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Understanding Microbes and Microbial Dominance

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Introduction

The word "microbe" stands as a generic descriptor for all microscopic organisms, i.e. bacteria, Archaea, fungi, microalgae, and protozoa together with the viruses (Rappé and Giovannoni, 2003; Whitman., *et al.* 1998). They live in highly organized and interactive communities that versatile, complex and difficult to analyze from many perspectives. However, understanding microbes in far greater detail and in realistic context of whole living systems and taking advantage of their complexities and surmounting the technical challenges of whole-systems biology is a daunting prospect.

One of the challenges is that microbes are exceedingly small-only 1/8000th the volume of a human cell and spanning about 1/100th the diameter of a human hair. Investigating processes within this size range is challenging (Curtis., *et al.* 2002; Rappé and Giovannoni, 2003; Lozupone and Knight, 2008; van der Heijden., *et al.* 2008). Likewise, microbial world encompasses millions of genes from thousands of species, with hundreds of thousands of proteins and multimolecular machines operating in a web of hundreds of interacting processes in response to numerous physical and chemical environmental variables (Schleifer, 2004; Falkowski., *et al*. 2008; Wilmes., *et al.* 2009).

Gene control is complex, with groups or cassettes of genes/operons directing coordinated transcription and translation of genes into interacting proteins. Also, microbes adapt rapidly in response to environmental change, an ability that underlines their survival for billions of years. For instance, various extremophile microbes have adapted to great extremes of pressure, temperature, pH, salinity, and radiation. Their high surface-to-volume ratio enhances interactions and supports adaptation. Unlike animal cells, they have no protective nucleus for their DNA, which leaves it more vulnerable to alteration. Genes move easily among species. Moreover, other microbial communities are awash in genetic material from viruses that confer additional genetic properties and expand their range of adaptability.

In addition, microbial communities can extend in size from cubic millimeter to cubic kilometer. Even relatively simple communities can have millions of genes, giving them a genetic diversity substantially greater than that of higher life forms, even humans. Recent investigations have focused on collecting DNA fragments from environmental samples in the sea and other natural ecosystems. These metagenomic studies have given us a glimpse into the intricacies of these natural ecosystems and their diverse functions (Whitman., et al. 1998; Elena and Lenski, 2003; Schloss and Handelsman, 2004).

Home of microbes: No corner of earth escapes the influence of microbes

Microbes live nearly everywhere- in soil, water, air, animals, humans, plants, foods. They live under natural conditions and in any extreme habitats- whether hot, cold, salty, arid, acidic, alkaline, high pressure, oxygen-free, or toxic- hot springs, geysers, volcanoes, and ocean vents. Probably the most important overriding features of microbes are their exceptional diversity and ability to occupy every imaginable habitat for life.

Indeed or carrying out processes that we had no idea where microbial in nature. There's hardly a niche on Earth that hasn't been colonized by microbes. Here are some of Earth's toughest microbes with records to debate (Sharp., *et al*. 1999; Torsvík., *et al.* 2002; Nee, 2003; Horner-Devine., *et al*. 2003; Curtis and Sloan, 2005; Pedrós-Alío, 2006; Sogin., *et al*. 2006; Lozupone and Knight, 2007; Huber., *et al.* 2007; Chen., *et al*. 2009; Pointing., *et al*. 2009; Dumbrell., *et al.* 2010).

Swimming in heat (Thermophiles)

Steaming hot pools and scalding hydrothermal vents provide a cozy habitat for heat-loving extremists. Such 'supper/hyper thermophiles' produce enzymes that are stable at high temperatures. Some have been isolated and put to work in everything from laundry detergents to food production. The upper limit for life had been widely recognized as 113°C, after a microbe *Pyrolobus fumari* that was discovered in 1997 inside a single hydrothermal vent in the Atlantic Ocean, 3650 meters below the surface. However, a microbe collected from a vent at 2400 meters down in the Pacific Ocean, has upped the chance. It survived and multiplied during a 10-hour blast in a 121°C autoclave, an oven used to sterilize medical equipment. It's been given the preliminary name of "Strain 121" and is in the same family as *Pyrolobus fumari* (Anderson., *et al*. 20011; Wolferen., *et al*. 2013).

Relaxing in cold (Psychrophiles)

The frostiest Polar Regions and the darkest depths of the ocean are home for a few microbes that prefer a good chill. Many are bacteria or similar single-celled microbes called Archaea, but some lichens called cryptoendoliths go to extremes by colonizing pores in Antarctic rock. There's also an alga that creates reddish watermelon snow. Cold-loving microbes have specialized cell membranes that don't stiffen in frigid temperatures, and many produce a kind of protein antifreeze. Microbes are known to grow at -12°C, and they survive at -20°C. Some studies even hint that a bacterium called *Colwellia psychrerythraea* strain 34H can withstand -196°C, the temperature of liquid nitrogen (Russell., *et al*. 1990; Bowman., *et al*. 1998; D'Amico., *et al*. 2006; Clarke., *et al.* 2013).

Enjoying in high salt concentration (Halophiles)

Despite its name, the Dead Sea does harbor life. It's the saltiest body of water on Earth, but a few microbes thrive there, in water eight times saltier than the ocean. *Haloarcula marismortui* is a microbe that has specialized proteins that protect it from the effects of salt (Anton., *et al.* 2000; Oren, 2002a; Oren, 2002b; Santos and da Costa, 2002; Gonçalves., *et al*. 2003).

Enjoying in acid (Acidiphiles)

Acidic hot springs and fountains that would eat away at human flesh are no match for some microbes that make themselves at home in the acid. The known are microbes of the genus Picrophilus. They thrive at a pH of 0.7, and can grow happily to a d pH of 0 (Van der Vossenberg., *et al.* 1998; Quaiser., *et al*. 2003; Singh, 2012).

Enjoying in alkaline (Alkaline-lovers)

The most alkaline environments in the world are soda lakes, which can have a pH as high as 12, similar to ammonia. A number of microbes enjoy those caustic conditions, including Natronomonas pharaonic (Horikoshi, 1999; Gonzalez*., et al*. 2010; Singh, 2012).

Refreshing in deep

Microbes from the *Pyrococcus* and *Thermococcus* genera were found in a mud core taken from 1.6 km below the sea floor off the coast. Though they represent the deepest life ever discovered beneath the sea floor, microbes of various kinds have been discovered at even greater depths under the continents. Communities of microbes have been found hunkered down in groundwater as far as 5 km below the surface of the land.

Scientists think life exists even further to the point where the subsurface heat becomes unbearable for life. Even the deepest part of the ocean, the Mariana Trench, which plunges 11 km below the surface of the Pacific Ocean, is inhabited. Drops of mud pulled from the trench have yielded a collection of bacteria, fungi and foraminifera, where the pressure would crush a human (Yayanos, 1995; Setteer, 1996; Adams, 1999; Marteinsson., *et al*. 1999; Di Giulio, 2005; Tefera, 2009; Birrieni., *et al*. 2011; Michoud and Jebbar, 2016).

Walking in dried up

Microbes like the bacterium Chroococcidiopsis have been in the most parched place on Earth, the Atacama Desert, which stretches nearly 1,000 km across South America. It rains only a few times a century. It's no coincidence that the desert has been used by film makers as a stand-in for Mars. There is also an evidence for the presence of similar microbe on the so-called "the hottest place on earth" Erta Ale, Danakil Depression, Ethiopia, where there is water scarcity and temperature riches 60-63°C. Water is thought to be crucial for life because it provides a medium for nutrients to diffuse into cells and wastes to drift out, and a solvent for critical metabolic reactions (Billi., *et al*. 2000; Tefera, 2009; Cockell., *et al*. 2011; Verseux., *et al*. 2016).

Nestling in a dump

Some microbes like nothing better than to be nestled in a toxic sludge of heavy metals like zinc, arsenic and cadmium. They thrive in hazardous waste dumps and in mine by making a meal out of metal. Geobacter bacteria, for example, convert dissolved uranium into a solid form, so it could be put to work cleaning up contaminated land (Anderson., *et al.* 2003; Cologgi, 2014).

Eating electricity

Some microbes have developed the ultimate stripped-down diet. They do not bother with food or oxygen. All they need to survive is pure electrical energy. The microbes, called *Geobacter metallireducens*, are getting their electrons from organic compounds, and passing them onto iron oxides. In other words they are eating waste – including ethanol – and effectively "breathing" iron instead of oxygen (Trembaly., *et al*. 2012; Marozava., *et al*. 2014).

Producing electricity

Geobacter species can be used to make microbial fuel cells - devices in which electrical current is harvested from bacteria that grow by transferring electrons from their food source to the anode of the device. Pure cultures of *Geobacter sulfurreducens* produce current densities that are among the highest known, and *G. sulfurreducens* has been enriched from a number of complex communities growing in biofilms on high-efficiency microbial fuel cells (Lovely., *et al*. 2001; Bond and Lovely, 2003).

Playing with a blast

Incredibly, the bacterium *Deinococcus radiodurans* can withstand about 2000 times the dose of ionizing radiation that would kill a human, making it the most radiation-resistant microbe known. A blast like that shatters the bacterium's chromosomes, but it can repair itself within hours (Battista., *et al*. 1999; Minton, 1999).

Flying in the space

Many studies confirm that a variety of bacteria such as B*acillus spp., Streptomyces maritimus, Janibacter hoylei, Methylobacterium sp., Acinetobacter radioresistens, Stenotrophomonas rhizophilia, Micrococcus spp., Staphylococcus pasteuri,* and *fungi such as Penicillium sp.,* *Cladosporium cladosporoides, Alternaria sp., Tilletiopis albescens, Engyodontium album* are isolated, using standard isolation media, from the stratosphere at heights of up to 77 km (Valtonen, 2008; Hornek., *et al*. 2010).

Ageing well

Microbes can survive for many, many millennia, though scientists are still debating how long. In 2000, scientists made a very astonishing claim that they had brought to life a 250 million-year-old bacterium dubbed *Bacillus permians*. According to the team, bacterial spores in a drop of water became trapped in a cavity inside salt crystals as they formed 250 million years ago. This and other similar reports remain controversial, but nevertheless, the ever growing list of long-lived microbes gives scientists hope that life may exist elsewhere in the solar system (Graur and Pupko, 2001; Nickle., *et al.* 2002).

Collective weight and power of microbes

Whether measured by the number of organisms or by total mass, the vast majority of life on this planet is microscopic. Nowhere is the principle of strength in numbers more apparent than in the collective power of microbes. Each individual microbe is but an almost weightless, one-celled organism, accounts for most of the planet's biomass-the total weight of all living things. The number of prokaryotes and the total amount of their cellular carbon on earth are estimated to be 4–6 × 10^{30} cells and 350–550 Pg of C (1 Pg = 10^{15}g), respectively. Most of the earth's prokaryotes occur in the open ocean, in soil, and in oceanic and terrestrial sub surfaces, where the numbers of cells are 1.2 × 10^{29}, 2.6×10^{29}, 3.5 × 10^{30}, and 0.25-2.5 × 10^{30}, respectively (Locey and Lennon, 2016).

Despite around 2000 microorganisms already have their genomes deciphered, a large number remains unexplored. These teaming multitudes profoundly influence the make-up and character of the environment in which we live. With their mighty collective muscle, microbes control every ecological process, from the decay of dead plants and animals to the production of oxygen. It may surprise that we know very little about the microbes that live in the world around us because insignificant number of them can be grown in the laboratory. Understanding which microbes are in each ecological niche and what they are doing there is critical for our understanding of the world (Whitman., *et al*. 1998; Tefera and Deressa, 2006, Falkowski., *et al*. 2008; Locey and Lennon, 2016).

Inhabiting human body

Microbes inhabit the human body. In fact, every person has more than 10 times as many microbes living on and inside his or her body as they have human cells. The human body has 10-100 trillion microbes living on it, making it one giant super-organism. Although most frequently associated with disease, microbes help us much more than they harm us by controlling many of the biological processes that are essential to our survival, including the maintenance of our skin and the digestion of our food.

Each person's digestive tract alone harbors about 3 pounds of bacteria. The microbes that normally live in associations with humans on the various surfaces of the body (called the normal flora), such as *Lactobacillus* and *Bifidobacterium*, are known to protect their hosts from infections, and otherwise promote nutrition and health. For the most part, we live peacefully alongside these strangers. Without them, human life would be open to every condition for death (Ursell., *et al.* 2012; Sommer and Bäckhed, 2013; Dinan., *et al.* 2015).

Restive engineers of our planet

Microbes are the major actors in the synthesis and degradation of all sorts of important molecules in environments. Here are some of the facts that they are the best and restive engineers of our planet (Nee, 2005; Nocera, 2009; Deamer, 2011; Gilbert and Neufeld, 2014).

Primary production

It involves photosynthetic organisms which take up CO_2 in the atmosphere and convert it to organic (cellular) material. Although terrestrial plants are obviously primary producers, planktonic algae and cyanobacteria account for nearly half of the primary production on the planet. Even some of the species, like Arthrospira, are serving as a food a food supplements. Specifically, Arthrospira is known as a holder of all food components and called "all in one" (Tefera., *et al*. 2016). These unicellular organisms which float in the ocean are the "grass of the sea", and they are the source of carbon from which marine life is derived (Field., *et al*. 1995; Hamilton., *et al.* 2016).

Biodegradation

There is no naturally-occurring organic compound that cannot be degraded by some microbe, although some synthetic compounds such as Teflon, Styrofoam, plastics, insecticides and pesticides are broken down slowly or not at all. Here are some facts on natural microbial factories (Ghazali., *et al*. 2004; Chaineau, 2005; Li., *et al*. 2008; Saratale., *et al*. 2009).

Oil-eaters

We are increasingly taking advantage of the versatile appetite of microbes to clean up environments that we have contaminated with crude oil, polychlorinated biphenyls (PCBs) and many other industrial wastes. Some microbes are hard at work cleaning oil spills. *Alcanivorax borkumensis* is one of the most important worldwide due to the fact it produces a wide variety of very efficient oil-degrading enzymes. *Pseudomonas aeruginosa* is playing a significant role in degrading oil (very much likely to be used in remediating oil spill). *Pseudomonas putida* is useful in degrading the organic solvents such as toluene (Ron and Rosenberg, 2002; Hazen., *et al*. 2010; Macauly, 2015; Shan and Yadavb, 2016).

Nylon-eaters

Flavobacterium Sp. K172 became popularly known as nylon-eating bacteria, and the enzymes used to digest the man-made molecules became collectively known as nylonase. Scientists have also been able to induce another species of bacteria, *Pseudomonas aeruginosa*, to evolve the capability to break down the same nylon byproducts in a laboratory by forcing them to live in an environment with no other source of nutrients (Prijambada., *et al*. 1995; Obst and Steinbüchel, 2004; Premraj and Doble, 2005; Sudhakar., *et al*. 2007).

Plastic-eaters

Microbiologists have found that the Vibrio's group of bacteria appears to be eating away the surfaces of the micro plastics. This could be very good news, provided they are actually digesting the polymer molecules and breaking down associated toxins (Shimao, 2001; Gautam., *et al.* 2007; Shah., *et al*. 2008; Tang., *et al*. 2017).

Nitrogen fixation

Nitrogen fixation results in replenishment of soil nitrogen removed by agricultural processes. Some bacteria fix nitrogen in symbiotic associations in plants. Other Nitrogen-fixing bacteria such as *Bradyrhizobium, Azospirillum, Beijerinckia, Azotobacter, Frankia, Anabaena, Nostoc, Trichodesmium, Calothrix, Phormidium, Scytonema,* and *Oscillatoria* are free-living in soil and aquatic habitats (Vitousek., *et al.* 2002; Bannert., *et al*. 2011; Latysheva., *et al*. 2012).

Fermentation

In the home and in industry, microbes are used in the production of fermented foods. Yeasts are used in the manufacture of beer and wine and for the leavening of breads, while lactic acid bacteria are used to make yogurt, cheese, sour cream, buttermilk and other fermented milk products (*Lactobacillus* spp., *Leuconostoc* spp.). Vinegars are produced by bacterial acetic acid fermentation. Other fermented foods include soy sauce, sauerkraut, dill pickles, olives, salami, cocoa and black teas. Surprisingly cacao seeds must be fermented, dried, and roasted to produce the chocolate flavor.

Fermentation and drying are done at the farm that grows the chocolate trees. These changes are the result of microbial growth such as S*accharomyces cerevisiae, Candida rugosa, Kluyveromyces marxianus, Lactobacillus sp., Streptococcus sp., Acetobacter sp., Gluconobacter sp., Geotrichium sp.,* and amylase obtained from *Aspergillus* until the final product of chocolate (Caplice and Fitzgerald, 1999; Parvez., *et al.* 2006; Chong., *et al*. 2009; Bokulich., *et al*. 2014).

Medical and pharmaceutical applications

In human and veterinary medicine, for the treatment and prevention of infectious diseases, microbes are a source of antibiotics and vaccines (Strobel and Daisy, 2003; Streit., *et al*. 2004; Ferrer-Miralles., *et al*. 2009; Gharaei-Fathabad, 2011).

Antibiotics

These are substances produced by microorganisms that kill or inhibit other microbes which are used in the treatment of infectious disease. Antibiotics are produced in nature by molds such as *Penicillium* and bacteria such as *Streptomyces* and *Bacillus* (Fischbach, 2009; Wackett, 2013).

Vaccines

These are substances derived from microorganisms used to immunize against disease. The microbes that are the cause of infectious disease are usually the ultimate source of vaccines. Thus, a version of the diphtheria toxin (called toxoid) is used to immunize against diphtheria, and parts of *Bordetella pertussis* cells are used to vaccinate against pertussis (whooping cough). The use of vaccines such as smallpox, polio, diphtheria, tetanus and whooping cough has led to virtual elimination of these diseases in regions of the world where the vaccines have been deployed (Brockstedt., *et al.* 2005; Davies, 2007; Meri., *et al.* 2008).

Biotechnological applications

The two thermophilic species *Thermus aquaticus* and *Thermococcus litoralis* are used as sources of the enzyme DNA polymerase, for the polymerase chain reaction (PCR) in DNA fingerprinting. As thermophiles have become increasingly important in biotechnological research, the number of bio prospecting groups searching for useful organic compounds in nature have dramatically increased as well (Schiraldi., *et al.* 2002; Arora and Sharma, 2010; Singh, 2010; Pérez-García., *et al*. 2011; Chauhan., *et al.* 2012; Balciunas., *et al*. 2013; Adrio and Demain, 2014; Mercado-Blanco and Lugtenberg, 2014).

Biomining

Thiobacillus ferooxidans gets its energy by metabolizing inorganic materials. As the bacteria eat, they release a waste product of acid and an oxidizing solution of ferric ions. Together these wash the metal right out of the ore. Today T. *ferooxidans* is used to extract more than 25 percent of all the copper mined in the world from what was once considered low-grade ore. Gold ore, once thought to be useless for mining, is also releasing its gold deposits with the help of *T. ferooxidans*. A brew of microbes and fertilizer can be poured directly onto piles of crude ore. This method is much cheaper, more efficient, and more environmentally friendly than other extraction processes (Siddiqui., *et al.* 2009; Imhoff., *et al*. 2011; Johnson, 2014).

Biocementing

Bio cementation is a process to produce binding material (bio cement) based on microbial induced carbonate precipitation (MICP) mechanism. This process can be applied in many fields such as construction, petroleum, erosion control, and environment. Application in construction field include wall and building coating method, soil strengthening and stabilizing, and sand stabilizing in earthquake prone zone. Considerable research on carbonate precipitation by bacteria has been performed using ureolytic bacteria such as *Sporosarcina pasteurii*. These bacteria are able to influence the precipitation of calcium carbonate by the production of an enzyme, urease. Calcium carbonate precipitation occurs as a consequence of bacterial metabolic activity that raises the pH of the proximal environment (Jian and Ivanov, 2009; Stabnikov, 2016).

Microbial conservation

Microbes may appear endlessly abundant, everywhere and to an extent interchangeable, but some do face real threats to their existence. It could be argued that protecting the ecosystem will suffice to protect its microbes. This is clearly sensible when resources are scarce. However, many ecosystems are neglected in conservation strategies simply because of the absence of larger organisms, for instance desert soil crusts, glaciers, or unusual geological formations.

Regardless of the importance of microbes, scientists have been able to study less than one percent of the estimated millions of microbial species that live on Earth. It is because microbes have strict nutritional requirements and interact with one another in complex ways that currently make it impossible to grow the overwhelming majority of them in the laboratory (Hawksworth and Colwell, 1992; Colwell, 1997; Colwell, 2009).

In the past few years, due to advances in molecular methods and techniques, our knowledge of microbial diversity has increased dramatically not only from a phylogenetic and taxonomic perspective but also from an ecological basis. New technologies, particularly in nucleic acid analysis, computer science, analytical chemistry, and habitat sampling and characterization place the study of microbial diversity on the cutting edge of science. Exploration, evaluation and exploitation of microbial diversity is essential for scientific, industrial and social development.

The vast microbial diversity of the natural world, combined with ingenious methods to access the diversity, can provide us with a bountiful source of new and valuable products. Therefore, continued research is needed to describe and conserve the unexplored resources for the preservation of natural ecosystems and the future benefit of mankind. Because, if all of Earth's microbes died, so would everything else, including us. But if everything else died, microbes would do just fine. Therefore, we need microbes more than they need us (Bodelier, 2011; Prakash., *et al*. 2013; Tefera, 2016).

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