbiota – that covering our teeth – was described in the XVII century by Antonie van Leeuwenhoek, a Dutch merchant, who observed them with a rudimentary microscope. He described them as a multitude of "animalcules", which in ancient Latin mean "little animals": there were so many in a water drop that he said "the water drop itself seemed alive". This is considered the very beginning of the history of microbiology, and since then we know that microbes are our companions for all our lives.

We can think to the human body as a coral, where our body is the trunk and branches, and the microbes are as the alive tiny coral polyps. Such microscopic life forms are so important for the correct functioning of our body that we could not survive without them. And they are so many that their number is as great as the number of the cells of our body.





2. ***Most of the microbes living in our body are beneficial***. However, sometimes some of those microbes can turn nasty, or some nasty microbes arrive from the outside and manage to fight their way into our body. When that happens, they may multiply and damage our cells and tissues, causing disease. Unlike our peaceful co-existence with good microbes, which is called "commensalism" or "symbiosis", our relationship with bad bugs is called "parasitism"; they are parasites.

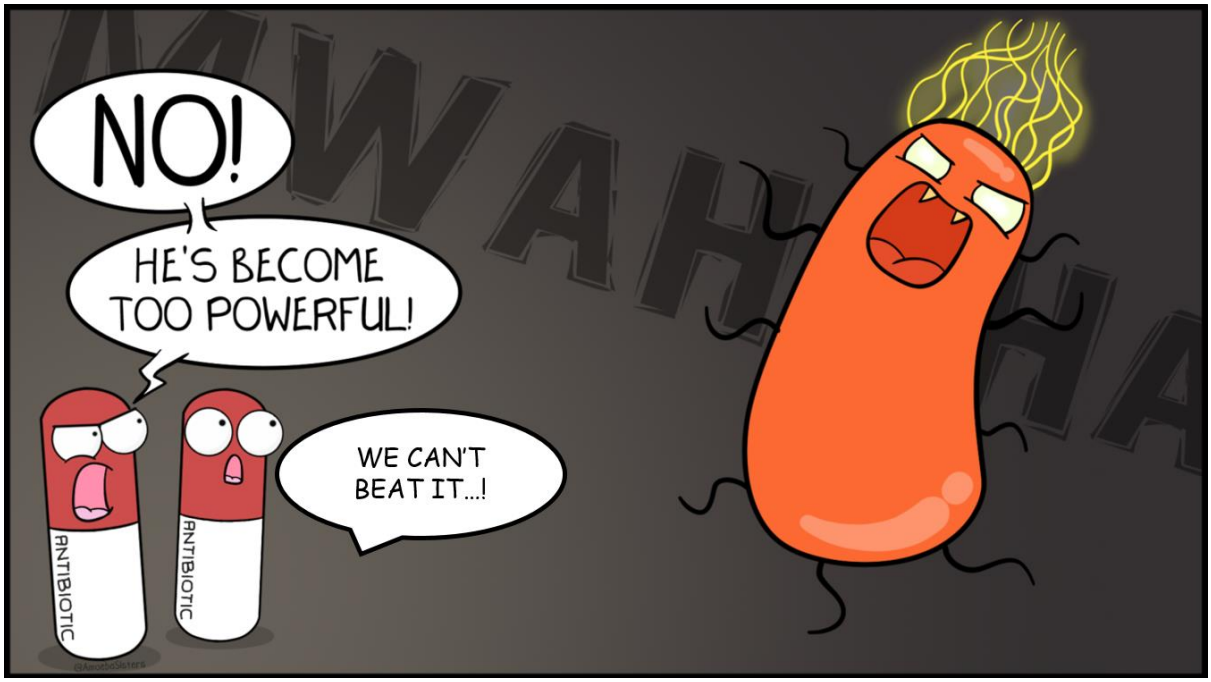
Interestingly, our good microbes are very important in our interaction with bad microbes trying to colonize our body, because they fight for us and try to prevent bad bugs gaining a foothold and establishing themselves on or in us. Our microbiota is our second skin, acting as a second barrier against invasions from the environment. It does this by occupying available space on our body surfaces and consuming available nutrients, so that newly-arriving microbes have a hard time finding space and food on our body. This fruitful behavior is called "*competitive exclusion*".

This function is fundamental for our health, so much so that when we take some antimicrobial medicine (such as antibiotics) during an infection, which will not only kill the parasite but also some of our microbiota friends, we may be advised to take some good microbes to restore the healthy microbiota, so that they can help us fight bad microbes and promote healing.

3. ***A similar situation is found in built environments***. We may consider every house, school, hospital, or other building as a super-organism, populated by billions of microbes coming from the environment, from the people living there, plants, animals, etc. Thus, each building has its own "microbiota", exactly like the living organisms and our body. The kind of microbes living in a built environment depends on how much that building is confined: more confined (closed) environments have more microbes derived from people living there, so the final microbiota resembles quite closely our microbiota.

This is particularly important in the hospital environment, since the hospital microbiota contains all the bad microbes introduced by ill people visiting or staying in the hospital, which can then transmit to other patients. Since hospital patients are particularly fragile, the transmission of bad microbes can be very threatening to them, potentially causing very severe diseases. Indeed, the microbes usually populating the hospital environment are particularly robust and resistant: why is this?

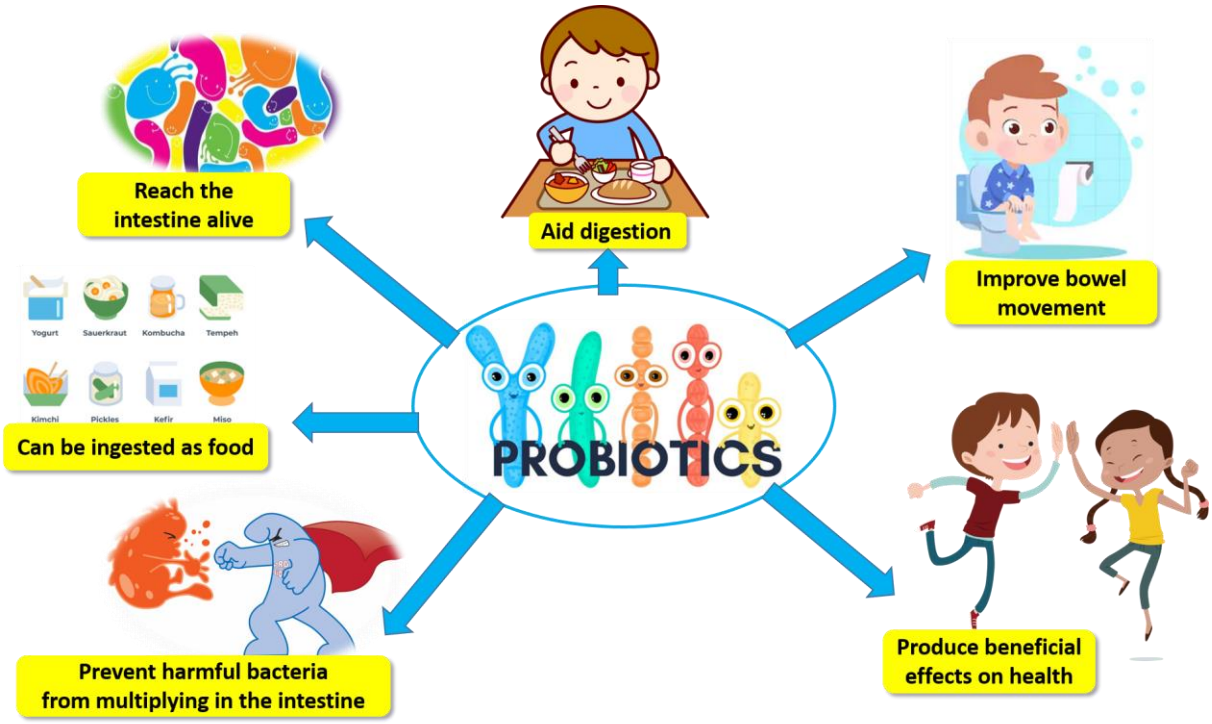
Firstly, as mentioned, the hospital microbiota originates from the microbes continuously spread by ill hospitalized people (so they are bad, pathogenic, disease-associated microbes). Secondly, in the hospital several disinfectants and anti-microbial drugs are used every day to cure ill people and disinfect the environment. Because of the continuous contact with such substances, the microbes residing in the hospital have learned to resist to them, in order to survive their widespread and continuous use. Over time, a great number of microbes residing in the hospital environment have become resistant to both disinfectants and antibiotics, and it becomes more and more difficult to kill them in the hospital, and to treat them in the patients they infect. This is a big concern worldwide, so much so that new solutions/inventions/ideas are desperately needed to solve this problem.



4. ***So far, the elimination of bad microbes in the hospital environment has been addressed by the use of chemical-based cleaning and disinfection.*** This is effective for a short time, but allows recontamination. Why is this? Disinfectants immediately remove microbes from surfaces, like floors, tables, instruments, but leave much space for new microbes to arrive and colonize, which occurs continuously. In the end, the bad microbes quickly recapture and colonize the space, and return as numerous as before disinfectant use. Moreover, disinfectants and chemicals have a high environmental impact (especially on surface waters) and, even more importantly, they induce bad microbes to become even more resistant to medicines, thus worsening the antimicrobial resistance concern.

5. ***Thus, starting from the idea that in our body good microbes can protect us from bad ones***, some investigators started thinking to apply the same principles to the hospital environment: "Can we use gentle good microbes, not dangerous for human health, to fight the nasty ones and chase them from the surfaces of the hospital buildings?"

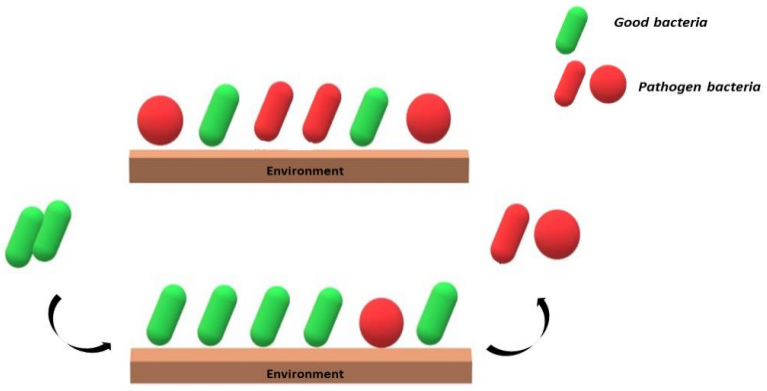
6. ***The chosen "good warrior" microbes were those called "probiotics",*** which are harmless microbes that can be very useful to restore health in the human body (for example those contained in the yogurt!): they are called "probiotics" because they help ("pro") the vital healthy functioning ("bio") of living organisms.



Moreover, some of them can survive in the environment quite easily, as they form highly resilient dormant "spores" that become active when the conditions allow germination (water, nutrients).

7. ***The first question to answer was: might we use something similar to clean away bad microbes*** and render the hospital environment safer and healthier for patients? Other important questions were: Would this approach be gentle to the environment? Would it be available for poorer countries, which do not have much money to invest in efficient cleaning methods? Would it reduce the selection of bad resistant microbes?

Well, researchers tried to answer these questions by doing experiments of probiotic use in their laboratories and in many hospitals, and what they found was even better than what they expected! Briefly, the probiotics contained in the gentle cleansers could replace bad microbes, through their ability to compete successfully with bad microbes for space and nutrients (the mechanism of *competitive exclusion*), and establish a healthy bacterial microbiota in the hospital environment, where the good bacteria overpower the bad ones.



8. ***An interesting discovery was that the good bacteria, once they have conquered the space, do not go away***, so preventing the colonization by pathogens and rendering ultimately the environment very safe and friendly for patients. In other words, the good microbes somehow "protected" hospitalized patients from infections, rendering the hospital environment much more wholesome. Furthermore, among bad microbes kicked out by probiotics, there were also most of the drug-resistant ones, so that curing the eventually remaining infections was much easier.

In the end, the idea to let good microbes fight for us turned the hospital into a healthier place. And since the probiotic cleaning is very cheap, it might be used in less rich countries that cannot afford the costs of expensive cleaning and disinfectants, and have big problems with infections.

And what would you think to use it in animal farms, for plants, on the school bus? What a great idea: let's try!

Relevance for Sustainable Development Goals and Grand Challenges

Goal 3. Ensure healthy lives and promote well-being for all at all ages (*improve health, reduce preventable disease and premature deaths).* The development of microbially-based sanitation systems represents new hygiene practices that do not require chemical disinfectants having a high environmental burden on the planet, and the ensuing negative effects on water, plants, and animals. They are also cheap, compared to chemicals, so can be used also in low-income countries, potentially saving many lives. The prevention of the development of drug-resistance is another very important point, not only in a life-saving perspective but also in a cost-saving perspective, due to the billions currently used to manage drug-resistant infections (economic sustainability).

Potential Implications for Decisions

1. ***Individual***
   - **a.** Weighing up the various microbial and non-microbial factors and aligning them with personal convictions (do the positive health benefits outweigh the usual habits regarding cleaning?).
   - **b.** Is it better to have a healthier environment or a polished and scented one?
   - **c.** Which consequences can be recognized at the environmental impact level when using a eco-sustainable microbially- based system or a conventional chemical one?

2. ***Community policies***
   - **a.** Local environmental consequences (impact on pollution of groundwater)
   - **b.** Health costs associated with infections contracted in hospitals, schools, communities

3. ***National policies***
   - **a.** Healthcare economics of healthcare-associated infections and community-acquired diseases
   - **b.** Positive influence on environmental pollution (groundwater)
   - **c.** Potential use in agriculture and animal farms

Pupil Participation

1. ***Class discussion of the possible issues associated with microbial cleaning***

2. ***Pupil awareness***
    a. Microbial cleaning has several consequences for the SDGs. Which of these are most important to you personally/as a class?
    b. Can you think of anything you might personally do to reduce the environmental impact related to cleaning procedures?

3. ***Exercises (could be made at any level, but these are probably secondary education level)***
    a. In most cities, community-acquired infections are an important issue to be managed. What other approaches to control such concern can you envision?
    b. Looking at the SDGs, how can we change our approach to cleaning procedures to bring them into sustainable living? What are the challenges and opportunities? Create a sustainable plan for cleaning different built environments in a hypothetical city (hospitals, schools, public transportation, animal farms, etc) and their associated environmental impacts.

The Evidence Base, Further Reading and Teaching Aids

Suggested book: "It's catching: The Infectious World of Germs and Microbes", by Jennifer Gardy (Author), Josh Holinaty (Illustrator); Published by Owlkids Books, 2014
ISBN 10: 1771470534 / ISBN 13: 9781771470537

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Glossary

Pathogen = any microorganism that causes disease
Bacterial spores = some bacteria can form thick-walled structures called spores when environmental conditions are unfavourable for bacterial growth. These are dormant forms that they can survive for very long periods of time.
Probiotics = live microorganisms that can provide health benefits when consumed, generally by improving or restoring the gut flora; they are considered generally safe to consume. Live probiotic cultures are part of fermented dairy products, other fermented foods, and probiotic-fortified foods