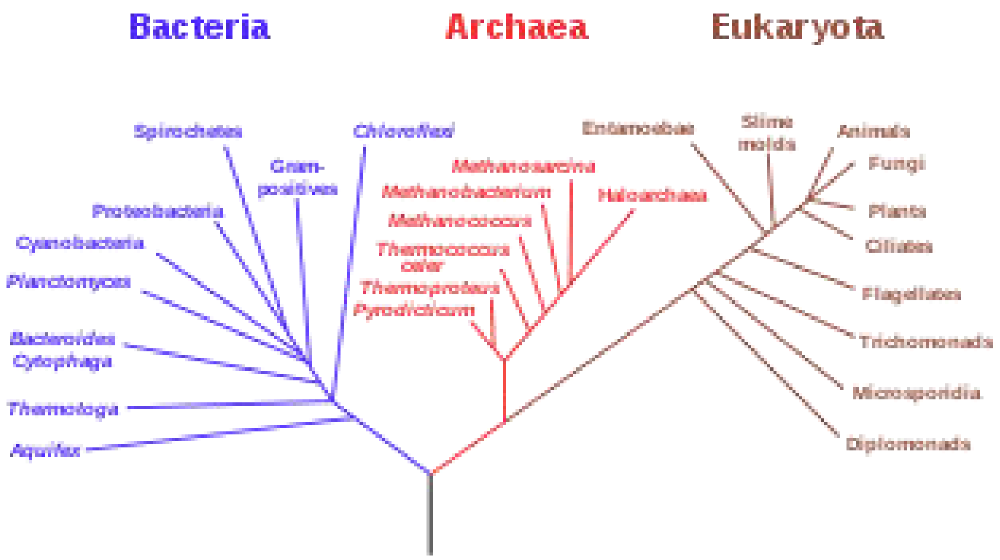
Classification and structure of microorganisms

Microorganisms can be found almost anywhere on Earth. Bacteria and archaea are almost always microscopic, while a number of eukaryotes are also microscopic, including most protists, some fungi, as well as some micro-animals and plants. Viruses are generally regarded as not living and therefore not considered as microorganisms, although a subfield of microbiology is virology, the study of viruses.

Evolution



Carl Woese's phylogenetic tree based on rRNA data shows the domains of Bacteria, Archaea, and Eukaryota. All are microorganisms except some eukaryote groups.

Single-celled microorganisms were the first forms of life to develop on Earth, approximately . billion years ago. Further evolution was slow, and for about billion years in the Precambrian eon, (much of the history of life on Earth), all organisms were microorganisms. Bacteria, algae and fungi have been identified in amber that is million years old, which shows that the morphology of microorganisms has changed little since at least the Triassic period. The newly discovered biological role played by nickel, however — especially that brought about by volcanic eruptions from the Siberian Traps — may have accelerated the evolution of methanogens towards the end of the Permian–Triassic extinction event.

Microorganisms tend to have a relatively fast rate of evolution. Most microorganisms can reproduce rapidly, and bacteria are also able to freely exchange genes through conjugation, transformation and transduction, even between widely divergent species. This horizontal gene transfer, coupled with a high mutation rate and other means of transformation, allows microorganisms to swiftly evolve (via natural selection) to survive in new environments and respond to environmental stresses. This rapid evolution is important in medicine, as it has led to the development of multidrug resistant pathogenic bacteria, *superbugs*, that are resistant to antibiotics.

A possible transitional form of microorganism between a prokaryote and a eukaryote was discovered in by Japanese scientists. *Parakaryon myojinensis* is a unique microorganism larger than a typical prokaryote, but with nuclear material enclosed in a membrane as in a eukaryote, and the presence of endosymbionts. This is seen to be the first plausible evolutionary form of microorganism, showing a stage of development from the prokaryote to the eukaryote.

Archaea

Archaea are prokaryotic unicellular organisms, and form the first domain of life, in Carl Woese's three-domain system. A prokaryote is defined as having no cell nucleus or other membrane bound-organelle. Archaea share this defining feature with the bacteria with which they were once grouped. In the microbiologist Woese proposed the three-domain system that divided living things into bacteria, archaea and eukaryotes, and thereby split the prokaryote domain.

Archaea differ from bacteria in both their genetics and biochemistry. For example, while bacterial cell membranes are made from phosphoglycerides with ester bonds, archaean membranes are made of ether lipids. Archaea were originally described as extremophiles living in extreme environments, such as hot springs, but have since been found in all types of habitats. Only now are scientists beginning to realize how common archaea are in the environment, with Crenarchaeota being the most common form of life in the ocean, dominating ecosystems below m in depth. These organisms are also common in soil and play a vital role in ammonia oxidation.

The combined domains of archaea and bacteria make up the most diverse and abundant group of organisms on Earth and inhabit practically all environments where the temperature is below + °C. They are found in water, soil, air, as the microbiome of an organism, hot springs and even deep beneath the Earth's crust in rocks. The number of prokaryotes is estimated to be around five nonillion, or × , accounting for at least half the biomass on Earth.

The biodiversity of the prokaryotes is unknown, but may be very large. A May estimate, based on laws of scaling from known numbers of species against the size of organism, gives an estimate of perhaps trillion species on the planet, of which most would be microorganisms. Currently, only one-thousandth of one percent of that total have been described. Archael cells of some species aggregate and transfer DNA from one cell to another through direct contact, particularly under stressful environmental conditions that cause DNA damage.

Bacteria

Bacteria like archaea are prokaryotic – unicellular, and having no cell nucleus or other membrane-bound organelle. Bacteria are microscopic, with a few extremely rare exceptions, such as *Thiomargarita namibiensis*. Bacteria function and reproduce as individual cells, but they can often aggregate in multicellular colonies. Some species such as myxobacteria can aggregate into complex swarming structures, operating as multicellular groups as part of their life cycle, or form clusters in bacterial colonies such as *E.coli*.

Their genome is usually a circular bacterial chromosome – a single loop of DNA, although they can also harbor small pieces of DNA called plasmids. These plasmids can be transferred between cells through bacterial conjugation. Bacteria have an enclosing cell wall, which provides strength and rigidity to their cells. They reproduce by binary fission or sometimes by budding, but do not undergo meiotic sexual reproduction. However, many bacterial species can transfer DNA between individual cells by a horizontal gene transfer process referred to as natural transformation. Some species form extraordinarily resilient spores, but for bacteria this is a mechanism for survival, not reproduction. Under optimal conditions bacteria can grow extremely rapidly and their numbers can double as quickly as every minutes.

Eukaryotes

Most living things that are visible to the naked eye in their adult form are eukaryotes, including humans. However, many eukaryotes are also microorganisms. Unlike bacteria and archaea, eukaryotes contain organelles such as the cell nucleus, the Golgi apparatus and mitochondria in their cells. The nucleus is an organelle that houses the DNA that makes up a cell's genome. DNA (Deoxyribonucleic acid) itself is arranged in complex chromosomes. Mitochondria are organelles vital in metabolism as they are the site of the citric acid cycle and oxidative phosphorylation. They evolved from symbiotic bacteria and retain a remnant genome. Like bacteria, plant cells have cell walls, and contain organelles such as chloroplasts in addition to the organelles in other eukaryotes. Chloroplasts produce energy from light by photosynthesis, and were also originally symbiotic bacteria.

Unicellular eukaryotes consist of a single cell throughout their life cycle. This qualification is significant since most multicellular eukaryotes consist of a single cell called a zygote only at the beginning of their life cycles. Microbial eukaryotes can be either haploid or diploid, and some organisms have multiple cell nuclei.

Unicellular eukaryotes usually reproduce asexually by mitosis under favorable conditions. However, under stressful conditions such as nutrient limitations and other conditions associated with DNA damage, they tend to reproduce sexually by meiosis and syngamy.

Protists

Of eukaryotic groups, the protists are most commonly unicellular and microscopic. This is a highly diverse group of organisms that are not easy to classify. Several algae species are multicellular protists, and slime molds have unique life cycles that involve switching between unicellular, colonial, and multicellular forms. The number of species of protists is unknown since only a small proportion has been identified. Protist diversity is high in oceans, deep sea-vents, river sediment and an acidic river, suggesting that many eukaryotic microbial communities may yet be discovered.

Fungi

The fungi have several unicellular species, such as baker's yeast (*Saccharomyces cerevisiae*) and fission yeast (*Schizosaccharomyces pombe*). Some fungi, such as the pathogenic yeast *Candida albicans*, can undergo phenotypic switching and grow as single cells in some environments, and filamentous hyphae in others.

Plants

The green algae are a large group of photosynthetic eukaryotes that include many microscopic organisms. Although some green algae are classified as protists, others such as charophyta are classified with embryophyte plants, which are the most familiar group of land plants. Algae can grow as single cells, or in long chains of cells. The green algae include unicellular and colonial flagellates, usually but not always with two flagella per cell, as well as various colonial, coccoid, and filamentous forms. In the Charales, which are the algae most closely related to higher plants, cells differentiate into several distinct tissues within the organism. There are about species of green algae.

Virus

A **virus** is a submicroscopic infectious agent that replicates only inside the living cells of an organism. Viruses infect all types of life forms, from animals and plants to microorganisms, including bacteria and archaea. Since Dmitri Ivanovsky's article describing a non-bacterial pathogen infecting tobacco plants and the discovery of the tobacco mosaic virus by Martinus Beijerinck in , more than , virus species have been described in detail of the millions of types of viruses in the environment. Viruses are found in almost every ecosystem on Earth and are the most numerous type of biological entity. The study of viruses is known as virology, a subspeciality of microbiology.

When infected, a host cell is forced to rapidly produce thousands of identical copies of the original virus. When not inside an infected cell or in the process of infecting a cell, viruses exist in the form of independent particles, or *virions*, consisting of: (i) the genetic material, i.e., long molecules of DNA or RNA that encode the structure of the proteins by which the virus acts; (ii) a protein coat, the *capsid*, which surrounds and protects the genetic material; and in some cases (iii) an outside envelope of lipids. The shapes of these virus particles range from simple helical and icosahedral forms to more complex structures. Most virus species have virions too small to be seen with an optical microscope, as they are one-hundredth the size of most bacteria.