Dirt is Good For You

Mummy: why should I wash my hands before snack if we have been told that dirt is good for you?

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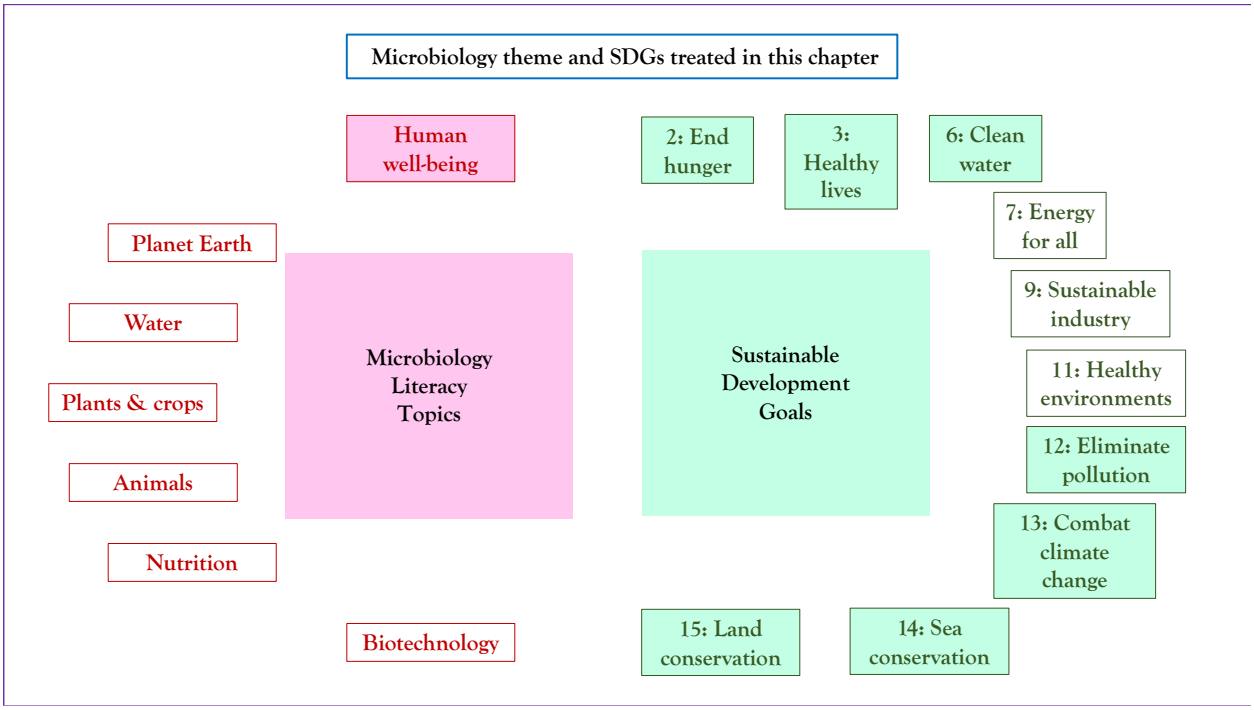
Storyline

A fundamental part of childhood is playing outside. Whether exploring, digging in the dirt, or assisting parents with gardening and farming, historically, children have spent much of their time in nature. While this is still true in some cases, the global population is quickly urbanizing, and more and more families now live in man-made environments where children's contact with plants, animals, or soil is low. As the global population becomes more urban, we have also observed increased prevalence of allergies, asthma, and other inflammatory diseases. We now know that these trends are likely related. Soil is home to a huge number of microbes, and scientists have hypothesized that exposure to these microbes can actually have significant benefits to our health, since they enrich the diversity of our microbiome, and help our immune systems develop. Lower exposure to these microbes may result in immune dysfunction and the development of allergies. In addition, the microbes in soil also support the crops we grow for food, recycle carbon dioxide from our atmosphere, purify our drinking water, and produce antibiotics that can be isolated and used for medicine. Therefore, land and climate management practices that help preserve soils and their biodiversity will have direct benefits for human health and quality of life.

The Microbiology and Societal Context

The Microbiology: microbiome enrichment and immune development, soil microbiome, carbon cycling, pathogens, soil conservation, urban biodiversity. *Sustainability Issues:* health, food and nutrition, environmental pollution, climate change.



Dirt is Good For You: the Microbiology

1. ***Soil adds biodiversity to our skin and gut microbiome:*** Studies have shown that direct contact with soil, or even exposure to small amounts of airborne soil can make a big difference in the microbial populations of our skin and gut. The biodiversity hypothesis theorizes that the total biodiversity of our environments influences our health by changing our microbiome. In Finland, children from urban environments with low exposure to soil were shown to have less biodiversity on their skin than children in rural environments. Studies on mice have also shown that exposure to microbially rich soil can increase the biodiversity of the gut. Higher biodiversity on our skin and in our gut can make these areas more resistant to infection by pathogens. So increased exposure to soil for both children and adults can actually help improve health. Making sure that green spaces are accessible to people who live in urban environments is an important way to promote health equity among communities. And, as shown in the image above, gardening is especially good for you and your microbiome!

2. ***Environmental biodiversity prevents allergies and inflammatory disease:*** In urban communities, an individual's exposure to diverse microbiota is lower than in rural communities because urban dwellers are less likely to be in close proximity to soil, plants, or animals. In addition, the widespread use of disinfectant and antibacterial cleaning products further removes biodiversity from most urban households. However, evidence shows that lower exposure to diverse microbiota increases the prevalence of inflammatory diseases and allergies. Especially for children, exposure to environmental allergens helps to build the innate immune system. Studies have shown that children who live in rural environments with higher exposure to environmental and animal-associated microbes have lower rates of inflammatory diseases, allergies, and asthma.

3. ***Soil microbes can enhance the nutrition of the plants you eat:*** Evidence suggests that the microbes present in healthy soils can improve the nutritional quality of the foods we eat, and can also help to preserve foods longer during transportation. Soil microbes that are symbionts of plant roots can help to increase the plant's content of minerals and secondary metabolites such as vitamins and antioxidants which are important parts of our diet.

4. ***Psychological benefits:*** Spending time outdoors also has psychological benefits for both children and adults. Allowing children to explore the outdoors and play in the dirt gives them an opportunity to exercise their curiosity and develop important behavioral skills. For many adults, time outdoors is also a way to reduce stress. Studies have shown that exposure to anti-inflammatory soil microbes can reduce stress behavior and stress induced symptoms in mice. Exposure to these microbes may have a similar effect in humans.

5. ***Soil pathogens:*** Antibiotics, disinfectants, and hygienic measures may reduce our contact with environmental microbes and consequently reduce our microbiome diversity. However, a few microbes in soil are able to cause disease under some circumstances, such as when they get into wounds or onto food. So: while exposure to soil may be good for you, good hygiene practices like hand washing, especially when we have cuts on our hands which can become infected, or before we touch food, are still essential when we have been handling things with soil on them, since they greatly

reduce transmission of human pathogens and disease. For example, manure used to fertilize crops may contain pathogenic strains of *E. coli*. This can occasionally be problematic for leafy greens, since they sit low on the soil, and are splashed when it rains/are watered, and are often eaten uncooked. An *E. coli* outbreak caused by contaminated romaine lettuce in 2019 sickened 167 people in the United States. In addition, studies show that soil that has undergone environmental stress and disturbance due to human activity contains more opportunistic potential human pathogens than immune-boosting microbes.

6. Soil conservation and climate change: Soil is the largest carbon sink on Earth! The activity of soil microbes helps to capture carbon dioxide from the Earth's atmosphere, and also supports the growth of forests and vegetation that capture carbon dioxide and conduct heat from Earth's surface. So, soils have a big role in regulating the Earth's climate. Healthy soil is necessary to reverse the effects of anthropogenic climate change, which will help to keep us, and our planet, healthy.

7. Soil cleans our drinking water: Soil also physically, chemically, and biologically cleans the fresh groundwater which eventually enters our sources of drinking water. The microbes in soil can utilize some pollutants and nitrates in the water for energy, which either removes them from the groundwater entirely, or degrades them into less harmful compounds. The large-scale removal of soil which is mainly caused by human construction can negatively impact the quality of our drinking water, which in turn affects our health.

8. Human activities reduce soil biodiversity: Soil is formed by the "weathering" of rocks by erosion forces of weather, rivers and glaciers, as well as microbial growth and chemical activities. Soil is also lost by the erosive forces of wind and rain, which transport it into rivers and seas. Unfortunately, human activities often pose a threat to soil preservation. It can take hundreds of years for soil to form, yet humans are causing soil erosion at an alarming rate. Construction, mining, and poorly managed farming practices can all cause extensive soil loss. In addition, climate change may reduce the amount of water and carbon that can be stored in existing soils, and decrease soil biodiversity. All of these things could break down all the benefits that healthy soils provide for us.

9. Urban green spaces improve community health: Urban green spaces are a way to bring nature into areas which are otherwise highly urbanized. Some examples include parks, community gardens, or playgrounds. Studies have shown that these spaces are associated with improved community mental and physical health. Green spaces may enrich the microbiome of urban populations in multiple ways. Giving children access to such spaces would help increase exposure to biodiversity in their environments. And community gardens can provide fresh produce to areas where food deserts are common. Expansion of these spaces could significantly improve human health and reduce urban biodiversity losses.

Relevance for Sustainable Development Goals and Grand Challenges

- **Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture** *(end hunger and malnutrition, increase agricultural productivity).* Access to affordable and nutritious food is often taken for granted, but for many individuals even in seemingly

affluent communities, this can be difficult to come by. In both rural and urban communities, food deserts are areas where healthy fresh foods are inaccessible to members of the population either by distance or by price. These factors pose a huge barrier to obtaining proper nutrition. Promoting urban gardening or community gardening can help to provide affordable sources of nutritious food in food deserts. This would help people learn about food production, improve nutrition, and help end hunger.

- **Goal 3. Ensure healthy lives and promote well-being for all at all ages** *(improve health, reduce preventable disease and premature deaths).* Spending more time outdoors in nature can also help to enrich our microbiome, and strengthen the immune system, especially in children. This could likely help reduce the prevalence of allergies, asthma, and other inflammatory diseases. In addition, spending time outdoors increases physical activity and has psychological benefits for both children and adults. All of these things could improve health and quality of life, and reduce the healthcare burden of preventable disease.
- **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).* Soils naturally filter and purify the groundwater that we drink, and absorb and store water, helping to hold it in the Earth's surface where it is available to us. Soil physically filters water through the pores between soil particles, and it also chemically filters water since some ions and molecules in the water bind to soil particles. When soil is removed, for example in a pavement-covered city, water cannot permeate into the ground, and instead runs over the surface. Instead of being filtered by soil as the water reaches the ground, this water picks up pollutants as it flows and needs to undergo further treatment before it is drinkable.
- **Goal 12/14. Ensure sustainable consumption and production patterns, and conserve and sustainably use the oceans, seas and marine resources for sustainable development** *(achieve sustainable production and use/consumption practices, reduce waste production/pollutant release into the environment, attain zero waste life cycles, inform people about sustainable development practices). (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).* Proper soil maintenance and soil biodiversity can reduce the amount of synthetic fertilizers that are used on large-scale mono-cropping farms. Community based farming and urban farming can also help to reduce fertilizer use. By reducing the amount of fertilizer that is used on industrial farms, through proper soil maintenance, we can reduce the amount of fertilizer runoff that enters the oceans and causes eutrophication.
- **Goal 13. Take urgent action to combat climate change and its impacts** *(reduce greenhouse gas emissions, mitigate consequences of global warming, develop early warning systems for global warming consequences, improve education about greenhouse gas production and global warming).* Healthy soil is vital to preventing climate change. Soils are the largest reservoir of carbon on Earth. The plants and microbes in soil remove carbon dioxide from the atmosphere and can store it in the Earth for hundreds of years. This helps to combat the accumulation of carbon dioxide in the atmosphere. Experiments have also shown that heating soils may reduce the amount of carbon they can store, which means that climate change may make soils less effective at removing atmospheric carbon.
- **Goal 15: Land conservation.** Protecting soils from erosion and degradation will preserve all the benefits that soil contributes to our lives. Land management and restorative farming

practices help to maintain agricultural soil over time, so we can support healthy soils that are productive for years to come.

Potential Implications for Decisions

1. ***Individual***
    a. Spending more time outdoors/giving children more outdoor time:
        i. Allows for exposure to more diverse microbiota
        ii. Strengthens innate immune system
        iii. Depends on accessibility of green spaces?
    b. Allowing non-sterile environment:
        i. Allows for greater environmental biodiversity
        ii. Could potentially increase risk of exposure to pathogens
    c. Starting personal garden:
        i. Increases exposure to diverse microbiota
        ii. Provides a low-cost source of nutritious food
        iii. Promotes soil health and biodiversity
        iv. Psychological benefits

2. ***Community policies***
    a. Preserving and expanding green spaces:
        i. Improve physical and mental health of community residents
        ii. Increase value of community property
        iii. Costs of construction and maintenance
    b. Starting community gardens:
        i. Improves community cohesion and cooperation
        ii. Provides access to nutritious foods for low-income members
        iii. Costs of startup and oversight
    c. Preserving sustainable natural watershed:
        i. Provides clean drinking water to community
        ii. Improved health reduces healthcare burden
        iii. Reduces costs of industrial water treatment

3. ***National policies***
    a. Stringent climate policy and soil protection policy:
        i. Protects soil erosion and degradation
        ii. Preserves soil biodiversity and carbon storage capacity
        iii. Preserves sources of clean drinking water
    b. Ensuring citizen access to green space (national parks/preserves, funding for state parks):
        i. Promotes biodiverse environments
        ii. Improves mental and physical health of citizens
        iii. May reduce the healthcare burden of allergies, asthma, etc.
    c. Agricultural policies:

i. Protect oceans from fertilizer runoff
ii. Preserve agricultural land from erosion/degradation

Pupil participation

1. Class discussion about ways that soil affects human health:
    a. Positive/negatives?
    b. Which aspect is the most important?
    c. What might our lives be like without soil?

2. Personal experiences:
    a. What are some of the ways that you are exposed to soil/soil microbes?
    b. What green spaces are available to you and how do you use them?
    c. What are some ways we could make green space more available?

3. Exercises/experiments:
    https://www.soils4teachers.org/lessons-and-activities

The evidence base, further reading and teaching aids

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Glossary

Urbanizing: Increasing the proportion of the population that lives in cities rather than the countryside.

Inflammatory diseases: Diseases characterized by inflammation, which is the body's normal response to damage or infection. With inflammatory diseases however, the body may trigger an inflammatory response when no damage or infection is present. Examples include allergies, asthma, autoimmune disorders, inflammatory bowel syndrome, and coeliac disease.

Microbiome: The collection of all the microbes that live in a specific environment. The gut microbiome, skin microbiome, and soil microbiome are some highly studied examples.

Immune dysfunction: When the immune system is not functioning properly. This can result in immune deficiency, or autoimmune disorders.

Carbon cycling: The large-scale process by which carbon is transferred between the Earth, living things, the ocean, and the atmosphere.

Biodiverse: An environment that contains a large variety of different organisms is biodiverse.

Human microbiome: The collection of all the microbes that live on/in the human body.

Biodiversity hypothesis: Theory stating that lower biodiversity in one's environment makes them more prone to immune dysfunction and inflammatory disease.

Pathogens: Microorganisms that can cause disease.

Health equity: When people across different social, economic, demographic, or geographic groups have equal access to healthcare, and to social determinants of health such as affordable nutrition and health education.

Environmental allergens: Molecules in our environment that trigger an immune response when we come into contact with them, even though they are not dangerous to our health.

Innate immune system: Defense mechanisms that are non-specific to the type of pathogen causing infection (compared to the adaptive immune system which is pathogen-specific). Includes inflammation response, some types of white blood cells, and chemical signals.

Symbionts: Two organisms that have a mutually beneficial relation to one another. A clownfish that lives in a sea anemone is a classic example. A human and a beneficial microbe that lives in their gut are also symbiotic.

Secondary metabolites: Molecules produced by bacteria, fungi, or plants which are not involved in normal processes of growth and reproduction. These molecules are generally produced for defense, and are often specific to individual species. Secondary metabolites are frequently isolated by humans to produce medicines.

E. coli: A species of bacteria that is commonly found in the gut of humans and other mammals. Some types of this bacteria are harmless, but others can cause serious food poisoning symptoms if ingested.

Opportunistic: Microbes that are not always pathogens, but can cause infection when the normal functions of the host are disrupted. Injury or a weakened immune system can make someone more vulnerable to opportunistic infections.

Carbon sink: An environment where carbon is stored. Soil is a carbon sink since it captures carbon dioxide from the atmosphere at a faster rate than it releases it. Soils are estimated to contain over four times as much carbon as the atmosphere.

Anthropogenic climate change: Changes to the Earth's climate which are caused by human activities. Most notably by the release of greenhouse gases into the atmosphere.

Nitrates: A compound that contains nitrogen and oxygen. They are commonly found in soil and fertilizer, but should generally be removed from drinking water during water treatment.

Food deserts: An urban area where it is difficult to find affordable high quality produce. Many of these areas are instead saturated by cheap, unhealthy food options.

Ions: A charged atom or molecule.

Synthetic fertilizers: Fertilizer that is not from an organic source like manure. Synthetic fertilizers are produced by humans using chemical processes and fossil fuel energy.

Mono-cropping: When a farm grows the same crop on the same land every year. This practice can deplete agricultural soil.

Eutrophication: When excess nutrients (commonly from fertilizer runoff) enter a body of water, it causes a bloom of algae that consume these nutrients. The algae also consume all the oxygen in the water, which results in areas of oxygen-depleted water that can no longer sustain aquatic life.