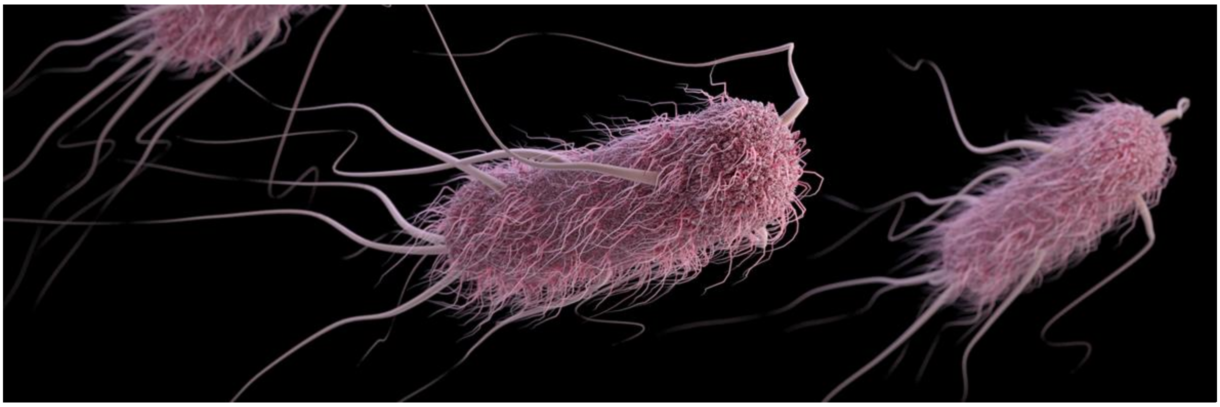
(source: http://www.cdc.gov/ecoli/)

First and forever a microbial world

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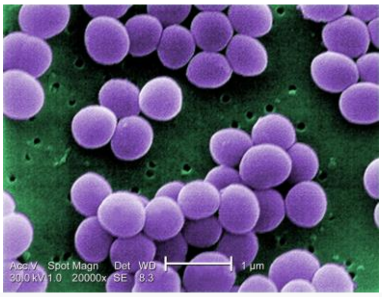
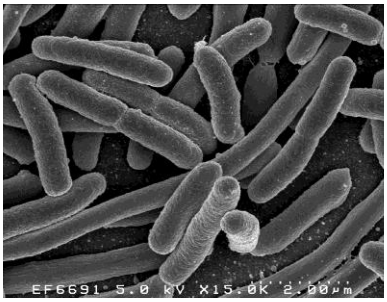
They are so small, we rarely give them a thought and yet they are out there in numbers too enormous for us to comprehend. In fact, they are estimated to constitute no less than half of the total mass of all life on Earth. So, when you next look out over the landscape covered by plants and teeming with insects, birds and animals, think of the roughly equivalent mass of life that you don't see. This invisible other half of life is the microbial world, made up of a great variety of microorganisms, so called because they typically measure only 0.5 to 5 micrometres across (that is about one-thousandth to one-hundredth the width of the 0.5 millimeter sized dot atop the letter i). Although they are nearly everywhere, to see them requires a microscope (although some exceptionally large species are visible to our naked eye, such as *Thiomargarita namibiensis*, which lives by accumulating spheres of elemental sulphur in its elongate cells in shelf sediments offshore Namibia in southwest Africa).

For what they lack in size, microorganisms make up for by their ubiquitous multitudes: 10 to 1000 billion in every teaspoon of soil, a billion or so in every 20 drops (one millilitre) of water, and each of us hosts on the order of 40,000 billion microbes thriving inside our body and out. Microbes have evolved to eke out a living in nearly every habitat on Earth, even those we don't normally associate with the living world: kilometres below the surface in deep rock fractures, and deep below the surface of massive ice sheets. Microbes can even survive in the vacuum of space, and include those left behind on the Moon by astronauts (most likely in a dormant, resting state). We tend to consider microbes as dangerous and something to kill off indiscriminately with antibiotics and disinfectants. Although some are pathogens, most microbes are benign and many others beneficial, if not essential to our well-being. We are only beginning to appreciate the roles played by the highly diverse microbes that thrive in our gut, our mouths and in every nook and cranny of our skin.

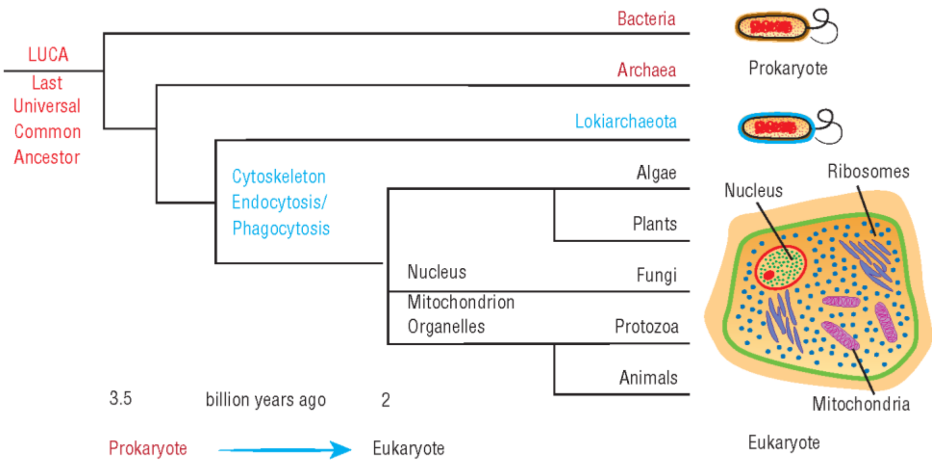


The bacteria *Staphylococcus aureus* (colourised from CDC/Matthew J. Arduino, DRPH/Photo Credit: Janice Haney Carr, scale bar is 1 micrometre).

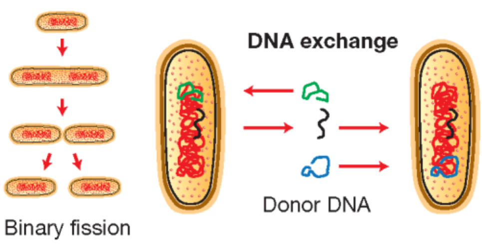


Escherichia coli (E. coli) bacteria (credit: NIAID, each around 2 micrometres long)

Microorganisms are unicellular, with each individual consisting of a single cell whose features are either relatively simple or complex. Those with generally small, simple cells are referred to as prokaryotes and include two main groups: bacteria and archaea. Their simple cells contain a single, circular loose strand of DNA along with ribosomes housed within a cell wall and membrane. Those with generally bigger and more complex cells in which the DNA occurs tightly coiled within a separate nucleus enclosed by a membrane and, along with ribosomes, contain organelle structures are referred to as eukaryotes. The eukaryotes are thought to have evolved from the merging of different prokaryotes. For example, mitochondria organelles, which act as the energy furnace within eukaryotes, were once separate bacteria that were at some stage taken in by and subsumed by archaea. Bacteria and archaea evolved by around 3.5 billion years ago, while the eukaryotes only evolved later by around 2 to 1.5 billion years ago. The evolution of eukaryotes was critical to the eventual evolution of all the big, visible organisms like plants and animals whose many cells are eukaryotic.



Even magnified under a microscope, the many different species of bacteria and archaea can be difficult to tell apart. Some species have many tiny hair-like cilia or long thread-like tails (flagella) to whip them about (see photo top), while others can bind together to form filaments or thin-film colonies. But most individual cells are either spherical to elongate in shape and difficult to tell apart from outward appearances. And this partially explains why archaea were only recently appreciated as being different from bacteria. One way to tell them apart is by what they do chemically, for bacteria and archaea are extremely versatile in the ways in which they metabolise. Some reduce carbon dioxide to methane, others fix nitrogen into nitrate while others convert nitrate to nitrogen, some oxidize sulphur to sulphate while others reduce sulphate to sulphide, and so on...each occupying the chemical niche best suited to their way of life. In essence, bacteria and archaea run most global elemental cycles at Earth's surface, accelerating the pace of chemical reactions so vital to all life forms big and small. Just how many species there are remains largely unknown, but the application of genetics has facilitated our ability to identify them, with thousands of species typically analysed within any given soil or water sample.



No sex please, we are prokaryotes! Bacteria and archaea reproduce by binary fission, where an individual makes an identical copy of itself and splits into two – a parent and its clone. They can also take up bits of DNA of interest that happen to be floating about in their surroundings or they can transfer specific bits of DNA among themselves. Such horizontal or lateral transfer of DNA helps them adapt to changes and to survive stressful times. They can also shut down and stay holed up as microbial cysts until better conditions return, even if that means remaining dormant for centuries or perhaps millions of years. Although microbes living today are probably not terribly different from the first of their kind that appeared 3.5 billion years ago, they can evolve rapidly. For example, so-called ‘superbugs’ evolve in hospitals by surviving the continuous onslaught of antibiotics and disinfectants.

Being the first to live on Earth, bacteria and archaea form the two deepest domains of life, and they are the life forms most likely to endure. Their small size, widespread distribution, genetic diversity and ability to shutdown make them far more likely than other organisms to survive whatever future catastrophes come along. As long as Earth is capable of supporting life it will always include a microbial world. In this sense, the meek shall inherit the earth, if the meekest among us are the smallest and simplest microorganisms. And if life exists on other Earth-like rocky planets orbiting within the wet and warm habitable zone of their stars, it too will most likely be microbial. When considering the abundance and amazing chemical promiscuity demonstrated by the element carbon on Earth, it seems reasonable to conjecture that microbes on other rocky planets are likely to be similar in many respects to our own. It is partly for this reason that we must take every precaution not to contaminate other worlds if we hope to determine unambiguously if life exists elsewhere.