高等农业院校教材

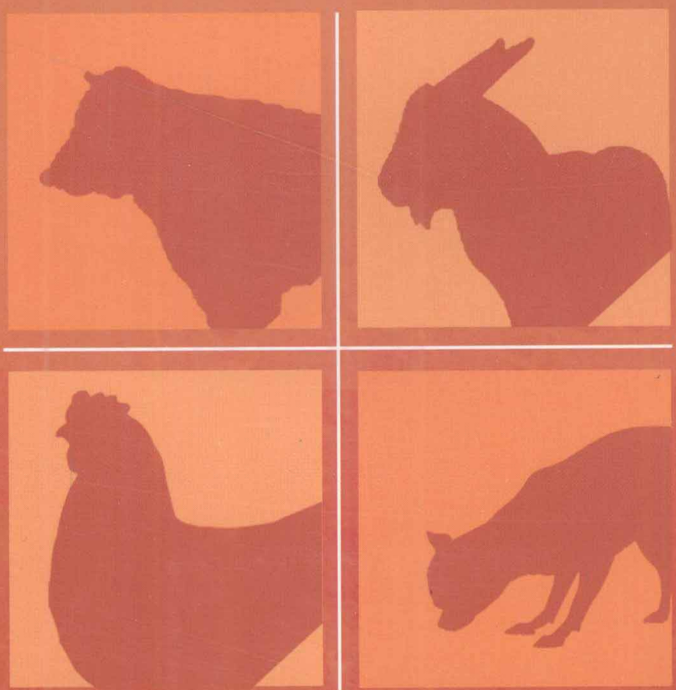
动物微生物学

Animal Microbiology

（英文版）

胡建和　杭柏林　王丽荣　主编

供动物医学专业用



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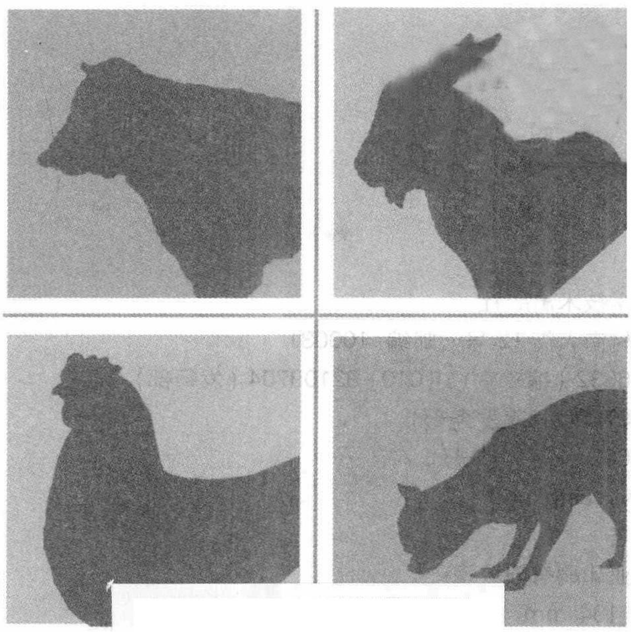

中国农业科学技术出版社

图书在版编目(CIP)数据

动物微生物学 = Animal Microbiology:英文/胡建和,杭柏林,王丽荣主编.—北京:中国农业科学技术出版社,2011.7
ISBN 978-7-5116-0501-6

Ⅰ.①动… Ⅱ.①胡…②杭…③王… Ⅲ.①兽医学:微生物学—英文 Ⅳ.①S852.6

中国版本图书馆CIP数据核字(2011)第114521号

责任编辑 闫庆健
责任校对 贾晓红

出 版 者 中国农业科学技术出版社
北京市中关村南大街12号 邮编:100081
电 话 (010)82106632(编辑室) (010)82109704(发行部)
(010)82109709(读者服务部)
传 真 (010)82106624
网 址 http://www.castp.cn
经 销 者 各地新华书店
印 刷 者 北京华忠兴业印刷有限公司
开 本 889 mm×1 194 mm 1/16
印 张 22.75
字 数 642千字
版 次 2011年7月第1版 2011年7月第1次印刷
定 价 60.00元

编写人员

主　编　胡建和　杭柏林　王丽荣

副主编　（排名不分先后）

韩庆功　高德琴　刘丽艳　陈全猷　李任峰

陈仕均　陈俊杰　唐海蓉　吴庚华　庞盼姣

编　委　（排名不分先后）

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徐彦召　高德琴　唐海蓉　崔艳红　韩庆功

前　　言

《动物微生物学》是动物医学专业的重要专业基础课程之一。学好《动物微生物学》是学习后续课程如《动物免疫学》、《动物传染病学》、《动物病理学》等的重要前提。

在现代，学科知识的更新日新月异，与国际接轨的程度越来越高。随着科学技术的不断进步，国际范围内《动物微生物学》的内容在过去的几年里有着快速发展。虽然在如此快速发展的领域内，任何一本书籍正式出版时，其内容可能已经过时，但为了国内学生能及时了解和掌握国际动物微生物学的发展状况，及其今后在工作中及时了解国际动物疫病流行新趋势与防控新措施，同时为改革教学内容和教学方法，提高人才培养的条件和手段，促进人才教育整体水平的提高，特编写了《动物微生物学》（英文版）教材。

本书主要分为三部分。第一部分为细菌学，主要包括细菌学总论、动物病原细菌学各论和四体（螺旋体、支原体、立克次体、衣原体）部分；第二部分为真菌学，主要包括真菌学总论和动物病原真菌学各论；第三部分为病毒学，主要包括病毒学总论和动物病原病毒学各论。

本书读者对象为动物医学专业学生和专门从事动物微生物学、动物传染病学与流行病学、动物免疫学、动物病理学的研究生，同时编者还希望本书为有关兽医工作者、从事微生物相关工作的学生和研究者提供帮助。

在编写过程中，编写人员参考了大量的国内外专业书籍、期刊和网站，尽可能使书籍的内容和体系既与国际接轨，又适合我国学生所用。由于参加编写的人员较多，层次复杂，使得本书有许多不足，特别是在参考文献的引用方面，做得还不够好，在此，向原作者致以诚挚歉意。

在本书编写过程中，编者得到了许多同事和朋友及临床兽医师的帮助，在此表示最诚挚的感谢。

鉴于编写人员写作水平和英文水平有限，书中不免存在一些瑕疵，望读者批评指正。

编　者

2011 年 4 月于新乡

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Introduction

Microbiology is the study of microorganisms or microbes, which are unicellular or cell-cluster microscopic organisms. This includes eukaryotes such as fungi and protists, and prokaryotes. Viruses, though not strictly classed as living organisms, are also studied. In short, microbiology refers to the study of life and organisms that are too small to be seen with the naked eye.

Microbiology is a broad term which includes virology, mycology, parasitology, bacteriology and other branches. A microbiologist is a specialist in microbiology.

Microbiology is researched actively, and the field is advancing continually. We have probably only studied about one percent of all of the microbe species on Earth. Although microbes were first observed over three hundred years ago, the field of microbiology can be said to be in its infancy relative to older biological disciplines such as zoology and botany.

1 History of Microbiology

1.1 Ancient

The existence of microorganisms was hypothesized for many centuries before their actual discovery in the 17th century. In 600 BCE, the ancient Indian surgeon Susruta held microbes responsible for several diseases and explained in Sushruta Samhita that they can be transmitted through contact, air or water. Theories on microorganisms were made by Roman scholar Marcus Terentius Varro in a book titled On Agriculture in which he warns against locating a homestead in the vicinity of swamps: "... and because there are bred certain minute creatures which cannot be seen by the eyes, which float in the air and enter the body through the mouth and nose and there cause serious diseases." This passage seems to indicate that the ancients were aware of the possibility that diseases could be spread by yet unseen organisms.

In The Canon of Medicine (1020), Avicenna stated that bodily secretion is contaminated by foul foreign earthly bodies before being infected. He also hypothesized on the contagious nature of tuberculosis and other infectious diseases, and used quarantine as a means of limiting the spread of contagious diseases.

When the Black Death bubonic plague reached al-Andalus in the 14th century, Ibn Khatima hypothesized that infectious diseases were caused by "minute bodies" which entered the human body and caused disease.

In 1546 Girolamo Fracastoro proposed that epidemic diseases were caused by transferable seedlike entities that could transmit infection by direct or indirect contact or even without contact over long distance.

All these early claims about the existence of microorganisms were speculative in nature and not based on any data or science. Microorganisms were neither proven and observed, nor correctly and accurately described until the 17th century. The reason for this was that all these early inquiries lacked the most fundamental tool for microbiology and bacteriology to exist as a science, and that was the microscope.

1.2 Modern

Bacteria, and other microorganisms, were first observed by Antonie van Leeuwenhoek (Fig. 0-1) in 1676 by means of a single-lens microscope of his own design. He called them "animalcules" and published his observations in a series of letters to the Royal Society. Antonie van Leeuwenhoek made one of the most important discoveries in biology and initiated the scientific fields of bacteriology and microbiology. The name "bacterium" was introduced much later, by Ehrenberg in 1828, derived from the Greek βακτηριον meaning "small stick". While Van Leeuwenhoek is often cited as the first microbiologist, the first recorded microbiological observation, that of the fruiting bodies of molds, was made earlier in 1665 by Robert Hooke.

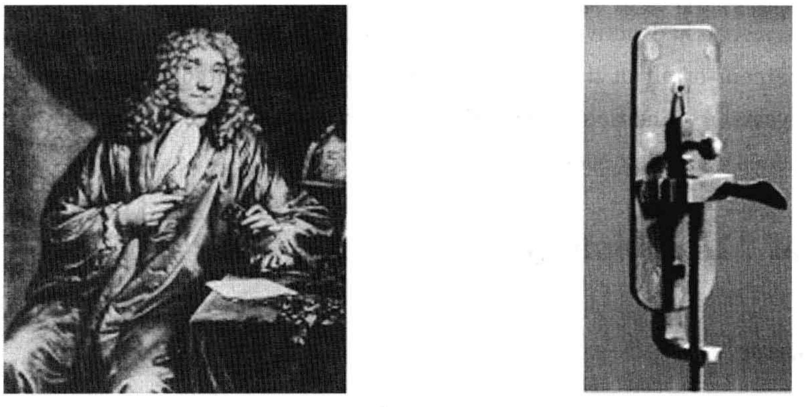

Fig. 0-1 Antoni van Leeuwenhoek (1632-1723) and one of his microscopes

(He was the first microbiologist and the first one to observe microorganisms using a microscope. Known as the Father of Microbiology, he did not invent the microscope, but he greatly developed it.)

The field of bacteriology (a subdiscipline of microbiology) is generally considered to have been founded by Ferdinand Cohn (1828-1898), a botanist whose studies on algae and photosynthetic bacteria led him to describe several bacteria including *Bacillus* and *Beggiatoa*. Cohn is also the first to formulate a scheme for the taxonomic classification of bacteria. Louis Pasteur (1822-1895) and Robert Koch (1843-1910) are contemporaries of Cohn and are often considered to be the founders of medical microbiology.

Pasteur (Fig. 0-2) is most famous for his series of experiments designed to disprove the widely held theory of spontaneous generation, thereby solidifying microbiology's identity as a biological science. Pasteur also designed methods for food preservation (pasteurization) and vaccines against several diseases such as anthrax, fowl cholera and rabies.

Koch (Fig. 0-3) is best known for his contributions to the germ theory of disease, proving that specific diseases were caused by specific pathogenic microorganisms. In his research into tuberculosis, Koch finally proved the germ theory, for which he was awarded a Nobel Prize in 1905. Koch was one of the first scientists to focus on the isolation of bacteria in pure culture resulting in his description of several novel bacteria including *Mycobacterium tuberculosis*, the causative agent of tuberculosis. He developed a series of criteria known as the Koch's postulates. Koch's postulates are: 1) The microorganism must be found in abundance in all organisms suffering from the disease, but should not be found in healthy animals. 2) The microorganism must be isolated from a diseased organism and grown in pure culture. 3) The cultured microorganism should cause disease when introduced into a healthy organism. 4) The microorganism must be re-isolated from the inoculated, diseased experimental host and identified as being identical to the original specific causative agent. These postulates are still used today.

Fig. 0-2 Louis Pasteur (1822-1895)

Fig. 0-3 Robert Koch (1843-1910)

Though it was known in the 19th century that bacteria were the cause of many diseases, no effective antibacterial treatments were available. In 1910, Paul Ehrlich developed the first antibiotic, by changing dyes that selectively stained *Treponema pallidum* (the spirochaete that causes syphilis) into compounds that selectively killed the pathogen. Ehrlich had been awarded a 1908 Nobel Prize for his work on immunology, and pioneered the use of stains to detect and identify bacteria, with his work being the basis of the Gram stain and the Ziehl-Neelsen stain.

While Pasteur and Koch are often considered the founders of microbiology, their work did not accurately reflect the true diversity of the microbial world because of their exclusive focus on microorganisms having direct medical relevance. It was not until the work of Martinus Beijerinck (1851-1931) and Sergei Winogradsky (1856-1953), the founders of general microbiology (an older term encompassing aspects of microbial physiology, diversity and ecology), that the true breadth of microbiology was revealed. Beijerinck made two major contributions to microbiology: the discovery of viruses and the development of enrichment culture techniques. While his work on the Tobacco Mosaic Virus established the basic principles of virology, it was his development of enrichment culturing that had the most immediate impact on microbiology by allowing for the cultivation of a wide range of microbes with wildly different physiologies. Winogradsky was the first to develop the concept of chemolithotrophy and to thereby reveal the essential role played by microorganisms in geochemical processes. He was responsible for the first isolation and description of both nitrifying and nitrogen-fixing bacteria.

A major step forward in the study of bacteria was the recognition in 1977 by Carl Woese that archaea had a separate line of evolutionary descent from bacteria. This new phylogenetic taxonomy was based on the sequencing of 16S ribosomal RNA (rRNA), and divided prokaryotes into two evolutionary domains, as part of the three-domain system.

2 Fields of Microbiology

The field of microbiology can be generally divided into several subdisciplines:

Microbial physiology: the study of how the microbial cell functions biochemically inclluding the study of microbial growth, microbial metabolism and microbial cell structure.

Microbial genetics: the study of how genes are organised and regulated in microbes in relation to their cellular functions, which is closely related to the field of molecular biology.

Cellular microbiology: a discipline bridging microbiology and cell biology.

Medical microbiology: the study of the pathogenic microbes and the role of microbes in human illness. It includes the study of microbial pathogenesis and epidemiology and is related to the study of disease pathology and immunology.

Animal microbiology: the study of the role of microbes in veterinary medicine and animal husbandry.

Environmental microbiology: the study of the function and diversity of microbes in their natural environments.

Evolutionary microbiology: the study of the evolution of microbes including the study of bacterial systematics and taxonomy.

Industrial microbiology: the exploitation of microbes for use in industrial processes including industrial fermentation and wastewater treatment.

Aeromicrobiology: the study of airborne microorganisms.

Food microbiology: the study of microorganisms causing food spoilage and foodborne illness, using microorganisms to produce foods, for example by fermentation.

Pharmaceutical microbiology: the study of microorganisms causing pharmaceutical contamination and spoilage.

3 Benefits of Microbiology

While there are undoubtedly someone who fear all microbes due to the association of some microbes with various human illnesses, many microbes are also responsible for numerous beneficial processes such as industrial fermentation (e. g., the production of alcohol and dairy products), antibiotic production and as vehicles for cloning in higher organisms such as plants. Scientists have also exploited their knowledge of microbes to produce biotechnologically important enzymes such as *Taq* polymerase, reporter genes for use in other genetic systems and novel molecular biology techniques such as the yeast two-hybrid system.

Bacteria can be used for the industrial production of amino acids. *Corynebacterium glutamicum* is one of the most important bacterial species with an annual production of more than two million tons of amino acids, mainly L-glutamate and L-lysine.

A variety of biopolymers, such as polysaccharides, polyesters, and polyamides, are produced by microorganisms. Microorganisms are used for the biotechnological production of biopolymers with tailored properties suitable for high-value medical application such as tissue engineering and drug delivery. Microorganisms are used for the biosynthesis of xanthan, alginate, cellulose, cyanophycin, levan, hyaluronic acid, organic acids, oligosaccharides and polysaccharide, and polyhydroxyalkanoates.

Microorganisms are beneficial for microbial biodegradation or bioremediation of domestic, agricultural and industrial wastes and subsurface pollution in soils, sediments and marine environments. The ability of each microorganism to degrade toxic waste depends on the nature of each contaminant. Since sites typically have multiple pollutant types, the most effective approach to microbial biodegradation is to use a mixture of bacterial species and strains, each specific to the biodegradation of one or more types of contaminants.

There are also various claims concerning the contributions to human and animal health by consuming probiotics(bacteria potentially beneficial to the digestive system) and/or prebiotics(substances consumed to promote the growth of probiotic microorganisms).

Recent research has suggested that microorganisms could be useful in the treatment of cancer. Various strains of non-pathogenic clostridia can infiltrate and replicate within solid tumors. Clostridial vectors can be administered safely and their potential to deliver therapeutic proteins has been demonstrated in a variety of preclinical models.

Ⅰ. Bacteriology

Chapter 1 Morphology and Structure of Bacteria

The bacteria (singular: bacterium) are a large group of unicellular microorganisms. Typically a few micrometres in length, bacteria have a wide range of shapes, ranging from spheres to rods and spirals. The study of bacteria is known as bacteriology, a branch of microbiology.

Bacteria are now classified as prokaryotes. Unlike cells of animals and other eukaryotes, bacterial cells do not contain a nucleus and rarely harbour membrane-bound organelles. Although the term bacteria traditionally included all prokaryotes, the scientific classification changed after the discovery in the 1990s that prokaryotes consist of two very different groups of organisms that evolved independently from an ancient common ancestor. These evolutionary domains are called Bacteria and Archaea.

Bacteria, despite their simplicity, contain a well developed cell structure which is responsible for many of their unique biological properties. Many structural features are unique to bacteria and are not found among archaea or eukaryotes. Because of the simplicity of bacteria relative to larger organisms and the ease with which they can be manipulated experimentally, the cell structure of bacteria has been well studied, revealing many biochemical principles that have been subsequently applied to other organisms.

1 Cell Morphology

Perhaps the most elemental structural property of bacteria is cell morphology (shape). Bacteria display a wide diversity of shapes and sizes, which is named morphologies.

Cell shape is generally characteristic of a given bacterial species, but can vary depending on growth conditions. Bacteria generally form distinctive cell morphologies when examined by light microscopy and distinct colony morphologies when grown on plates. These are often the first characteristics observed by a microbiologist to determine the identity of an unknown bacterial culture.

Typical examples include: coccus (spherical), bacillus (rod-like), spirillum (spiral), filamentous (Fig. 1-1). Most bacterial species are either spherical, called cocci (singular: coccus) or rod-shaped, called bacilli (singular: bacillus). Some rod-shaped bacteria, called vibrio, are slightly curved or comma-shaped; others, can be spiral-shaped, called spirilla, or tightly coiled, called spirochaetes. A small number of species even have tetrahedral or cuboidal shapes. More recently, bacteria were discovered deep under the Earth's crust that growed as long rods with a star-shaped cross-section. The large surface area to volume ratio of this morphology may give these bacteria an advantage in nutrient-poor environments. This wide variety of shapes is determined by the bacterial cell wall and cytoskeleton, and is important because it can influence the ability of bacteria to acquire nutrients, attach to surfaces, swim through liquids and escape predators.

Many bacterial species exist simply as single cells, while others associate in characteristic patterns: Streptococcus form chains, and Staphylococcus group together in "bunch of grapes" clusters. Bacteria can also be elongated to form filaments, for example the Actinobacteria. Filamentous bacteria are often surrounded by a sheath that contains many individual cells. Certain types, such as species of the genus Nocardia, even form complex, branched filaments, similar in appearance to fungal mycelia.

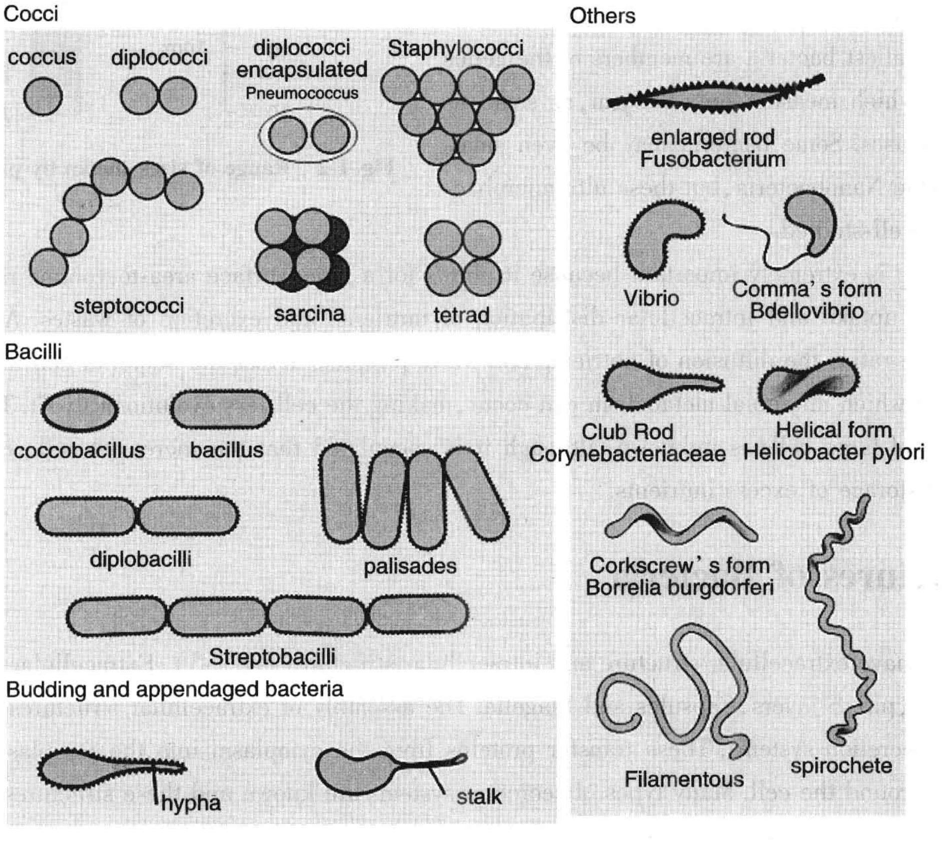

Fig. 1-1 Morphology of Bacteria

Bacteria often attach to surfaces and form dense aggregations called biofilms or bacterial mats. These films can range from a few micrometers in thickness to up to half a meter in depth, and may contain multiple species of bacteria, protists and archaea. Bacteria living in biofilms display a complex arrangement of cells and extracellular components, forming secondary structures such as microcolonies, through which there are networks of channels to enable better diffusion of nutrients. In natural environments, such as soil or the surfaces of plants, the majority of bacteria are bound to surfaces in biofilms. Biofilms are also important in medicine, as these structures are often present during chronic bacterial infections or in infections of implanted medical devices, and bacteria protected within biofilms are much harder to kill than individual isolated bacteria.

2 Cell Size

Perhaps the most obvious structural characteristic of bacteria is (with some exceptions) their small size(Fig. 1-2). For example, *Escherichia coli* cells, an "average" sized bacterium, are about 2 micrometres (μm) long and 0.5 μm in diameter, with a cell volume of 0.6-0.7 μm^3. Bacterial cells are about one tenth the sizes of eukaryotic cells and are typically 0.5-5.0μm length. However, a few species, for example *Thiomargarita namibiensis*, are up to half a millimetre(mm) long and are visible to the unaided eye. Among the smallest bacteria are members of the genus Mycoplasma, which measure only 0.3μm, as small as the largest viruses. Some bacteria may be even smaller, for example Nanobacteria, but these ultramicrobacteria are not well-studied.

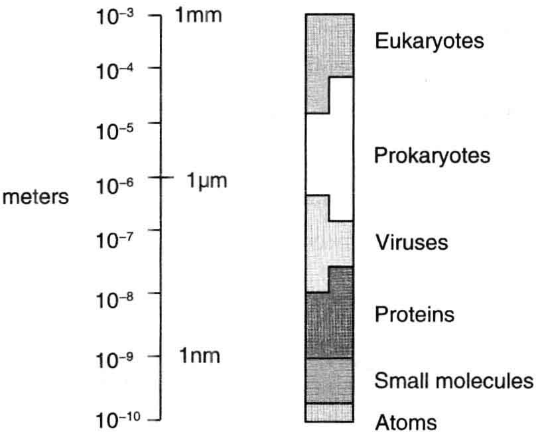

Fig. 1-2 Range of sizes shown by prokaryotes

Small size is extremely important because it allows for a large surface area-to-volume ratio which allows for rapid uptake and intracellular distribution of nutrients and excretion of wastes. At low surface area-to-volume ratios the diffusion of nutrients and waste products across the bacterial cell membrane limits the rate at which microbial metabolism can occur, making the cell less evolutionarily fit. The reason for the existence of large cells is unknown, although it is speculated that the increased cell volume is used primarily for storage of excess nutrients.

3 Structures of Bacteria

Bacteria have extracellular structure and intracellular structure(Fig. 1-3). Extracellular structures include Fimbria, pili, S-layers, Capsules and Flagella. The assembly of extracellular structures is dependent on bacterial secretion systems. These transfer proteins from the cytoplasm into the periplasm or into the environment around the cell. Many types of secretion systems are known and these structures are often essential for the virulence of pathogens, so they are intensively studied. But, in fact, we talk a lot about that bacteria have basic structure and specific structure.

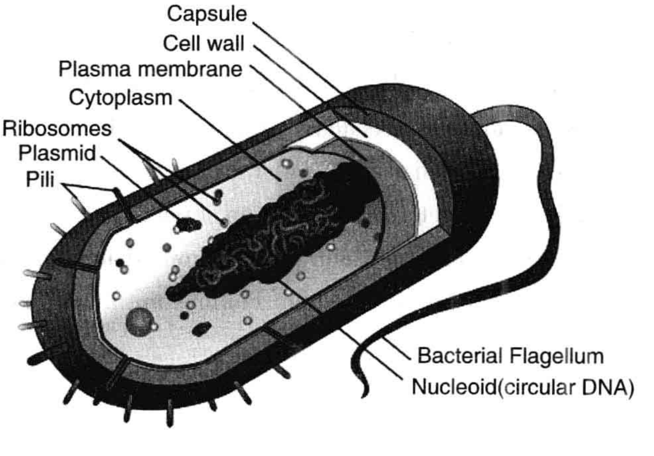

Fig. 1-3 Structure and contents of a typical bacterial cell