Project Breakthrough

Disruptive Technology Executive Briefs

THE MICROBIOME

Our microscopic allies

The human microbiome is all the genetic material from the microbes - bacteria, fungi, protozoa and viruses - that live on and inside the human body. The microbiome benefits human health through vitamin production, provision of nutrients and educating and training our immune system.

The idea of using bugs instead of drugs and chemicals is not new, with probiotic yoghurts common place. However, ongoing research is just starting to unlock the potential of this treatment, with startling results being seen across chronic diseases and mental health.

The bacteria, known as microbiota, also play a critical role in animal and plant health and ecosystems. The microbiota of the soil can help create disease resistance in plants and allow them to extract more nutrients from the soil.

The technology

The Human Microbiome Project, which has sequenced 300 individuals' microbiomes, has brought real insights into what they do and how they can affect human disease and health.

Improvements in DNA sequencing technology can identify the indicators of a healthy microbiota. Deviations can then be tracked to understand an individual's risk of disease at different points in their life. This means personalised treatment through precise modification of an individual's microbiota may soon be achievable.

The potential

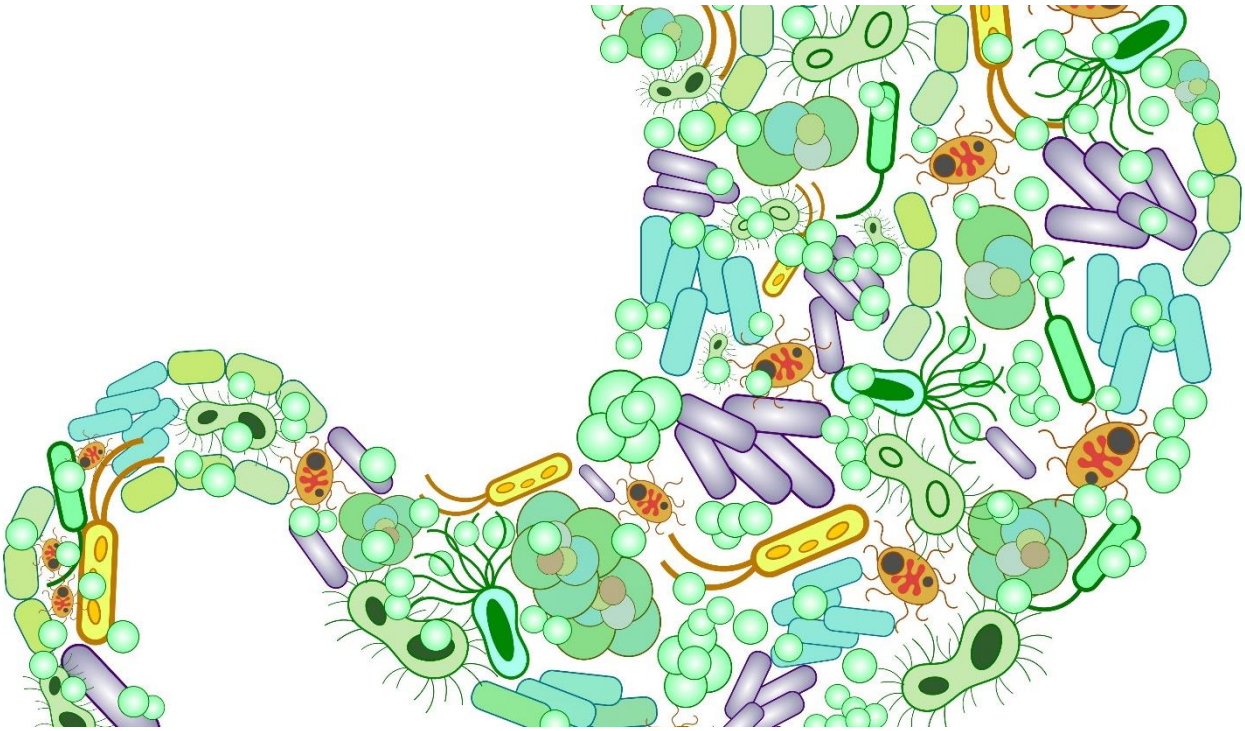
Looking to the future, the microbiota will increasingly be used to tackle and prevent many diseases including those in crops and chronic human illnesses. The role of the microbiota in health is leading to new insights into diseases and providing ways to uncover new targets for drugs and ways to use bacteria to treat infection.

The barriers

With an ever growing antibacterial culture, we are isolating ourselves from the good microbes as well as the bad. In some cases this is leading to their extinction and we do not yet understand the impact. That means education and public perception will be key to ensuring the potential of the microbiome is realised.

United Nations Global Compact

Some Example Applications…



Bugs as drugs

The Wellcome Trust Sanger Institute is working to create a pill full of bacteria that will restore a healthy gut microbiota where the balance between healthy and unhealthy bacteria has been disrupted. One example is where unhealthy levels of have grown. When C. difficile bacteria levels increase this is an example of where serious health problems can occur. It is very difficult to treat with antibiotics and the pill will provide a simple and accessible way to put micro-organisms into intestine of a sick patient that can combat the infection. The approach of replacing gut bacteria has shown to be successful in more than 90% of examples, in some cases saving lives.

Agriculture and climate change

Research into soil microbiota has shown how some species can enhance plant defences against infection. However, other species can cause problems and Rothamsted Research found one strain of bacteria removed nitrogen from the soil. This depleted the nutrients needed for plant growth and created greenhouse gases. That underlines the need to develop a clear understanding of the impact of soil microbiota.

Mental health

The American College of Neuropsychopharmacology has acknowledged the strong scientific link between gut bacteria and mental health. This is opening up a whole new avenue of potential treatments to help conditions such as bipolar disorder.

Key Numbers

$71.7bn

Estimated market size in 2023/4 for Pro/Prebiotics

Source: Global Market Insights/Grandview Research

2321

Microbiome patent applications (2011-16)

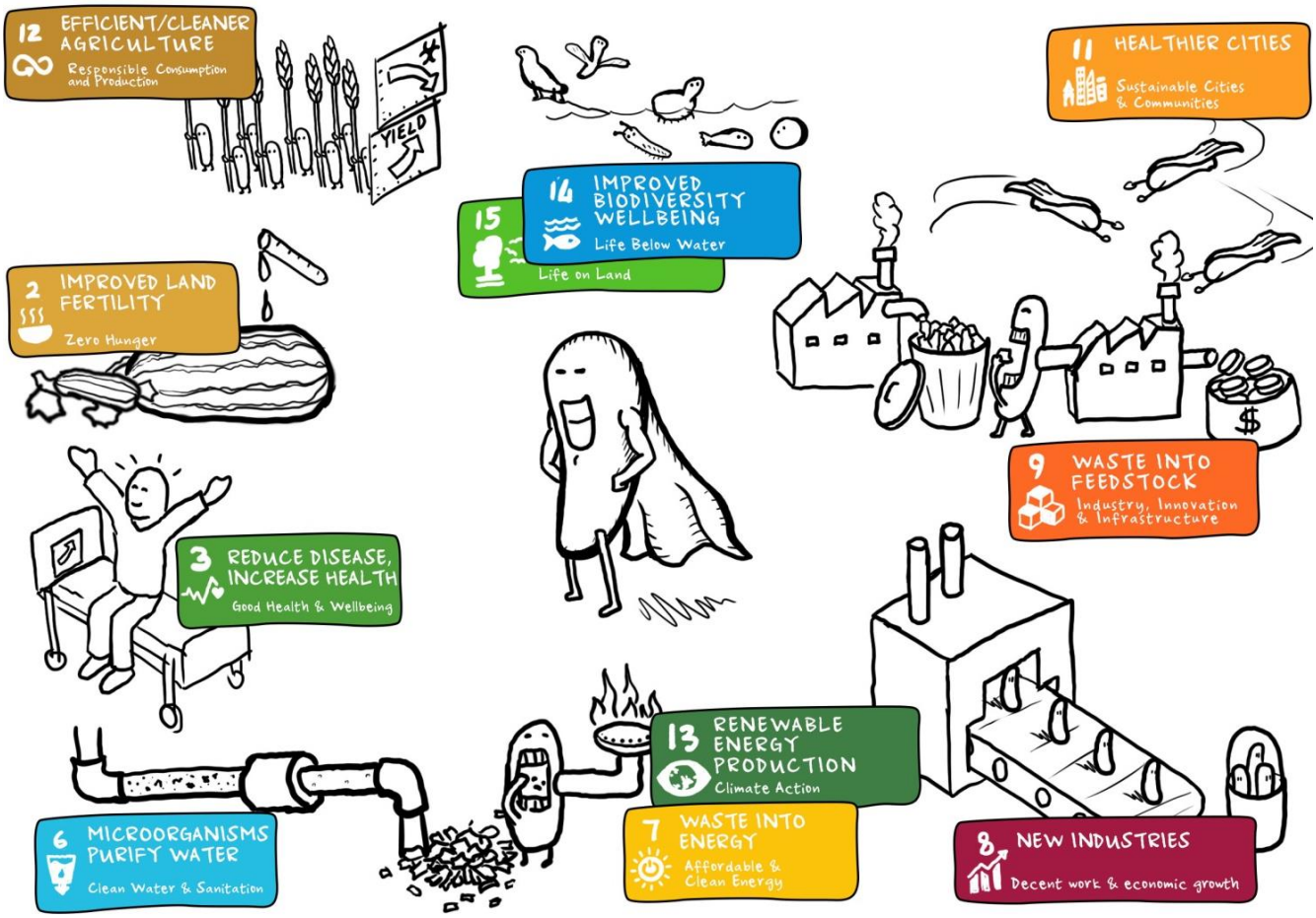
Source: Frost and Sullivan

106

Ongoing projects from discovery to clinical trials

Source: Intellisness

Advancing the Sustainable Development Goals (SDGs)



The microbiome has the potential to advance many of the SDGs. Below are some examples of areas of application across a wide variety of sectors.

π SDG 2 Zero hunger

- Improve the nutritional value of food and reduce the susceptibility of crops to disease, enhancing yields.
- Improve the fertility of land, including nitrogen fixation, to convert it into arable land in a variety of environments.
- Improve an individual's microbiota so they can get more nutrients from the food they consume.

π SDG 3 Good health and wellbeing

- Optimise a person's microbiota to reduce their risk of illness including infectious and chronic diseases.
- Use the microbiota to help identify new biological targets for the discovery of new therapies, new antibiotics and other anti-microbial molecules that bacteria use.
- Use 'bugs as drugs'.

π SDG 6 Clean water and sanitation

- Micro-organisms to purify the water in rivers, streams and lakes.
- Reduced nutrient run off from agriculture through using biofertilisers to reduce pollution.

π SDG 7 Affordable and clean energy

- Biofuels from non food products such as abundant but underused lignocellulose (biomass) and greenhouse gases e.g. carbon monoxide and carbon dioxide.

π SDG 8 Decent work and economic growth

- New technologies across a range of industries to create new jobs and new businesses.
- Make new or improved industries. One example, would be helping to create arable land and energy production opportunities in countries that are resource poor.

π SDG 9 Industry, innovation and infrastructure

- Innovation to overcome the significant technical challenges in understanding and implementing this technology.
- Products that will create new and advanced industries including in healthcare and chemicals.
- Sustainable industries that use waste and unwanted products from one part of the economy and convert them into useful products e.g. the use of greenhouse gases to create biofuels; the reduction in fossil-fuel based agricultural chemicals in favour of beneficial micro-organisms.

π SDG 11 Sustainable cities and communities

- Exposure to a wider more diverse microbiota than typically exists in urban areas as this may link with human health and disease.
- Urban farms that use micro-organisms to enable crops and plants to grow.

π SDG 12 Responsible consumption and production

- Agrichemical industry using fewer chemicals, reducing waste, nutrient run-off, pollution and clean-up.
- Conversion of waste products and underused products to useful products such as biofuels.

π SDG 13 Climate action

- Improved soil microbiotas using micro-organisms that do not give off greenhouse gases.
- Reduced use of fossil fuels for chemical and energy industries, using micro-organisms to produce biofuels.
- Use of micro-organisms to reduce waste greenhouse gases and make useful products.

π π SDG14/15 Life above land/below water

- Reduced pollution with new bio products and manufacturing methods, and increased ability to clean up water.
- Use of microbiota to preserve biodiversity and wellbeing of many other species.

Potential Negative Impacts and Barriers

Society has become increasingly concerned about germs and this attitude is having an impact on the use of microbiota:

The anti-bacterial balance

The increasing use of hygiene products such as anti-bacterial hand wash is reducing our everyday exposure to microbes. It is now thought that everyday exposure to different microbial species is important for normal development of the immune system. Without this, the risk of allergic disease is thought to increase - this is known as the hygiene hypothesis.

Microscopic extinctions

The hygiene hypothesis also suggests that changes to the environment and our lifestyle means some species of the microbiota are being eliminated from the environment. Many of these species have co-evolved with humans and it is not yet known what the longer term implications of their disappearance will be for the environment and human health.

Uncontrolled antibiotics

Over-prescription of antibiotics also has a significant impact on our microbiota. However in many societies antibiotics are demanded by patients even for viral infections.

Regulation

Regulation may need to change. Already in the US the FDA has banned certain ingredients in anti-microbial hand gels as they are linked with allergies in children. This will lead to new product development that is more microbiota friendly.

Public acceptance

A change in attitudes towards germs, antibiotics and using waste products as medicine will be one of the most difficult barriers to overcome. Not all microbes are beneficial and providing the right advice and education to help transform attitudes is crucial.

Technical Considerations

Whilst great progress has been made using genome sequencing to identify the individual species making up the microbiota, there is still a lot of work to do understand the functions and health implications both of individual microbes and of the ecosystem of co-habiting microbes:

The 'unculturable'
In order to study the bacteria in our microbiota, it is important to be able to grow or culture the bacteria in the laboratory. This presents many difficulties with many bacteria being perceived as 'unculturable'. However, a number of techniques are being developed which are beginning to tackle this challenge.

The lack of a common baseline
Due to the scale and complexity of the microbiota and because of the unexpected variability between individuals, studies to determine the role of the microbiota in health and disease are challenging.

The circular micro-economy
Species within the microbial ecosystem interact with each other. Certain bacteria produce substances as a waste product which go on to feed other bacteria, creating a mutual dependence within the system. That means understanding the role each species plays in isolation does not give the true picture. The complexity of the system requires powerful analytics, using systems biology and big data to derive more accurate insights.

Safe sampling
Sampling some parts of the microbiota is challenging. For example, a biopsy is needed to understand the microbiota of the small intestine. This is an invasive procedure and carries a risk of internal bleeding. It also can produce inaccurate results as the microbiota varies throughout the intestine.

Other disruptive technologies
In some cases a micro-organism's metabolism may need to be re-engineered for some purposes e.g. advanced biofuels. Other disruptive technologies, such as Gene Editing, will be needed to do this posing a number of technical challenges that need to be overcome.

Enabling New Business Models

An increasing understanding of the role of the microbiota in human health will impact pharmaceutical and biotech companies across the value chain.

The areas likely to see the biggest impact are drug discovery and drug development and manufacture. In addition, new diagnostics approaches will be needed for some microbiota treatments. There will also need to be new ways to provide drugs to patients.

These developments will have an impact on regulatory authorities and healthcare services, particularly through more personalised and precision medicine.

In the agricultural sector, biofertilisers could have a disruptive influence on the agrichemicals business through a reduced need for fertiliser and pesticides. It could also disrupt agricultural practices and increase the amount of land available for growing crops and change the types of crops that can be grown in these areas. This will open up new opportunities for farmers and for start-ups in agricultural technology.

The microbiota offers huge potential for both big businesses and small start-ups to use data from large government projects such as the Human Microbiome Project.

The microbiome will enable a number of the disruptive business model levers identified on the Project Breakthrough website, specifically:

A more personalised product or service
Tailored therapeutics based on an individual's microbiota and genetic profile.

A closed-loop process
Biofertilisers can multiply organically and produce waste products beneficial for the ecosystem, as well as removing or reducing the need for consumption of agrichemicals and disposal of their waste products. The human microbiota can also produce essential vitamins required by the host, reducing the need for the use of supplements.

More Examples...

Analysing people's microbiota to make personalised dietary recommendations

http://personalnutrition.org/AboutGuests.aspx

Biofertilisers function as key players in sustainable agriculture

https://www.scientificamerican.com/article/microbes-added-to-seeds-could-boost-crop-production/

Understanding the role of the lung microbiome in respiratory disease

http://www.gsk.com/en-gb/behind-the-science/innovation/take-a-deep-breath-your-lung-microbiome-will-appreciate-it/

United Nations Global Compact

The United Nations Global Compact is a call to companies everywhere to align their operations and strategies with ten universally accepted principles in the areas of human rights, labour, environment and anti-corruption, and to take action in support of UN goals and issues embodied in the Sustainable Development Goals. The UN Global Compact is a leadership platform for the development, implementation and disclosure of responsible corporate practices. It is the largest corporate sustainability initiative in the world, with more than 9,000 companies and 3,000 non-business signatories globally.

Project Breakthrough

Project Breakthrough – a collaboration between UN Global Compact, Volans and partners – spotlights the best thinking in sustainable innovation. It showcases innovators across mainstream companies and next generation entrepreneurs who are developing solutions with the potential to achieve exponential impact. It features analysis and resources designed to help leaders understand the new business models and technologies that will be crucial in achieving the SDGs, catalysing action amongst today's businesses to meet the needs of tomorrow's world.

The Disruptive Technology Executive Briefs are produced in collaboration with PA Consulting Group, combining cross sector technology, innovation and business design expertise. The briefs are intended as an easy to digest introduction to disruptive technologies, to help organisations understand how they could advance the Sustainable Development Goals and business performance. These overviews explore key features, examples of applications, potential positive and negative impacts, and how they may enable the new business models.

Visit www.projectbreakthrough.io for more information, or contact projectbreakthrough@unglobalcompact.org