

# Good essay on microbiology: principles and applications

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Microbiology is the study of microorganisms. Microorganisms are those organisms that are less than a millimeter in size and require the help of a microscope to view them. Microorganisms can be unicellular or multicellular but have very simple cell structure, unlike the highly developed, complex organisms such as larger animals and humans. Microorganisms are classified based on criteria such as their cell structure, pattern of growth, nutrition, reproduction method, etc. However, microbial classification is a challenging task due to the dual nature of some microorganisms that exhibit both animal and plant like characteristics. Some microorganisms are photosynthetic like plants but they also have the ability to move from one location to the other using flagella and cilia like animals. Nevertheless, most microbiologists agree that organisms can be divided into bacteria, archaea and eukarya based on ribosomal RNA (rRNA) structure (Willey, Sherwood & Woolverton, 2009). Microbes reside within the human body in the form of normal flora that help in digestion. There are also other harmful microorganisms such as bacteria, fungi and viruses cause diseases in animals, humans and plants via food, water, air and direct contact. Through genetic engineering and microbial gene technology, humans have found out many ways to manipulate microorganisms to produce vaccines, recombinant drugs, fight agricultural pests and help in bioremediation (Kar, 2008).

## **Historical developments in microbiology**

The study of microorganisms became possible after the invention of the microscope and observations by Robert Hooke and Anton van Leeuwenhoek. Carolus Linnaeus developed a taxonomic classification system for all organisms and Matthias Schleiden and Theodor Schwann, who developed the

cell theory suggesting that a cell was the smallest functional unit of all organisms that could perform all functions of the organism. The theory of spontaneous generation was the counter idea for germ theory that suggested that organisms generated spontaneously through some invisible vital force and oxygen. Louis Pasteur, using his swan neck flasks, disproved the theory of spontaneous generation. He was also responsible for discovering fermentation and pasteurization (Tortora, Funke & Case, 2013). The development of germ theory was a major breakthrough in the study of microorganisms, because it proved that invisible, live organisms and not supernatural forces caused diseases (Willey et al., 2009). It took Robert Koch's experiments to prove the germ theory. Koch was the first to isolate bacteria on culture media using pure culture techniques and study them in vitro. He started with liquid culture media but added the inert agar to the media to produce solid medium to grow bacterial cultures. Koch's postulates listed four principles of microbiology of a disease. They stated that there must be the presence of the causative organism in the body whenever a disease occurs; the organism must be isolated to confirm the disease; the same disease must occur in a person or animal inoculated with the microorganism; and a culture of the infected person or animal must produce the same microorganism on media. His works were able to find the causative agent for tuberculosis, cholera, malaria, typhoid, sleeping sickness and many other diseases. In an attempt to reduce infection by microorganisms during surgery, Joseph Lister developed various techniques and chemical antiseptic solutions and is considered as the father of antiseptics (Black, 2012). Knowing that specific organisms produce specific diseases, Edward Jenner

experimented and invented vaccines. In the early part of the twentieth century, Alexander Fleming discovered another way to inhibit growth of bacteria- the antibiotics that were produced by fungi. Today, microbiology is used as a major diagnostic tool as well as a way to save lives, thanks to the contributions of the above-mentioned scientists (Tortora et al., 2013).

## **Microbial classification**

Classification based on cell structure

Organisms can be divided into prokaryotes and eukaryotes. As described earlier, microorganisms can also be classified into three types, namely, bacteria, archaea and eukarya. Bacteria and archaea are prokaryotic organisms while Eukarya encompasses the eukaryotic organisms. This classification is based on the cell structure of the organisms (Tortora et al., 2013). Prokaryotic cells are 4 µm and smaller in size and contain a nucleoid, single circular chromosome, 70S ribosomes, pili and a plasmid. Cell organelles such as peroxisomes, chloroplast, Golgi complex, endoplasmic reticulum and mitotic spindle are absent in prokaryotes. The prokaryotes also lack cytoskeleton, cilia, histone, nucleolus and sexual mode of reproduction. All bacteria are prokaryotic. Archaea are prokaryotic organisms too but their cell walls do not contain peptidoglycan. Eukaryotic organisms are those that contain membrane-enclosed nucleus that contain the nucleolus and nuclear material bound by histone. The ribosomes are 80S in the cytoplasm and the cell organelles contain 70S ribosomes. The cell wall is made of cellulose or chitin instead of peptidoglycan. They have cilia but not pili (Black, 2012). Fungi, protozoa, algae, viruses and all multicellular

organisms are classified as eukaryotes (Tortora et al., 2013). Bacteria are often named based on their shapes. For example, rod shaped bacteria are called Bacillus; circular bacteria are called Coccus; paired cocci are called Diplococcus; chained cocci are called Streptococcus; clustered cocci are called Staphylococcus; bacterial cells arranged in cuboids of eight are called Sarcina; and comma shaped bacteria are named Vibrio (Kar, 2008).

### **Microscopy, staining and classification**

Characterization of microbes was possible with the discovery of microscope. Some common types of microscopes used in microbiology are dark-field illumination microscope, compound light microscope, phase contrast microscope, differential interference contrast microscope, fluorescence microscope, confocal microscope, atomic force microscope, transmission electric microscope, scanning electron microscope and scanning tunneling microscope. The organisms are mounted on glass slides using techniques such as smearing, wet mounting and hanging drop methods. They are also stained for better viewing using a dye that binds to the organelles and other cell structures of the organism. The dyes are acidic or basic in nature and are used based on the target organelles pH. Simple staining techniques use a single dye while differential staining use multiple stains to distinguish one microorganism from the other. Among the stains used for bacterial studies, Gram stain is a popular one and is widely used to classify microorganisms. Gram-positive bacteria are those that stain well with crystal violet and retain the color after wash while Gram-negative bacteria lose the crystal violet stain after a rinse and take up any counter stain applied to the same slide

(Black, 2012). Staining is used in diagnostic microbiology for the identification of organisms such *Streptococcus pneumoniae*, *Mycobacterium leprae*, *Nocardia* sp., *Clostridium* sp. and *Bacillus* sp. (Kar, 2008).

## **Classification based on growth environment**

Microorganisms that need oxygen to grow are called obligate aerobes while those that prefer an environment without oxygen but can grow in an aerobic environment are called facultative aerobes. Microorganisms that grow in the absence of oxygen are called anaerobes. Obligatory anaerobes cannot survive in the presence of oxygen while facultative anaerobes can grow in either environment (Kar, 2008). Microorganisms are also classified as photoautotrophs, chemoautotrophs, photoheterotrophs and chemiheterotrophs based on their nutrition and metabolism (Black, 2012).

## **Bergey's Manual of Systematic Bacteriology**

Bergey's Manual is one of the exhaustive literature on taxonomic classification of microorganisms. It classifies each microorganisms into order, suborder, family, genus and species (Kar, 2008).

## **Culturing microorganisms in vitro**

### Medium

Microorganisms are cultured in culture medium that are liquid or solid preparations. Culture media act as a nourishing base, storage system as well as a transport system. Culture media can be selective, differential, enriched, general purpose, complex or defined in nature. A typical nutrient broth (NB) contains peptone and beef extract but is devoid of agar. Some media also

contain pH indicators, salts, gelatin, casein, sugars and digested animal tissue. Defined, selective and differential media can be used as a diagnostic tool for pathogen identification (Willey et al., 2009).

## **Pure culture techniques**

Pure culture techniques are used for isolation of a single species of microorganism that is difficult to study in a mixed culture. Streaking a plate of solid agar-based medium is one pure culture technique used for the isolation of a single colony of the desired microorganism. Other techniques include pour plating and spread plating where the mixed culture is diluted several times using serial dilution technique and pour or spread on a plate of agar medium (Willey et al., 2009).

## **Continuous culture techniques**

For industrial and large-scale production purposes, microorganisms are grown in large bioreactors that feed new enriched medium through an inlet while removing the depleted medium through an outlet in a continuous manner. Such a system holds the microorganisms in a closed container with optimal growth environment and nutrients (Willey et al., 2009).

## **Commercial applications of microbiology**

Sewage water treatment and bioremediation

Sewage water contains large amounts of organic wastes that can be removed by the action of beneficial sewage metabolizing bacteria such as Zoogloea. These bacteria convert the organic content of the sewage into carbon dioxide and water. The beneficial bacteria are loaded onto a biofilm

and immersed into the sewage water for digestion (Tortora et al., 2013). Oil spills and other solvents can be cleaned up using recombinant strains of *Burkholderia cepacia* (Willey et al., 2009).

## **Food microbiology**

The focus of food industries in reducing contamination is equal to the focus given on the taste of the product. However, the food industry also embraces some microorganisms for food production. *Propionibacterium* is used in making Swiss cheese; *Penicillium* is used for preparation of Blue cheese and Roquefort cheese; *Streptococcus thermophiles* and *Lactobacillus delbrueckii bulgaricus* is used in yogurt production; and *Saccharomyces cerevisiae* is used in baking. Beer is made using bottom yeast while ale is made using top yeast; *Aspergillus* is used for making sake; and wine is made using *Acetobacter* and *Gluconobacter* (Tortora et al., 2013).

## **Metabolite production**

Metabolites such as citric acid is produced by *Aspergillus niger* in a continuous batch culture. Antibiotics such as penicillin are produced by batch cultures of *Penicillium*. Bacteria and fungi also help in mass production of amino acids such as L-glutamate, phenylalanine, L-aspartate, lysine and methionine. Microorganisms such as *Pseudomonas*, *Propionibacterium* and *Acetobacter* produce metabolites such as steroids, proteases, estrogens, progesterone, glucose isomerase and vitamins. Different strains of *Streptomyces hygroscopicus* are used for industrial production of many different antibiotics. Recombinant DNA technology is used for mass



production of vaccines using genetically modified bacteria (Tortora et al., 2013).

### **Metal leaching**

*Thiobacillus ferrooxidans* is widely used in metal leaching in metallurgy and ore production. Metals such as gold, copper, cobalt and uranium are leached using bacteria (Tortora et al., 2013). *Leptospirillum* are used for leaving low grade copper from ores (Willey et al., 2009).

### **Agricultural microbiology and bioaugmentation**

*Bacillus thuringiensis* is used as a pest control agent while *Rhizobium* and *Bradyrhizobium* are used for nitrogen-fixation. Both of these processes help in improved agricultural output (Tortora et al., 2013).

### **Conclusion**

Microbiology is a vast field that has been segregated into many different fields such as immunology, biotechnology, microbial physiology, medical biochemistry and medical diagnostics. Microbiology helps understand the interaction and involvement of microorganisms in every aspect of human life and the environment. The past discoveries by great scientists about the pathogenicity, immune system, biochemistry and physiology have led to the commercial exploitation of the microorganisms for human welfare.

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