The Nutrition Academy

MICROBIOME COURSE

WHAT IS THE MICROBIOME/MICROBIOTA?

Lesson 1

What is the Microbiome/Microbiota?

This Lesson will introduce you to the microbiome. We will explore the differences between the microbiota, the microbiome and microorganisms and why collectively, the microbiome/microbiota are so important for your health and wellbeing.

What is the microbiome?

Microorganism: A living thing too small to be seen without magnification; an organism of microscopic size.

The **microbiome** can be characterised as the collection of genes and genomes within the **microbiota**.

What is the microbiota?

Microbiota: the collection of microbial organisms inhabiting a defined environment, such as a specific body site.

The microbiota is a term that is used to describe the collection of **microorganisms** inhabiting a defined environment, such as a specific body site (for example, your gut!). The human microbiota consists of bacteria, viruses, worms and certain species of fungi. The most abundant microorganisms found in your microbiota are bacteria.

Microbiome: the collection of genes and genomes within the microbiota.

The numbers and richness of your microbiota are enormous and diverse. They inhabit every part of your body such as sweat glands, orifices, skin; you name it, your microbiota will have its own specific body part and population of microorganisms that inhabit it **(Figure 1).**

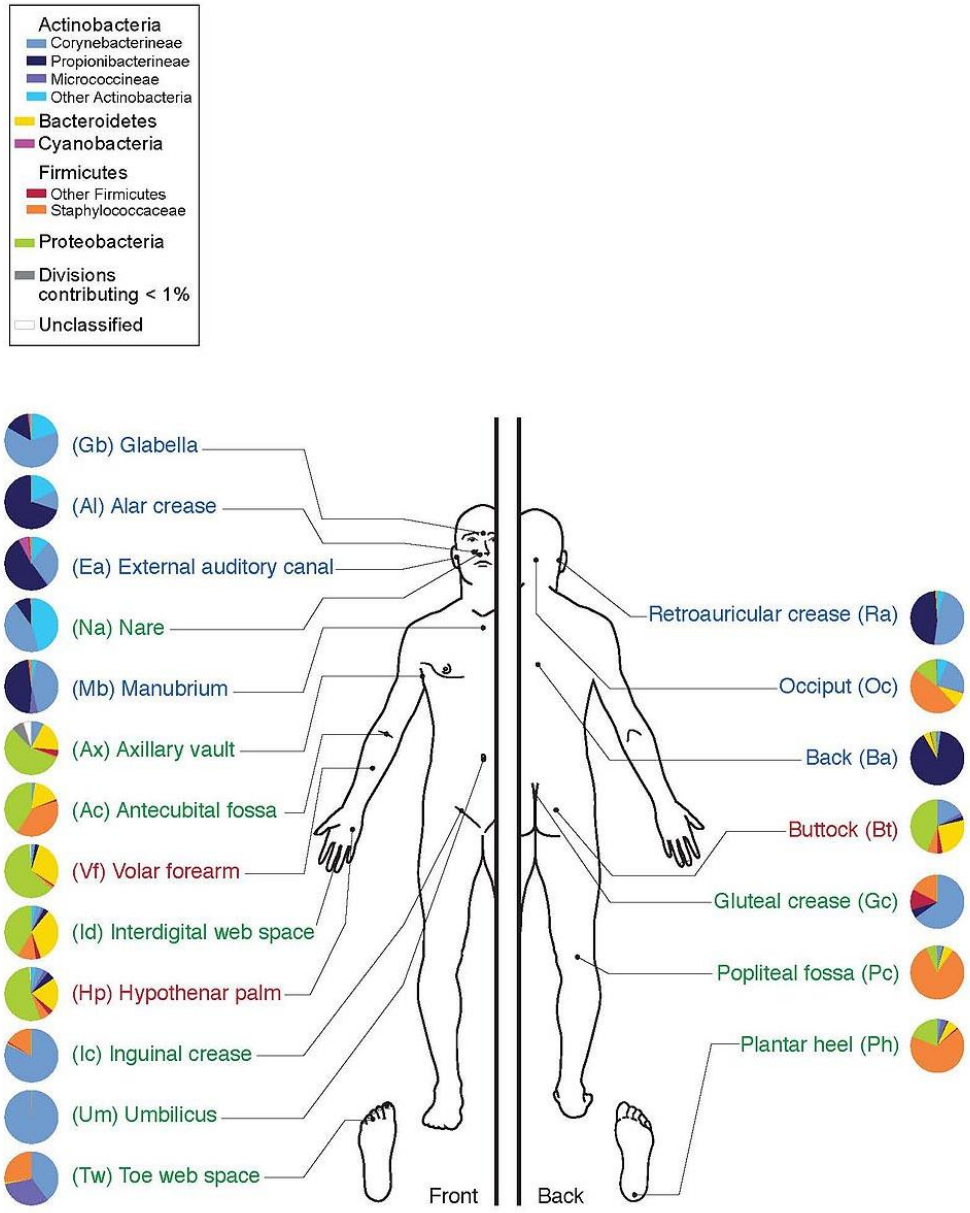

Figure 1: The skin microbiota. Source: http://www.genome.gov/dmd/img.cfm?node=Photos/Graphics&id=85320

How many microorganisms are there?

Despite our general anthropocentric view of the world, it is microbes, not humans, that dominate our planet in diversity and numbers [1]. Microorganisms existed on Earth long before humans and will continue to exist long after we are gone.

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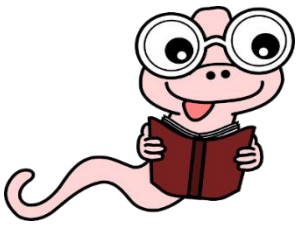
The human body serves as a scaffold for the assembly of microorganisms. It has been estimated that the number of microorganisms living on and inside us outnumbers our own cells by ten microorganisms to one human cell [2]. Just imagine this for a moment; there are ten trillion cells in the human body and therefore one hundred trillion microorganisms that make our body their home. That is, you are 90% microorganism, 10% human[3].

Microorganisms inhabit almost every part of your body and, although sometimes they can cause sickness, most of the time they live in harmony with their host (your body) and provide important functions for your survival [4]. These functions include helping you to digest food; production of vitamins that you cannot make yourself; protecting you from harmful microorganisms through the use of defense mechanisms; metabolism; and reproduction. Microorganisms are with you from birth to death and can influence your growth and development which is why they are so crucial to your survival [5].

The human and the microbial genome

Surely, we are more complex than a worm?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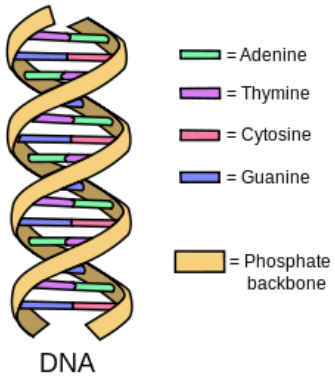
The human genome is estimated to contain 23,000 genes that encode for the proteins that make us what we are [6]. However, some scientists have suggested that this is not nearly enough genes to create such a complex organism as a human. They might be right! The nematode (worm) contains 20,000 genes that make it a worm. Accordingly, a growing number of studies on the human genome suggest that what makes us human, are the genes of the trillions of microorganisms that reside in our body 6. It is estimated that these microorganisms alone contain 8 million genes or 360 times more bacterial genes than human genes [7].

The Human Microbiome Project: an introduction



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In 2008 the National Institute of Health (NIH) funded a 5-year project with the goal to define the microbiome of healthy adults using 242 participants. This project looked at multiple sites on the human body including the oral cavity, skin, gastrointestinal tract and the vagina [4]. To uncover what kind of microorganisms resided in these body parts the scientists used a technique to "read" the microbial DNA gene sequence. As each species has a unique DNA sequence, the information obtained helped identify the kind of microorganisms that reside in a specific body location.

Many studies have found that each anatomical site of the human body has a specific dominant bacterial presence[3]. For example, the vaginal microbiota is mainly made up of lactic acid-producing bacterial (mainly *Lactobacillus sp.*) species that maintain homeostasis of the microbiota [8 9 10]. This species is thought to play a significant part in preventing bacterial vaginosis, yeast infections, sexually transmitted infections, urinary tract infections, and HIV infections.

Researchers believe that the presence of an established symbiotic community in the host may prevent colonisation of pathogens. Environmental factors, such as sex, menstrual cycle and hormone cycles can play a significant role in disrupting the microbiota of the vagina creating times of stability and times of extreme variability and instability [1].

The gut microbiome: a teaser

Another very interesting and emerging area of research is the gastrointestinal tract and its microbiota. We will discuss this in more detail in Lesson 5. The gastrointestinal tract or gut microbiota has been called a "virtual organ within an organ"[11].

Information for the following section was sourced from Talaro, K.P, Foundations in Microbiology12 and Willey, J.M. et. al. Prescott's Microbiology[13].

Microorganisms: what are they?

Living cells can be divided in two types: Eukaryotic and Prokaryotic **(Figure 2).** Eukaryotic cells are those found in various protozoa, plants, various algae, animals, humans and fungi. Prokaryotic cells are bacterial. They are different to the eukaryotic cell in structure and function and often appear to be much simpler.

Eukaryotic cells have a defined nucleus and many other membrane-bound organelles that carry out numerous processes. Prokaryotic cells are small cells that lack any true membrane-enclosed nucleus; they are “open plan”.

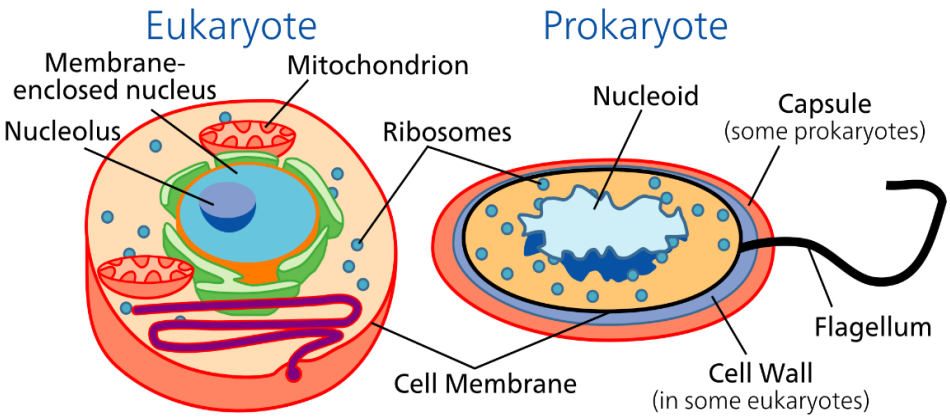


Figure 1: Eukaryote Vs Prokaryote cell. Source: http://www.aboutthemcat.org/biology/prokaryotic-vs-eukaryotic-cells.php

Protozoa are a group of single celled microscopic animals which include amoebas and ciliates among others. They are actually Eukaryotes, not Prokaryotes.

Now let’s take a closer look at microorganisms so we can get to know and understand them a bit better. Microorganisms can be separated into seven groups: Bacteria, Viruses, Archaea, Protozoa, Helminths, Fungi and Algae14. The definition of a microorganism is a living thing which is too small to be seen without magnification. These microscopic organisms collectively are often referred to as microbes, microorganisms, germs or bugs (depending on their role in infection or disease). But we don’t want to start off by giving microbes a bad reputation!

Helminths are known as parasitic worms and are also Eukaryotes. They are often associated with the intestine but are not always found just in the intestine.

Microorganisms are of great interest in many different areas of research including;

- **Immunology:** the study of complex immune chemicals and cells that are produced in response to infection
- **Public Health:** monitors and controls the spread of infectious diseases in our communities and includes Food and Agricultural microbiology
- **Biotechnology:** any process in humans that use the metabolism of a living thing to obtain a product and includes Genetic engineering and recombinant DNA technology.

Fungi are single celled Eukaryotes and that live via decomposing and absorbing organic material that they grow in.

Algae are chlorophyll containing eukaryotic organisms that can range from a single cell to a multicellular form and are mainly aquatic.

The world of microbes is extraordinary. You will learn more about them as you go through this course but it is important to understand that Microbes don't just cause disease, they are highly important for our health and well-being.

They inhabit every corner of the earth and into the atmosphere. The role of soil based microbes has important implications for plant and animal nutrition, soil water retention, carbon sequestration and temperature modulation of ecologies.

Grouping bacteria

Bacteria can be grouped based on their respiration and the way they obtain energy. These groups are:

1) Aerobic respiration: characteristic of animals, many bacteria, fungi and protozoa and use oxygen as their final electron acceptor to generate energy.
2) Anaerobic respiration: used when there is no oxygen available and an inorganic molecule is used as a final electron acceptor to supply energy.
3) Fermentation: energy is extracted through the degradation of substrates into simpler reduced metabolites.

Host: An organism that harbours another organism.

The difference between these three forms of energy extraction is important. Microbes in and on our body will be aerobic, anaerobic or fermenters or they may have the ability to do two or all three of these types of respiration.

Symbiont: An organism that has a relationship with another organism that can be described as mutualistic, commensalistic or cooperative.

Symbiosis: The living together/close association of two different organisms. Each organism is called a symbiont.

Mutualism: Organisms living in an obligatory relationship that is mutually beneficial.

Parasitism: An organism lives within a host and obtains nutrients and protection but gives some degree of harm to the host.

Commensalism: A relationship where one species benefits from another without causing harm.

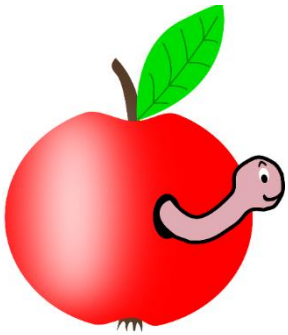
Ecological Theory

Now, it is hard to understand the microbiota and subsequent microbiome without having a bit of the ecological theory about the host-microbiota system. It is important to understand that microorganisms inhabiting a defined environment generally live in symbiosis. Broadly, symbiosis is defined as "different organisms living together". Symbiosis is often used as an umbrella term to include those relationships that are described as mutualism, parasitism and commensalism in nature 15.

Essentially, microbial ecology is the ecology of microorganisms which involves their relationship with one another and their environment. Bacteria and Archaea have enormous versatility within their metabolic and physiological abilities and are essential to virtually all biogeochemical cycling processes on earth. As a result, understanding microorganism ecology is very challenging but could help find solutions to major challenges facing humans today such as climate change and disease. We have come a long way since microorganisms (or Germs) were thought of as only causing disease. As a society we rely on microbial processes for wastewater treatment, industrial chemical production, pharmaceutical production and bioremediation16.

Ecological theory is used to classify, interpret and predict what goes on around us and provides us with an understanding and explanation of the interactions between the microorganisms and their physical, chemical and biological environments. Theories can often generate predictions. This is specifically true in disciplines such as microbiology where it is often difficult to study microorganisms in nature due to their microscopic size and the diversity of their communities. Moreover, many are extremely difficult to grow in the laboratory, and even if they do grow, this does not represent a true microbial environment where we can reliably measure microbe-host interactions 16.

We don't want to "bog-you-down" too much with the ecological theory of microorganisms, but just give you some general background about why these remarkable "bugs" are one of the most highlighted and well-researched areas of science today. Particularly from a health context, it is now known that microorganisms are essential for life on Earth and specifically, human health and well-being.



So instead of that favorite adage:

"An apple a day keeps the doctor away"

Perhaps this can now be modified to:

"A microbe a day keeps the doctor away"

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