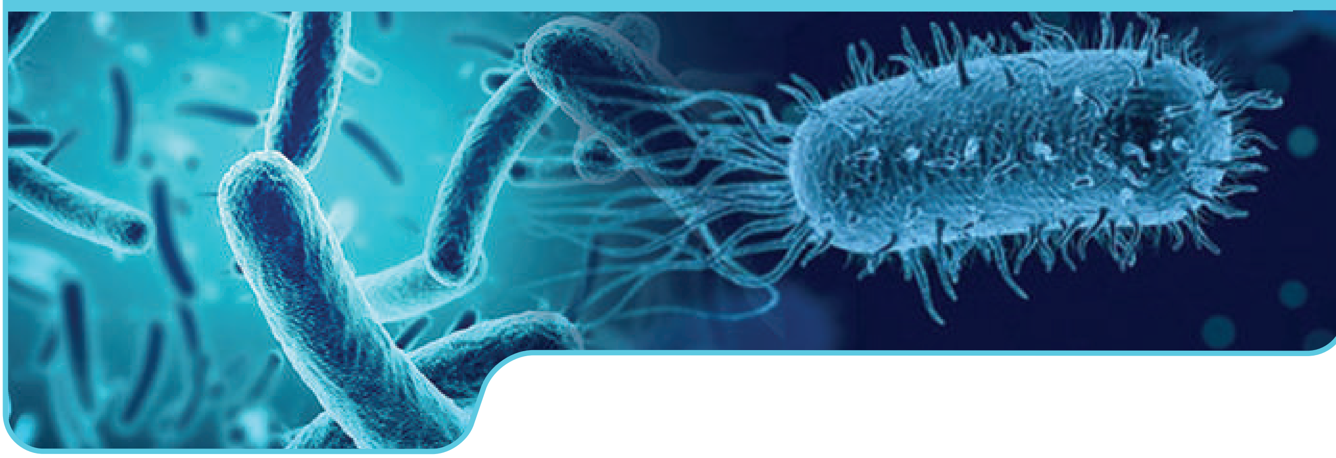
Living microbes: An invaluable global wealth

Vidya Nidhi S. A. Kulasooriya



Among all life forms on planet earth, microorganisms which are invisible to the naked eye, are the most abundant, most widely distributed and are indispensable for the continuation of life, which they themselves originated.

The discovery of microorganisms by Anton Van Leeuwenhoek (1632 – 1723) brought about a revolution in science. The immediate reaction to this discovery was confusion among taxonomists at that time, because all living things had been grouped either as plants or animals. It was not possible to include microorganisms in either group because,they not only showed characters common to both but also possessed features unique to them and certain taxonomists called them "Chaos". With the accumulation of knowledge on their morphology, physiology, biochemistry, genetics and molecular biology, it became evident that microorganisms are an extremely diverse group with only one feature in common,that is, their minute size which make them invisible to the unaided eye. The discovery of these organisms led to a new discipline of science termed **Microbiology**: the study of microorganisms.

Pioneering studies in microbiology were done by well known European scientists mostly during the 19th century. Landmark studies in medical microbiology pioneered by Louis Pasteur, Ferdinand Cohen and Robert Koch (founders of bacteriology), the discovery of filterable viruses by Beijerinck,and the work of many plant and animal pathologists demonstrated that microorganisms are the causative organisms responsible for contagious diseases. It was also reported that most pathogens of plants and animals were also microorganisms. All this made microbes to be considered as dreaded germ's and several methods and materials were developed to destroy them.

These attitudes changed with the realization of the vital roles that

could be played by microorganisms in the continuation of life on Earth, and several other beneficial activities. The initial suggestion of Humphrey Davy in 1836, that plants may fix atmospheric nitrogen, was demonstrated by Boussinghalt (1838) and Atwater (1885) for symbiotic N_2-fixation in legumes, and Jodin (1862) for free living microorganisms. Beijerinck (1901) demonstrated aerobic nitrogen fixation by *Aerobacter chroococcum* and sulfate reduction, a form of anaerobic respiration, and Sergei N. Winogradsky (1856–1953), an Ukrainian-Russian microbiologist, soil scientist and ecologist demonstrated anaerobic N_2-fixation in *Clostridium pasteurianum*, and also proposed the concept of cycling of nutrients. He also reported that *Beggiatoa* oxidized hydrogen sulfide (H_2S) as an energy source. His research on nitrifying bacteria reported the first known form of chemoautotrophy, and how a lithotroph fixed CO_2 to make organic compounds using chemical energy. These discoveries had important implications on the understanding of biogeochemical cycles. Also the improvement and application of biological N_2-fixation in crop production gave a special impetus for microorganisms. After centuries of research studies it is now accepted that biological nitrogen fixation is confined to certain prokaryotic microorganisms and their symbiotic associations. Alexander Fleming (1881 – 1955) British (Scottish) physician, microbiologist and pharmacologist's work resulted in the discovery of lysozyme (Fleming 1922), and isolated, identified and reported the first antibiotic penicillin obtained from the fungus *Penicillium* (Fleming 1929). The subsequent preparation of a myriad of antibiotics from microorganisms, are landmark findings that changed the negative attitudes of society towards microorganisms.

Modern society therefore looks at microorganisms in a more balanced manner with due recognition to the important roles that they play in accepting both positive and negative impacts that they have on our lives. According to current thinking, nothing more than 1% of all microorganisms are detrimental to human lives, where as a significant proportion are beneficial and the vast majority are neutral waiting to be explored and utilized.

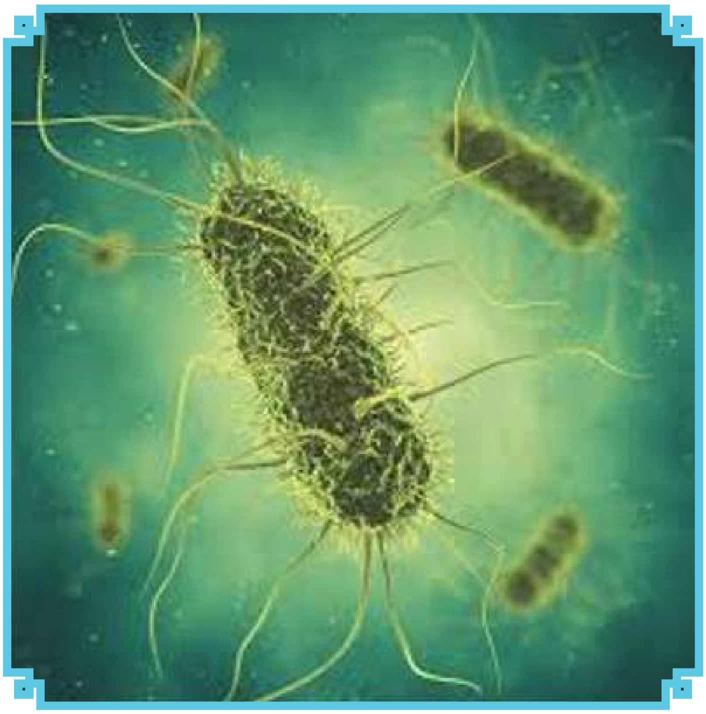
Origin and Evolution

The origin of life on earth is believed to have commenced some 3.8 billion years ago (bya). Scientific evidence supports that during abiotic evolution the entities that gave rise to non-nucleated, prokaryotic microorganisms possessed only Ribose Nucleic Acid (RNA) as their genetic material. The O_2 evolving Protocyanobacteria appeared around 2.8 bya. During the Paleoproterozoic Era (2.5 to 1.6 bya), the earth began to cool down followed by continuous torrential rain. These led to the proliferation of cyanobacteria in the marine phytoplankton which fixed and stored part of the carbon and released oxygen (O_2) that reduced atmospheric methane through oxidation. Meanwhile the chloroplasts that evolved through processes of endosymbioses between cyanobacteria and heterotrophic eukaryotic ancestors accelerated release of O_2 to the atmosphere. Intense solar rays bombarding the earth converted some of the O_2 to ozone (O_3) which buildup a protective O_3 layer that enabled the evolution and migration of life forms from the oceans to land. The oxygenation of the atmosphere also triggered off the development of the aerobic process of respiration. Respiration was far more efficient than the anaerobic processes of fermentation, and the aerobes proliferated at a dramatic pace driving the anaerobes to near extinction. Today aerobes are the dominant living forms among both flora and fauna thriving under an atmosphere containing 21% of oxygen. These evidences clearly show the crucial roles played by ancestral microorganisms, and if not for them all other life forms that we see today may not be there. Microorganisms are ubiquitous in their global distribution occupying all the nooks and corners of the planet earth including extreme habitats such as hot springs, hypersaline localities, freezing environments and arid deserts. These versatile abilities and the intimate relationships including endosymbiosis they exhibit with all other forms of life are reflections of their pioneering ancestry. For 2.2 billion years they had been the only occupants of the primitive Earth. During this very long period microorganisms would have developed mechanisms to utilize all the abiotic resources available on earth. This vast microbial biodiversity possessing an invaluable germplasm is a natural **biowealth** available for man to study, discover and utilize for all his needs and requirements. Therefore it is also not surprising to find intimate associations of microorganisms including endosymbiosis with all other living beings (plants, animals and man) because all of them have evolved in habitats teeming with microbes. It is alarmed to learn that the microbial cell population within us is more numerous than all the cells in our body tissues.

The widespread symbiotic relationships between microorganisms and all other living organisms on earth had given rise to a novel theory of 'Symbiogenic Evolution'. This concept suggests that besides mutation, genetic recombination and natural selection, evolution would have involved symbiotic associations to form consortia of new structural dimensions. According to this theory most eukaryotic organisms are really consortia of organisms functioning in harmony towards common goals of development and adaptation. It has been reported that soil microorganisms seldom associate as individuals with roots of higher plants, but more so as consortia of multi functional microorganisms. Such root associated microbial communities have been termed **rhizosphere microbiomes**. Recent research studies on the preparation of novel biofertilizers, are focussed more on the development of multi-microbial inoculants to establish more efficient rhizosphere microbiomes.

Uses of Microorganisms

Microorganisms are the primary agents of decomposition of organic matter, an exclusive process that enables the continuation of life on earth. They may have been used for thousands of years (even prior to their discovery) in the traditional practices of brewing alcoholic drinks and making bakery products. Subsequent to their discovery, microorganisms were used to elucidate basic processes of life such as photosynthesis, respiration, metabolism, reproduction and genetics, because they can be cultured under controlled conditions to obtain genetically and metabolically uniform populations. In biotechnology and



molecular biology including genetic engineering, microorganisms are used as tools of genetic exchange. Today some of these organisms are selected, sometimes genetically modified and utilized extensively in the pharmaceutical and nutraceutical industries, as well as in the manufacture of dairy products, preparation of bio-fertilizers and bio-pesticides, production of biofuels, eco-friendly agents of sewage treatment, cleansing of oil spills, extraction of valuable metals, and in the development of microbial-fuel cells. Most of these uses can be exploited significantly in developing countries like Sri Lanka particularly for eco-friendly, sustainable activities.

On the negative side there are possibilities to develop genetically modified, more virulent plant and animal pathogens including those against human being. The dreadful Corona viruses that we are experiencing today is a classic example, but so far there is no unequivocal evidence to show that it had been produced intentionally. It is absolutely necessary that we become aware of such potential dangers of bio-terrorism and biological warfare. There are however international agreements, conventions and agencies to monitor, detect and control such nefarious activities.

From the foregoing it is evident that the 'Microbial World' presents an array of organisms with a very wide range of diversity, and presents an invaluable gene pool which originated around 3.8 billion years ago. This germplasm had undergone evolution, natural selection and adaptation in harmony with all the changes undergone by the earth. These evolutionary processes are continuing incessantly, and it is most likely that the best adapted organisms among all living beings against the impending climate changes would be microbes. There is much more to be discovered among this fascinating biowealth, and it is our foremost responsibility to protect this storehouse of invaluable genes for future utilization. It is also vital that we protect our endemic microflora because there are millions of organisms waiting to be explored and utilized. Recently two pharmaceutical products have been patented overseas and released under the names 'Lankamycin and Lankacidin' from bacteria isolated from Sri Lankan soils. We should all be alert against such exploitation of our endemic microorganisms, and laws have to be strengthened and implemented with vigour to prevent this type of bio-piracy. The most practical way to protect microbial biodiversity is the conservation of their natural habitats and ecosystems.

Vidya Nidhi Prof. S. A. Kulasooriya
Emeritus Professor and
former Professor of Microbiology
Faculty of Science,
University of Peradeniya.