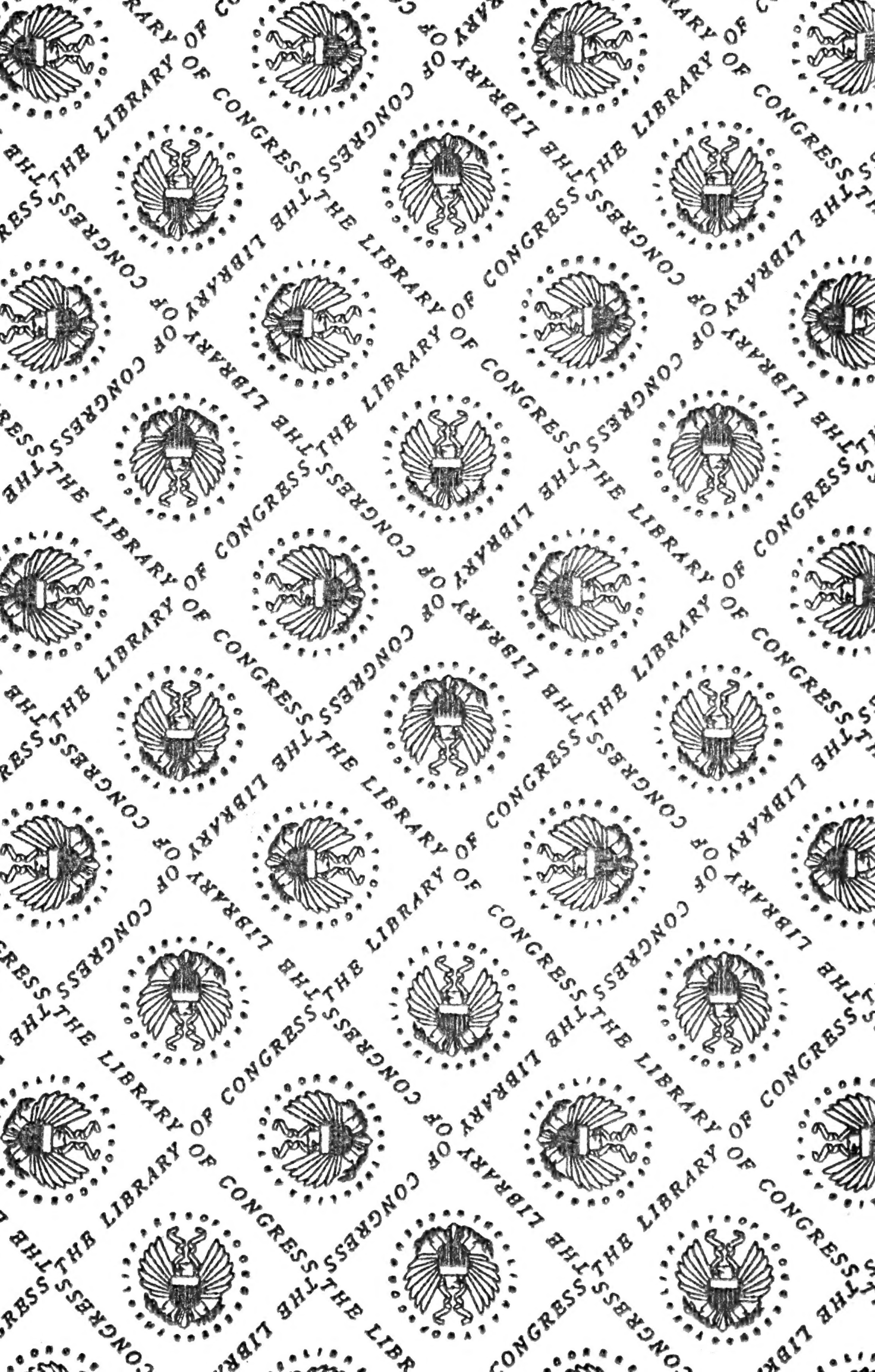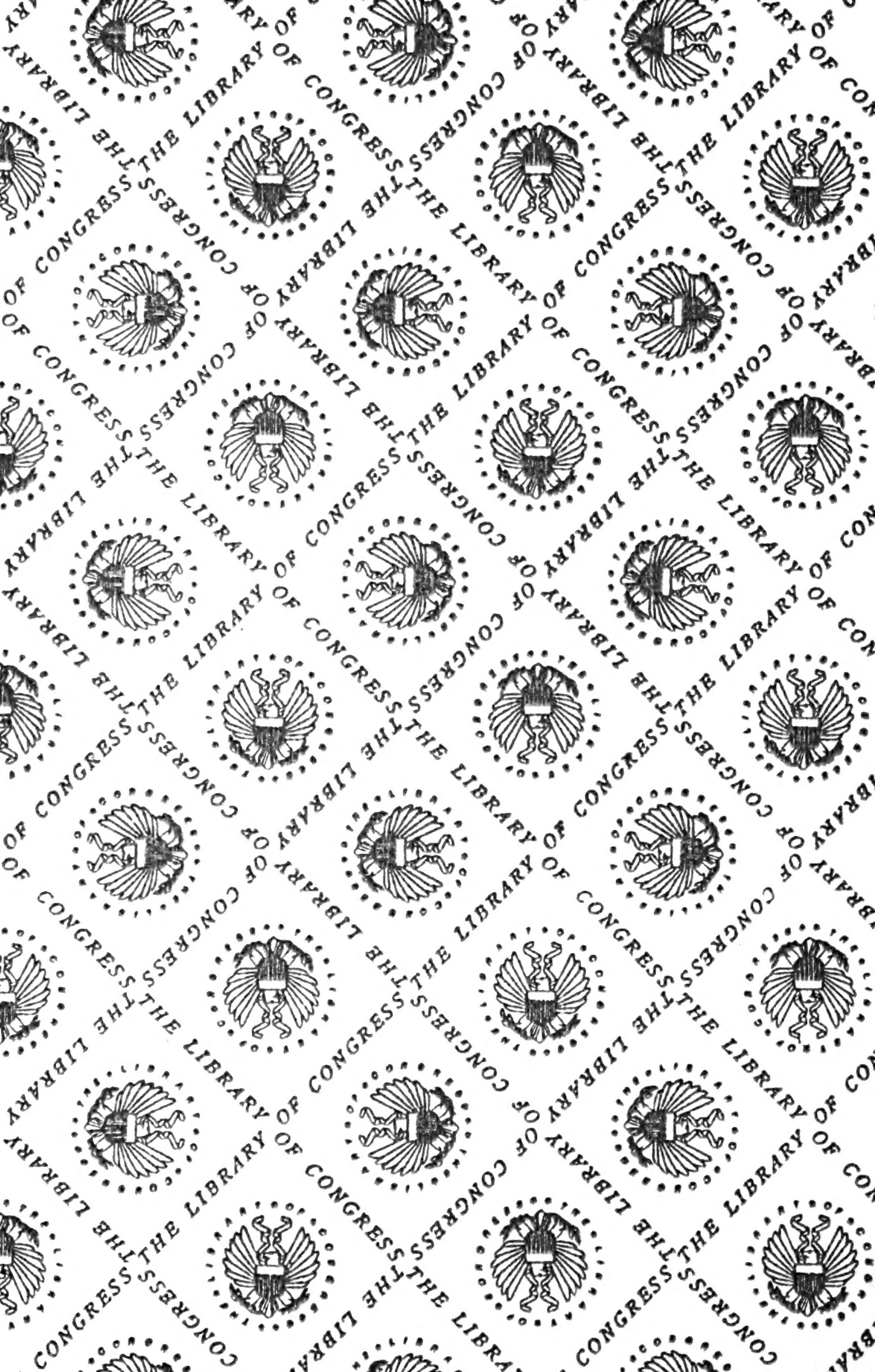.

AN INTRODUCTION

TO

BACTERIOLOGY

FOR NURSES

BY

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SECOND REVISED EDITION

PREFACE

TO THE SECOND EDITION.

In the preparation of this second edition it has been the intention of the author to bring the subject matter abreast of the many advances made in the last few years, but not to change the arrangement of the book. In order to do this many of the chapters have been rewritten. In the chapter on IMMUNITY the principles of complement fixation have been added in as simple a way as it is possible to do with a complex and rather confusing subject.

HARRY W. CAREY, A.B., M.D.

TROY, N. Y.

PREFACE

TO THE FIRST EDITION.

MANY of the duties of the nurse require a knowledge of the principles of bacteriology in order to be performed intelligently. It is difficult, however, for anyone instructing nurses, to decide just how much of the subject to attempt to teach.

The basis of this book is the lecture notes that I have used during the last eight years in teaching the nurses of the Samaritan Hospital Training School. In incorporating them into book form I have endeavored to present clearly and in simple language that portion of the subject essential for the nurse to know. A few blank pages have been inserted at the end of each chapter for the convenience of the student in adding useful notes from time to time.

HARRY W. CAREY, A.B., M.D.

TROY, N. Y.

(iv)

CONTENTS.

ILLUSTRATIONS.

CHAPTER I.

THE HISTORY OF BACTERIOLOGY.

THE history of this science is interesting because it tells how the study of bacteria developed from mere theories into a science based upon facts. Long before anything was known of the existence of germs, references could be found in the writings of the ancient Greeks discussing the possibility of disease passing from one person to another. The agent of infection was supposed to originate from the air or moisture.

With the instruments of ancient times it was impossible to see the minute living particles which we now know as germs; in fact, it is doubtful that such minute forms were thought of. The seventeenth century, however, marked a new era in the making of optical instruments. Anthony von Leeuwenhoeck in 1675, a linen draper of Amsterdam in Holland, succeeded in perfecting a lens of much greater magnifying power than those hitherto in use. By means of this lens he was able to see minute living animalcules in saliva, water, and other fluids, that were smaller than any seen before. The descriptions of the animalcules he saw were very accurate and correspond to some of the forms we recognize today.

The discovery of germs

The discovery of these minute living organisms provoked a great deal of discussion, as may be imagined. Perhaps the question most debated was

The theory of spontaneous generation

their source and mode of origin. Among the lowest forms of animal life known at that time were the maggots found in putrefying meat. It was supposed that they developed from the meat during the process of putrefaction. The animalcules of von Leeuwenhoeck too were believed to originate spontaneously. This theory of spontaneous generation held sway and, although there were many opposed to this doctrine, it was not until nearly a hundred years later that Spallanzani (1769), an Italian, tried by experiment to show that micro-organisms could not develop in this way. He took animal matter and mixed it with water in a flask. After boiling the mixture and sealing the neck of the flask he found that it could be kept for a long time without putrefying and without any micro-organisms developing in it. This experiment was subjected to much criticism, however, because the air so essential for the development of life was excluded by sealing the flask. This objection was met by modifying the experiment, first by admitting air that had passed through strong sulphuric acid, and later by filtering the air through cotton used to plug the mouth of the flask. It remained for Pasteur (1860) to settle the question beyond dispute by showing that the entrance of dust into mixtures that had been boiled was sufficient to set up putrefaction on account of the germs carried in with it. So long as the air was filtered free of germs by cotton plugs, just so long the mixtures remained free from growth.

Experiments proving spontaneous generation incorrect

These experiments had a far-reaching influence upon the conception of bacteriology, as may be imagined, and proved beyond question that *germs originate only from germs.* Upon this fact rest all our ideas of preventing the spread of disease and the aseptic precautions used in surgery.

The association of micro-organisms with the production of disease, conceived long before the organisms were seen, received much attention after the observations of von Leeuwenhoeck. During the next hundred years all sorts and kinds of disease were one after another attributed to the growth of germs in the body. Von Plenciz (1762), a physician of Vienna, was perhaps the foremost advocate of these new ideas of the causation of disease. He believed not only that germs gave rise to some diseases, but that each disease had its own particular germ which, after entering the body, developed and multiplied. These theories of von Plenciz were subjected to much ridicule, to be sure; but they continued to gain adherents nevertheless, and have proven, as we know, to be correct. Some years later Henle (1840) collected and published all the work that had been done up to that time, and pointed out that the causal relationship of germs to disease could not be proven simply by finding germs in the diseased tissues of the body, but that they must also be grown and studied outside of the body. Experiments to prove the doctrines of Henle were lacking chiefly because

the instruments and methods for studying germs at that time were inadequate.

In the next thirty to forty years many new methods were introduced which marked a rapid progress in the study of germs; for example, the use of aniline dyes for coloring germs so that they could be seen better under the microscope, and solid and fluid culture media on which germs could be cultivated and different kinds separated and studied. The develop-
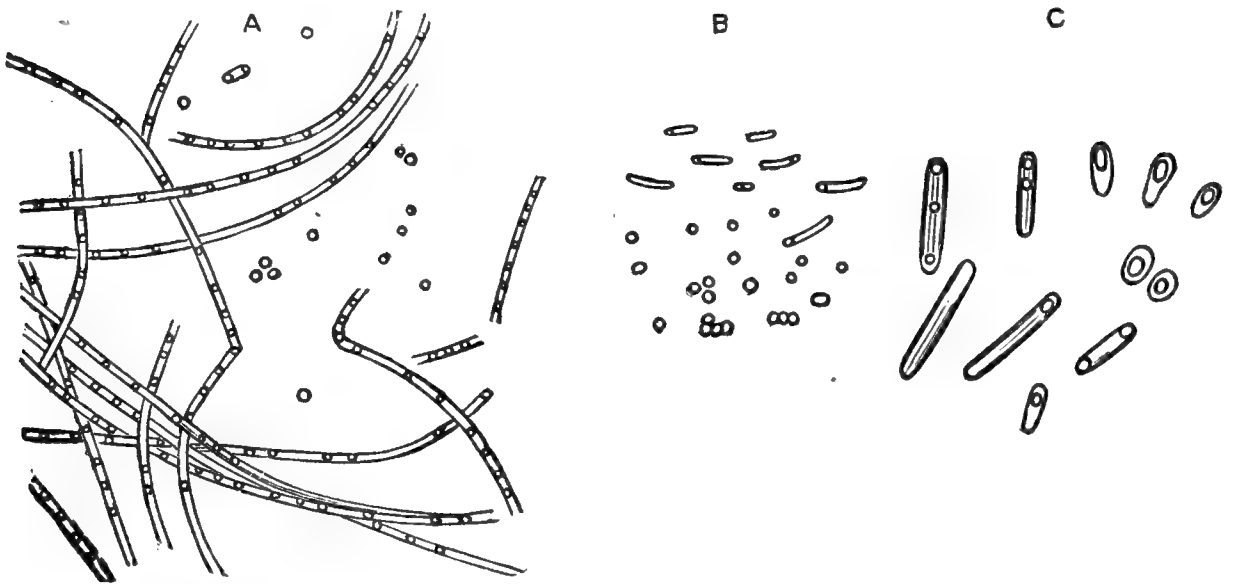
Fig. 1.—Anthrax bacilli. Spore formation and spore germination. *A,* from the spleen of a mouse after twenty-four hours' cultivation in aqueous humor. Spores arranged in rods like a string of pearls. ×650. *B,* germination of spores. ×650. *C,* the same, greatly magnified. ×1650. (*Koch.*)

ment of these new methods was due chiefly to the genius of Koch, who also laid down certain laws or conditions which had to be fulfilled before any germ could be said to be the cause of any specific disease.

The laws or postulates of Koch were:

1. The same organism should be constantly present in that particular pathological condition.

2. The bacteria should be isolated in pure culture from the infected tissue.

3. The same pathological condition should be reproduced by inoculating animals with the bacteria.

4. The same bacteria should be recovered from the inoculated animal.

With improved methods and appliances the relationship of germs to specific diseases could be proven experimentally, and the discovery of the germs of many diseases followed with great rapidity. Since 1879 the germs causing the following diseases have been discovered: Diphtheria, Leprosy, Typhoid Fever, Tuberculosis, Tetanus (Lockjaw), Influenza, Bubonic Plague, Cholera, Meningitis, Pneumonia, Syphilis, Gonorrhea, and others.

The study of the life history or biology of these germs has led to our present knowledge of the cause, the course, and ways of preventing most of the infectious diseases, and has put into the hands of physicians the means whereby the character of an infectious disease may be detected.

From this brief sketch it is easy to appreciate that bacteriology is, comparatively speaking, a new science, and that its greatest progress has occurred in our time. It is advancing now even more rapidly than ever before along lines destined to be of the greatest service to humanity. Efforts are being directed particularly to the discovery of antitoxins and serums that will protect against the infectious diseases.

CHAPTER II.

THE CLASSIFICATION, MORPHOLOGY, BIOLOGY, AND DISTRIBUTION OF BACTERIA.

WE have referred to micro-organisms as germs, a popular term, but not exact enough for our use. The term "germs" may be taken to mean any microscopic organism, animal or vegetable.

In the animal kingdom the lowest forms of life are called Protozoa (sing. Protozoön), of which there are several types: Sarcodina, Mastigophora, and Sporozoa. The discussion of the protozoa will be reserved until a later chapter.

Classification of bacteria

In the vegetable kingdom we are particularly interested in the fungi, which are subdivided into Hyphomycetes or molds, Blastomycetes or yeasts, and Schizomycetes or bacteria. The bacteria are by far the most important of the three; so we will confine ourselves solely to them for the present, and leave the yeasts and molds for a subsequent chapter.

Definition of bacterium

The word bacterium is derived from a Greek word meaning a rod; the plural form is bacteria. A bacterium may be defined as a minute living organism composed of one cell, belonging to the vegetable kingdom.

Structure

The structure of bacteria is difficult to make out but they appear to be but masses of protoplasm. The central portion is more dense and stains more deeply with aniline dyes, like the nuclei of animal cells so that some believe that bacteria have nuclei. The extreme outer margin may be very dense, too, and in some varieties it constitutes a capsule.

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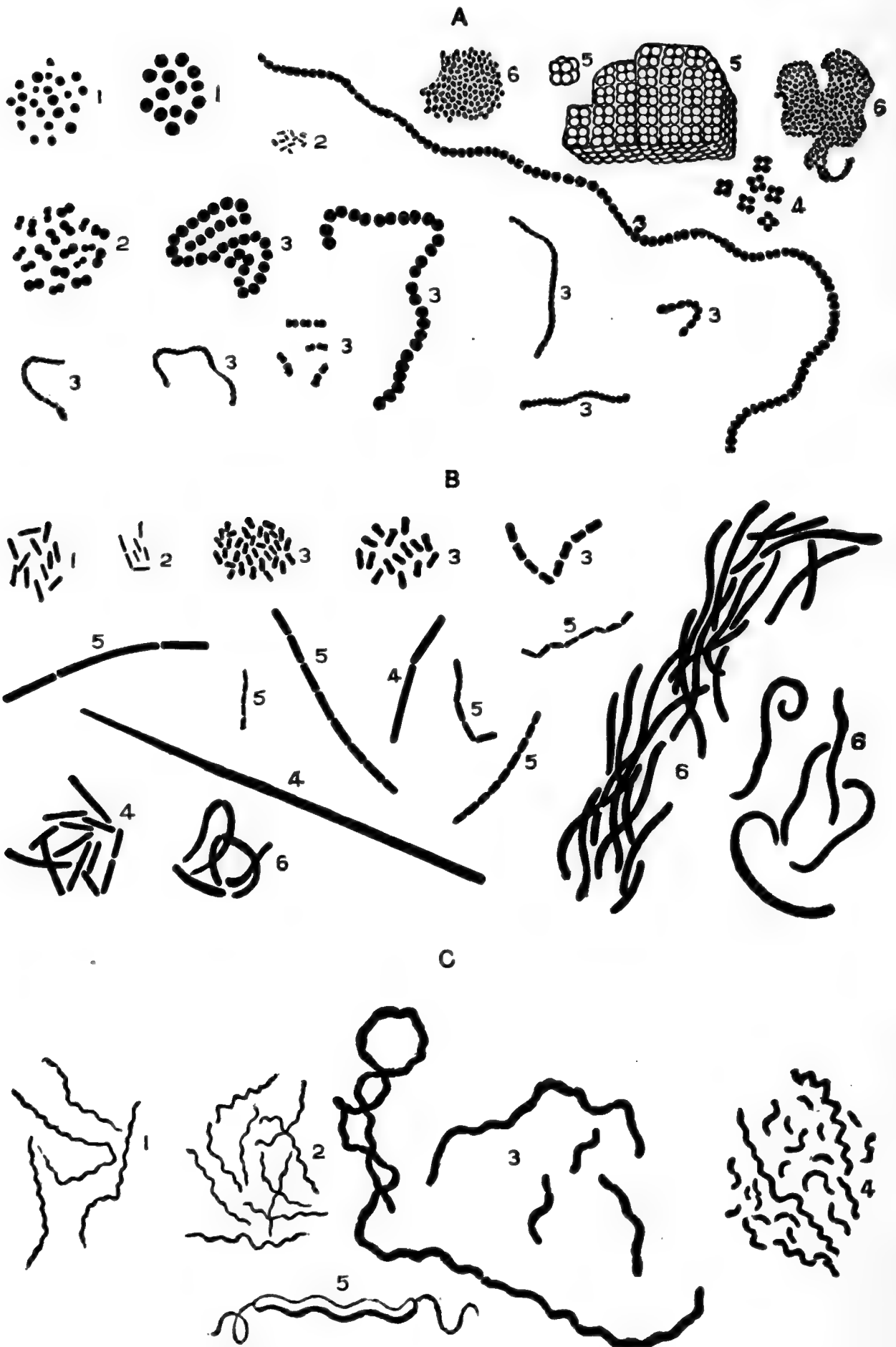
Fig. 2.—Different forms of bacteria. *A*, cocci; *B*, bacilli; *C*, spirilla. (*Baumgarten.*)

(7)

The morphological characters of bacteria—that is, their size and shape—vary greatly, and upon this basis it is convenient to subdivide them into three types:—

A. Coccus; pleural form, Cocci.

B. Bacillus; plural form, Bacilli.

C. Spirillum; plural form, Spirilla.

The cocci are shaped like berries, that is, about spherical. They may be flattened on one side or concave, or split like a coffee-bean. They may be arranged in pairs called diplococci; in fours, tetracocci; or in cubes, sarcinæ. They are commonly arranged in long strings or chains termed streptococci, or in masses often likened to bunches of grapes, staphylococci. The bacilli are rod-shaped, sometimes slightly curved, and vary greatly in length, from $1/_{1000}$ to $1/_{25000}$ of an inch. They occasionally form in chains or rows. The spirilla are spiral or corkscrew-shaped, as the name implies. They vary both in length and in the number of spirals. Of these three types the bacilli are by far the most numerous and the spirilla the least numerous. The types are not interchangeable; so it is not possible for a coccus to become a bacillus or a bacillus a spirillum.

In order to see them it is necessary to use a microscope of high magnifying power; indeed, it is highly probable that some forms of bacteria are so small that they cannot be seen with any of the microscopes that we have.

Bacteria reproduce by what is known as binary fission; that means a pinching off or splitting in the middle, each part developing into another organism. Reproduction occurs only under conditions favorable for bacterial growth. The rate of division or multiplication is very fast, sometimes every fifteen minutes. Starting with one organism one can imagine what an enormous number may develop in twenty-four hours at this rate.

Under conditions unfavorable to the life and growth, some kinds of bacteria may assume another form to avoid extermination. This is called spore formation. These spores are round or oval bodies, much smaller than the organisms from which they originate, and differ from them in having a thick protective capsule that enables them to withstand heat, sunlight, and, in fact, any harmful influence. The spores may be formed inside the body of the organism and extruded from it, or the whole organism may be changed into a spore. As a rule, one forms in each organism, either in the center or at one end, but in some kinds of bacteria a spore may form at each end. When conditions again become favorable for growth the spore may elongate and gradually assume its original shape, or the bacillus may form inside the body of the spore and burst the capsule. Spore formation

The power of locomotion is observed in some bacteria. When watched under the microscope they may be seen moving across the field of vision. The motility depends upon small, thread-like processes pro- Motility

jecting from the bodies of the bacteria, called flagella (singular form, flagellum), which by moving to and fro with a whip-like motion propel the bodies forward. The flagella may be single or multiple, and may be placed at one or both ends or all around the bacterium. The motility of spirilla is somewhat different. The amount of protoplasm about the nucleus is much more abundant than in the bacilli, and this by an undulating, wave-like motion drives the organism forward. The phenomenon of locomotion is limited to bacilli and spirilla; the cocci do not move. (See Fig. 7, page 61.)

Proper-ties of bacteria The property of producing pigment or coloring matter is peculiar to some kinds of bacteria. The pigment may be entirely within the body of the organism or it may be set free from it and color the material upon which the bacteria are growing. Bacteria exhibit variations in the way they stain with aniline dyes. Some will resist the action of dyes unless they are applied hot and then they will not give up the stain if exposed to the action of decolorizing solutions; the tubercle bacillus is a notable example. Solutions containing iodine (Gram's solution) also fixes the stain in some bacteria. These are spoken of as being Gram positive. Other properties of bacteria that may be mentioned are the fermentation of sugars into alcohol, the production of characteristic odors, the formation of acids and alkalies, and the production of light. The property of producing poisons is perhaps the most important of all, and will be spoken of in detail in the chapter on immunity.

From what has been said of the properties of bacteria it is possible to make a number of classifications; for example, there are the spore-forming and non-spore-forming bacteria, the motile and non-motile, fermenting and non-fermenting, acid forming and alkali forming, etc. By observing these properties of bacteria it is possible to identify them.

Like all plants bacteria require food, which must Nutriment be in very simple form to enable them to assimilate it. Oxygen, carbon, nitrogen, hydrogen, and chemical salts form their chief food. They derive the oxygen from the air, although some varieties of bacteria take it from substances in which the oxygen is combined with other chemical elements. The bacteria that take their oxygen from the air are called aërobic bacteria, while those taking it from substances containing it in combined form are called anaërobic bacteria. The line of demarcation between the aërobic and the anaërobic bacteria is not fixed, as sometimes bacteria thriving best under aërobic conditions will, nevertheless, grow in the absence of free oxygen and *vice versâ*. These are spoken of as facultative anaërobes or aërobes, as the case may be. The carbon is obtained from proteids, carbohydrates (starchy substances), or fats. The hydrogen is derived for the most part from water. The nitrogen is obtained from proteids such as albumin. The salts required for nutrition are sodium, potassium, and magnesium.

Certain conditions of environment exert a great deal of influence upon the life and growth of bacteria.

The influence of temperature is most important. Most bacteria thrive best at 37.5° C., and as the temperature varies above or below this point growth is retarded. A temperature of 62° C. will kill most bacteria. Low temperatures are not so destructive, for by experiments it has been proven that a temperature of 200° below zero (centigrade) will not kill all bacteria.

Moisture is essential for the growth of bacteria, as the food material upon which bacteria thrive must be in solution. The reaction of the food material is of considerable moment, for the bacteria will not grow if too much acid or alkali is present. A neutral or slightly acid reaction gives the best growth.

In order to cultivate bacteria, substances may be made artificially, called culture media, and may be solid or fluid. The common kinds of solid media are agar-agar, agar-agar with some kind of sugar added, gelatin, and coagulated blood serum. Solid media are employed when it is desired to observe either the surface growth or the growth in the depth of the medium. Fluid media are used for the determination of motility, acid formation, fermentation, and coagulation. Those most often used are litmus milk, bouillon, and peptone broth. The media are prepared in the laboratory. After the ingredients have been dissolved by boiling, the whole is filtered, run into test-tubes, plugged with cotton, and finally sterilized by steam under 15 pounds pressure for 20 minutes on 3 successive days in order that no bacteria may develop in it except those introduced for the purpose of study.

The distribution of bacteria in nature is practically universal. They are found in the soil, in the air, in the food we eat, and in the water we drink. In fact, wherever plants and animals live, bacteria are found. Their distribution, however, is not equal. The soil is the chief home of bacteria on account of the large amount of animal matter in it. They are present in greatest number at the surface and diminish in the deeper layers. The reason for this is that the closely packed particles of the soil will not permit the bacteria to penetrate beyond the superficial layers. Surface water which contains bacteria in great number is rendered practically free from them by this filtering action of the soil.

In the air the number of bacteria is directly proportional to the amount of dust. When the wind blows the dust into the air, large numbers of bacteria are carried with it; but when the air is quiet, the bacteria by force of gravity settle to the ground. It is a well-known fact that bacteria will not leave a moist surface; so in wet weather the number of bacteria in the air is considerably less than at other times. At high altitudes and far out at sea there are practically no bacteria in the air, as there is no dust. Many bacteria in the soil and air do not exist as a rule in their true form, but as spores which develop into bacteria when the conditions for growth become favorable.

Water as it leaves the clouds in the form of rain is free from bacteria, but as the rain-drops approach the earth particles of dust adhere to them. After the

Distribution

Soil

Air

Water

rain becomes mixed with the soil, the number of bacteria present is very large.

Foods become contaminated with bacteria in a variety of ways. Vegetables always have the soil bacteria on their surface. Meats if exposed to the air take up bacteria from the dust. The surfaces of fruits become contaminated with bacteria in the same way. In order to diminish the contamination of foods as much as possible, ordinances are in force in many cities that require meats, fruits, candies, etc., to be covered with glass when displayed for sale.

Func-
tion of
bacteria

With bacteria so widely distributed on the earth, the question arises as to their use or function in the world. We are accustomed to think of bacteria solely as the cause of disease, and offhand we would say that this was their chief function. This is not true by any means, for instead of being harmful to life they are very beneficial; in fact, life could not be maintained without them. The causation of disease is a function limited to a small group of micro-organisms, and is of lesser importance. The much more important use of bacteria relates to their ability to produce substances called ferments or enzymes, which have the property of reducing complex organic compounds into simpler compounds and chemical elements.

The plants which form the food of animals would soon be exhausted unless they could obtain proper nutriment to sustain life and reproduce their kind. They live mainly upon carbon and nitrogen in the form of nitrates, which would soon be consumed from the

soil unless the supply was continually replenished. Now, the source of carbon and nitrogen is the excretions and secretions of animals, which contain these elements in combination with other elements. By the action of bacteria the complex animal matter is decomposed into the chemical elements that compose it. In this way the plants derive their carbon and nitrogen from the soil. Within the body the bacteria carry on much the same activities. The digestion and absorption in the intestine is dependent to a large extent on the breaking-down action of bacteria. We cannot absorb meat and vegetable as such, and it is only after our food has been separated into simple compounds and elements that it is absorbed to nourish the body. In this process the bacteria play no small part. But bacteria are not only agents capable of breaking down complex substances; they also build up substances from chemical elements. Some plants take their nitrogen from the air, but they would not be able to do so were it not for the presence of certain bacteria growing in the roots.

The maintenance of life in the world is often described as a cycle; first, the chemical elements are built up into plants, the plants nourish the animals, then the animal tissue is consumed and excreted to be broken down into elements. In each step the bacteria play a most important part.

These activities of bacteria and their enzymes are made use of commercially; the fermenting action on sugars converting them into alcohol is used in making

Commercial use of bacteria

beer and wine, the clotting of milk by bacteria in making cheese, the fermenting of cabbage in making sauerkraut.

Pto-maines It may be well to mention here certain substances that are formed principally in the decomposition of meat and fish by bacteria. They are called ptomaines, and are present in partially decomposed animal and vegetable matter. Some of them are highly poisonous. The most common poisonous ptomaines are those found in partially decomposed meat, fish, and ice-cream.

CHAPTER III.

THE DESTRUCTION OF BACTERIA, STERILIZATION AND DISINFECTION.

THE knowledge of the means by which bacteria are destroyed underlies the methods employed in disinfection, sterilization, and antisepsis as they are used in preventing the spread of infection. The term disinfection means the total destruction of bacteria by any agent, while sterilization is limited to the destruction of bacteria by heat. An antiseptic is a chemical agent that prevents the growth and multiplication of bacteria, but does not necessarily destroy them. A deodorant is a substance that masks offensive odors or substitutes an agreeable odor for a disagreeable one. Some of the disinfectants and antiseptics are also deodorants, but few of the deodorants have disinfectant properties.

Definition of disinfection

Sterilization and antisepsis

The agents that affect bacteria injuriously may be physical or chemical. Among the physical agents may be mentioned drying, light, and heat.

Physical agents

Drying prevents the growth of bacteria and will eventually destroy them. The spores of bacteria, however, will resist drying for a much longer time. It is for this reason that the bacterial content of dust is chiefly in the form of spores. The effect of drying is influenced by the temperature at which the drying

Drying

takes place, being much more injurious at high than at low temperature.

Sunlight Sunlight is a very powerful and effective agent for destroying bacteria. By experiment it has been proven that the tubercle bacillus, the cause of consumption, is killed by sunlight in two hours or less, depending upon the thickness of the material surrounding it. The effect of electric light and the X-ray is very much less powerful than sunlight, and to be effective must be concentrated and allowed to act for a greater length of time.

Heat Heat is the most powerful of all the physical agents. Its destructive action is dependent upon the degree of temperature and the length of time it is applied; the higher the temperature, the less the time required. It may be employed either as dry or moist heat. Dry heat is used in the sterilization of glassware, such as flasks, test-tubes, swabs, and pipettes. The temperature should reach 140° to 150° C., and must be allowed to act for one hour in order to effect sterilization. The instrument used for this purpose is called a dry-heat sterilizer, and consists of a double-walled box made of sheet iron and asbestos. An opening in the top admits a thermometer by which the temperature of the inner chamber may be measured. The flame, usually a triple Bunsen burner, generates the heat underneath, which circulates between the walls of the box, keeping the temperature even on all sides.

For sterilizing all sorts of surgical instruments, except those with cutting edge, moist heat is used. It

is more effective than dry heat, because it has greater penetration. Boiling for thirty minutes will destroy all forms of pathogenic bacteria and their spores. The destructive action is intensified and the danger of rusting avoided if sodium carbonate is added to
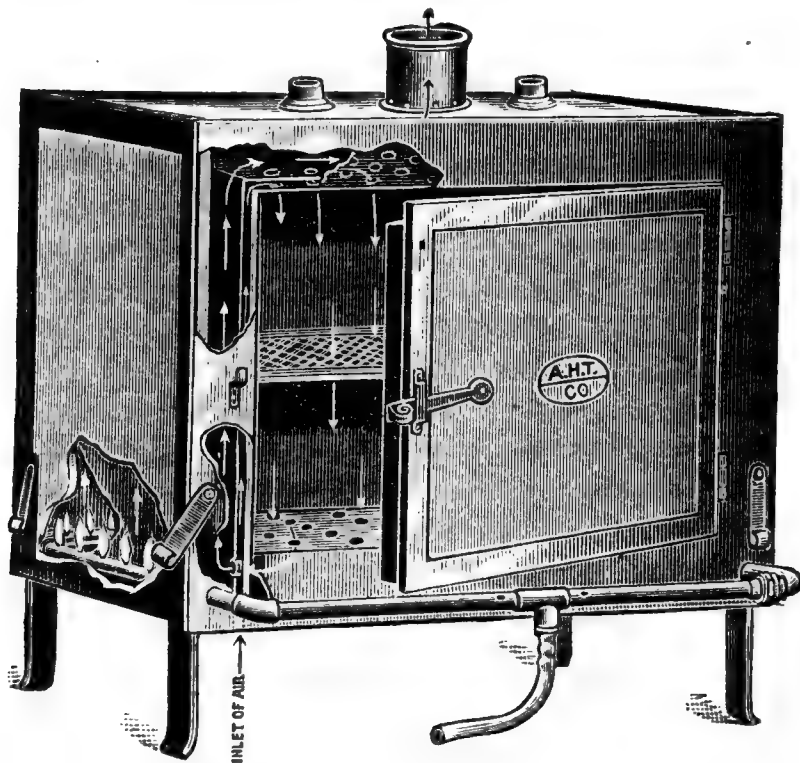
Fig. 3.—Dry heat sterilizer.

the water in amount sufficient to make a 1 per cent. solution.

Live steam is employed for sterilizing dressings. The instrument most often used is the Arnold steril-izer, which consists of two metal chambers, one within the other, beneath which is a pan containing the water to be heated. A flame underneath boils the water and generates the steam, which rises to the upper chamber and penetrates the contents. The exposure of dress-

ings in this way to live steam will kill pathogenic bacteria in thirty minutes but not their spores.

Certain kinds of culture media, particularly those containing sugars are sterilized by the Arnold method. In order to destroy the spores the media is exposed to the steam for thirty minutes on three successive days. After each exposure the media is exposed to room temperature to permit the spores to develop into bacteria. At the end of the third exposure it is presumed that all spores have developed into bacteria and all bacteria destroyed by the steam. Live steam is also used for killing bacteria in milk, and will be considered under the subject of pasteurization.

The most effective method of sterilizing by heat is the use of steam under pressure. The action of the steam is intensified and its penetrating power increased by the pressure. The instrument used is called an autoclave. It consists of a double-walled cylinder or globe made of metal, with a steam gauge and vent at the top. The materials to be sterilized are placed in the inner chamber, the door closed, and the steam allowed to enter the outer jacket. The vent at the top is left open until all of the air has been forced out of the inner chamber. The vent is now closed and steam is allowed to enter the inner chamber until the gauge registers a pressure of 15 pounds, or one atmosphere, and allowed to remain so for twenty to thirty minutes. This exposure will kill all bacteria and spores. If any fluid contained in flasks or test-tubes is being sterilized, care must be taken that the steam
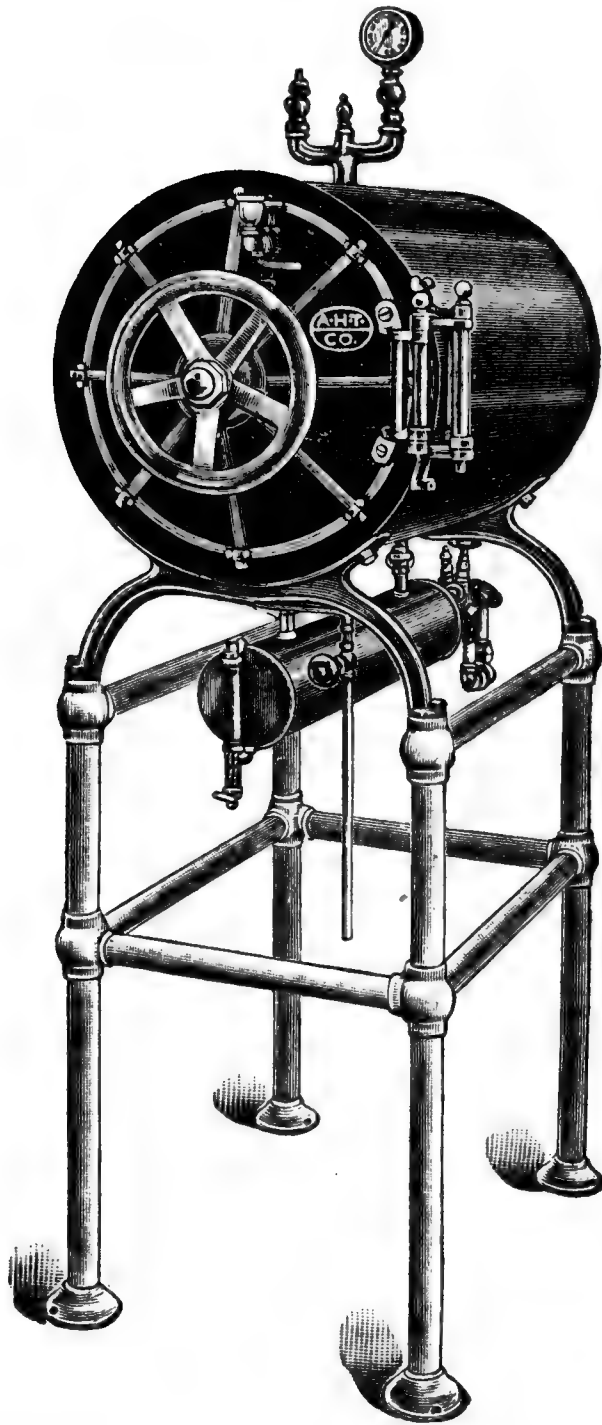
Fig. 4.—Autoclave.

be allowed to escape gradually at the end of the exposure, otherwise the suction will draw the plugs from them. Much larger sterilizers which embody the same principles as the one just described are used by

hospitals, quarantine stations, and departments of health in cities for disinfecting wearing apparel, bed-clothing and bedding.

Chemical agents

The number of chemical agents having destructive action on bacteria is very large. It will suffice to mention a few of the common ones, and describe the way they may be applied best. Chemical disinfectants may be used dry, in solution, or in the form of gas. As examples of dry disinfectants, boric acid, bismuth, and iodoform may be mentioned. All are used in concentrated form as they are obtained commercially. Boric acid and bismuth are weakly bactericidal, and have an antiseptic rather than a disinfectant action. Iodoform when iodine is set free is disinfectant. Their chief use is on infected wounds.

Dry dis-infection

Some of the most used disinfectant solutions are as follows:—

Formalin	10-20%.
Bichloride of mercury	1 : 500-1 : 1000.
Carbolic acid	5%.
Chlorinated lime	5%.
Dakin's solution	1-4%.
Hydrogen peroxide	20%.
Alcohol	70%.

Not all of these solutions are equally efficacious for disinfecting and each one has its advantages and disadvantages.

Formalin is an excecllent disinfectant, and, in addition, is also a good deodorant. It does not injure fabrics, is not poisonous, and does not coagulate albu-

min. It is liable to rust iron and steel. It is suitable for the disinfection of urine, sputum, feces, and albuminous discharges. It is not a good skin disinfectant because it hardens the skin and in some cases will cause a dermatitis.

Bichloride of mercury is of limited usefulness because it is a corrosive poison, corrodes all metals, and coagulates albumin. This last action renders it of little use for the disinfection of sputum, feces, or pus. On the other hand, it is excellent for disinfecting floors, walls, and furniture; that is, surface disinfection. In the strength of 1 : 1000 it kills bacteria in a half an hour, but for spores a 1 : 500 solution must be used. It is widely used for skin disinfection; for this purpose a 1 : 1000 solution is sufficiently strong. On account of the poisonous property of bichloride solutions it is safer to add coloring material to prevent any possibility of their being drunk by mistake.

Carbolic acid is suitable for the disinfection of intestinal discharges, sputum, urine, floors, furniture, soiled linen, and clothing. It will coagulate albumin, but its action is not interfered with to so great an extent as is the case with bichloride of mercury. Cresols, chemical substances closely related to carbolic acid, are more powerful and not so poisonous. They may be used in 5 per cent. solution.

Chlorinated lime is a deodorant as well as a disinfectant, both properties being dependent upon the liberation of chlorine gas in the presence of moisture. It is most widely known and used for the disinfec-

tion of intestinal discharges of typhoid fever patients. It undergoes decomposition readily; so care must be taken that it be fresh if good results are expected. For disinfecting stools the amount of lime solution should be much in excess of the amount of the stool, and it should be allowed to act for several hours. It can also be used for disinfecting floors and woodwork, but should not be used on colored fabrics, as it is a powerful bleacher.

Dakin's solution is a neutral solution of sodium hypochlorite. It is used in strengths varying from 1 to 4 per cent. During the war it was used a great deal for the disinfection of wounds either in the form of wet dressings or by irrigation. The solution decomposes readily, so care must be used that the solution is fresh and kept in well stoppered bottles. Chloramine-T is a more stable form of hypochlorite solution and is generally used in 2 per cent. strength in the treatment of wounds. Dichloramine-T is another chlorine disinfectant but is insoluble in water. It is dissolved in oil or paraffin and is sprayed on wounds or gauze covering wounds in from 6 to 10 per cent. strength.

Hydrogen peroxide decomposes readily, giving off free oxygen upon which its disinfectant action depends. It is used to a large extent for destroying the pus bacteria of superficial wounds, and is an excellent mouth disinfectant.

Alcohol, either absolute or in 95 per cent. strength, is weakly disinfectant. The addition of water seems

to add to its disinfecting action. Solutions of 50 to 70 per cent. are the best. The use of alcohol is limited. Perhaps its greatest usefulness is in destroying bacteria in the skin, although even for this it is rarely depended upon alone.

Of the disinfectant gases only the two most often used need be mentioned: Sulphur-dioxide gas is made by burning roll sulphur in the presence of water vapor. The vapor is essential because the disinfectant action depends upon the formation of sulphurous acid, which is made by the combination of the water vapor with the fumes of sulphur. It requires about 8 pounds of sulphur for every 3000 cubic feet of air space, and it should be allowed to act for at least twenty-four hours. It is a surface disinfectant having very little penetrating power, and is not as reliable as it was once thought to be. It is liable to corrode fabrics and destroy colors. It tarnishes metals and leaves a disagreeable odor for some time after it is used.

Formaldehyde gas is made in a variety of ways. For use in hospitals and by boards of health an autoclave is used, which generates the gas under pressure. After the room has been sealed to prevent the gas from escaping, the gas from the autoclave is forced into the room through the keyhole of the door. A much simpler way that is practical for home disinfection is the burning of paraform candles in the presence of moisture. The disinfectant action is strongest when the temperature of the room is between 90° and 100° F. The gas is a surface disinfectant; conse-

quently, articles to be disinfected should be hung up or so arranged as to allow the free circulation of the gas about them. It is the most efficient disinfectant known when properly used, and is also a deodorant. It has no harmful action on clothing or other household goods. The vapor is very irritating to the eyes and upper air-passages. Although the gas is very destructive to bacteria and their spores, it will not kill vermin.

Disin-
fection of
excre-
tions

In disinfecting during or after illness of contagious or infectious nature, it is necessary to render all discharges, excreta, and so on, non-infectious and, at the conclusion of the illness, to render the apartment in which the patient has been sick safe for others to occupy. In practical disinfection the choice of the disinfectant should be governed by the source and character of the material to be disinfected, and by the expense, the ease, and the thoroughness with which the disinfectant may be applied.

Sputum

Sputum always contains a large proportion of mucus, in which the bacteria are imbedded. In order to destroy these bacteria, chemical agents of considerable penetrating power are required, and should be allowed to act for considerable periods of time. The two that best meet these requirements are formalin, 10 per cent. solution, and carbolic acid in 5 per cent. strength. A much safer way is to collect all sputum in paper sputum-cups or paper napkins and then burn them. This way has been in use a long time for the disposal of tuberculous sputum, but it is

equally as practical for the mouth and nasal discharges of diphtheria, tonsillitis, pneumonia, and cerebrospinal meningitis.

Feces can be quickly and thoroughly destroyed by burning them or mixing them with boiling water. If chemical disinfectants are employed, formalin (10 per cent.) or carbolic acid (5 per cent.) may be used. The amount of either of these solutions should be twice that of the stool. Chlorinated lime, so long used for stool disinfection, has no advantages over formalin or carbolic acid, and is not so easy to use. The urine may be disinfected in the same manner as the stools. *Feces*

Clothing, towels, napkins, and bedding should be soaked for one-half hour in a 5 per cent. solution of carbolic acid before leaving the sickroom to be laundered. Dishes, knives, forks, etc., should be immersed in 5 per cent. carbolic solution and then boiled. It seems hardly necessary to say that one set of dishes should be kept in the sickroom for the exclusive use of the patient, and cleaned there. *Clothing*

Apartments occupied by persons sick with contagious or infectious disease should not be occupied again until the room and its contents have been thoroughly disinfected. In order to simplify this procedure a little forethought on the part of the nurse, in removing from the sickroom all articles not to be used, will assist a great deal. Carpets, upholstered furniture, hangings, pictures, and bric-a-brac can easily be spared from the room. At the conclusion of the illness by far the most effective means of ren- *Apartments*

dering the room free from infection is a thorough
scrubbing of everything washable with soap and hot
water, a continued exposure of the room to fresh air
and sunlight, and the burning of everything that can-
not be washed or is of small value. The effect of the
scrubbing is increased if followed by a solution of car-
bolic acid or bichloride solution. If arrangements
cannot be made to have the mattress sterilized by
steam under pressure it is safer to burn it.

If the disinfection of the apartments by gas,
either formaldehyde or sulphur, is to be employed, it
should follow the cleansing of the room after the
manner described above. The room must first of all
be sealed to prevent the gas from escaping. This can
be done by plugging with cotton all crevices about the
windows and doors, and pasting paper over radiators
and ventilators.

Not much dependence should be placed on gas
disinfection alone. It should be clearly understood
that a thorough application of soap and water and free
exposure to fresh air and sunlight are much to be
preferred to the simple introduction of formalin gas
or any other disinfectant without due regard to the
proper disposition of the room contents, temperature,
time of exposure, and the quantity of the disinfectant
used. The careless use of gas disinfection and the
popular belief that filling a room with gas kills all con-
tagion have led to disastrous consequences, and are
responsible for the disrepute into which disinfection
has fallen in some quarters.

CHAPTER IV.

INFECTION, IMMUNITY AND IMMUNITY REACTIONS.

In the preceding chapters we have been dealing with the subject of bacteriology in the broadest sense. Attention has been directed to the function of bacteria in the life of the world; to their appearance, their manner of growth, and the means employed for their destruction. As physicians and nurses our interest centers about a very small part of the bacterial kingdom, the one having to do with the production of disease. Bacteria that produce disease are termed pathogenic, while those varieties that do not are called non-pathogenic. By far the larger number of pathogenic bacteria thrive only in the living tissues of animals. These are called parasites. Some kinds of bacteria thrive only on dead tissues or wounded surfaces and, by decomposing them, form poisons (ptomaines) which may be absorbed and give rise to symptoms such as fever, chills, and headache. These are termed saprophytes. When pathogenic bacteria gain access to the tissues and produce injury and symptoms, we say that infection has taken place.

Here it may be well to say a word as to the meaning of the terms "infectious" and "contagious." They have been used somewhat loosely and have led to a great deal of confusion. Any disease that is caused by the entrance into the body of a living micro-

(29)

organism is called infectious. As examples of infectious disease, diphtheria, pneumonia, influenza, tuberculosis, and syphilis may be mentioned; although there are many others. A contagious disease is one that is transmitted from one person to another by simply coming into the presence of or touching the sick. Smallpox, scarlet fever, measles, chickenpox, and German measles are usually classed as contagious diseases. All contagious diseases are infectious, but not all infectious diseases are contagious. Diseases like cholera, glanders, pneumonia, plague, tuberculosis, and syphilis cannot be transmitted through the air or by coming into the presence of the sick. Typhoid fever may be considered infectious through water and other infected foods, and contagious by contact with the so-called typhoid carriers.

The terms "infestation" or "infestion" are applied to diseases caused by entrance into the body of small parasites such as amebæ, worms, and so on.

Factors influencing infection

While the presence of pathogenic bacteria is necessary to cause infection, other factors of much importance must be taken into consideration. This must be so as everyday experience shows. In any epidemic of infectious disease only a portion of those exposed become infected. Even among those infected the disease presents all variations from the very mild to the most severe. The factors that influence the onset and course of infections relate both to the bacteria and the individuals exposed to them.

So far as the bacteria themselves are concerned,

infection depends in part on their power of producing disease, that is, their virulence. Conditions that are not suited to the growth of bacteria will diminish or destroy the virulence; the continued cultivation of bacteria outside the body on artificial culture media will do this. Bacteria that have lost the power of producing disease are spoken of as being attenuated. Another factor that modifies infection is the number of bacteria that invade the tissues. While the exact number of bacteria necessary to cause infection is not known, it may be said that the greater the virulence the fewer the bacteria required. The path by which bacteria enter the tissues frequently determines whether infection is caused or not. The bacilli of typhoid fever to cause infection must be swallowed, but if they are rubbed into the skin no infection results. On the other hand, the pus-forming bacteria like the staphylococci and streptococci may be swallowed without causing infection, but if they are rubbed into the skin a boil or an abscess is almost sure to result. So to cause infection bacteria must enter the body through channels best adapted to their growth and multiplication.

Concerning the individual exposed to infection it is known that everyone is endowed to a variable degree with defensive substances in the blood and tissues that tend to overcome and destroy invading bacteria. Unhealthy people, as everyone knows, are more likely to become infected and to succumb to infection than the healthy. This power of the human

On the part of bacteria

Virulence

Attenuation

Avenue of infection

On the part of the individual

organism to resist infection will be discussed more fully under the subject of immunity.

How does infection take place? It is the result of the invasion of the body tissues by pathogenic bacteria that live either on the surface of the body or from those that live on the mucous membranes inside the body. Injuries play an important part in causing infections. Injuries caused by firearms may be the entering point of tetanus bacilli, the cause of lockjaw, while rabies or hydrophobia is spread through the bites of mad dogs. Careless manipulations with soiled catheters, speculums, syringes, and so on may cause injury to the tissues and be the means of introducing bacteria. In the case of the contagious fevers like measles, chicken-pox, whooping-cough, and scarlet fever the infecting agent seems to be in the air and causes infection by being inhaled. Bedding, clothing, and utensils that have been contaminated with infectious material may be the means of spreading infection. Finally, the bites of insects and vermin may cause infection. It is known that certain kinds of mosquitoes transmit malarial fever and yellow fever; flies may spread typhoid fever by depositing the typhoid bacilli on food materials.

The body may be looked upon as the host for large numbers of bacteria. At birth, however, all healthy animals are free from bacteria; but almost immediately afterward they are deposited upon the surface of the body by the dust in the air, and are introduced into the body by food and by the air

Infection from bacteria outside the body

Infection from bacteria living inside the body

breathed. When these bacteria gain access to the body, only those survive that find the conditions favorable for their existence. For this reason it is found that each cavity or portion of the body harbors a group of bacteria peculiar to it. The varieties of bacteria found in the saliva, for example, are quite different from those found in the intestine. Most of these constant bacteria of the body are harmless, but some pathogenic forms occur which manifest their power to produce disease only when some injury affords a point of entrance to the tissues or the resistance of the individual is lowered. Thus in the skin there may be many kinds of bacteria, the most important of which are the pus-forming cocci, the staphylococci, and streptococci. They do no harm under normal conditions, but if there is any injury to the skin these organisms may enter and give rise to a boil, an abscess, or erysipelas. It is mainly against these pus-forming bacteria that the preparation of the patient before operation is directed. Unfortunately these bacteria live actually in the skin, that is, below the surface; so that skin disinfection must be very thorough to be effectual and, even under most favorable conditions, cannot be considered as absolute.

In the air-passages large numbers of bacteria are found which enter with the air breathed in. Most of them are caught on the moist surfaces of the mouth, throat, and nose; very few if any ever reach the lungs directly through the trachea and bronchi. In the mouth the pneumococci, staphylococci, and strepto-

cocci are frequently present, but do no harm unless the vitality is lowered. The stomach is generally free from bacteria, due to the acid in its secretions. If however there is any disturbance of digestion and the secretions are no longer acid, the bacteria swallowed in the food may cause fermentation and other disorders. The intestine harbors great numbers of bacteria, chiefly the colon bacillus and others closely allied to it. They are, in health, not only harmless, but of much benefit in breaking down the food into substances that can be absorbed for nutriment of the tissues. Under conditions of lowered resistance or when injury to the intestines has been done, they may cause infection.

After infection has taken place it may remain localized in the form of a boil or abscess, or it may spread so that the blood contains the infecting organism. When infections become generalized the condition is called septicemia, and when there is added to this scattered areas of pus formation throughout the body the condition is called pyemia. Toxemia is the condition caused by the poisons of bacteria, either in local or general infections.

How do bacteria produce injury to the tissues? In two ways: The multiplication of bacteria in the tissues may cause injury in a mechanical way by obstructing the very small blood-vessels, causing the necrosis or death of the tissue. The absorption of the necrotic material gives rise to the symptoms of infection. Much greater injury is produced by the absorp-

tion of the poisons or toxins made by the bacteria. These poisons may be extracellular or intracellular. The extracellular toxins are thrown out of the bodies of the bacteria into the tissues or media in which they are growing. The word toxin when used alone is taken to mean an extracellular toxin. The intracellular or endotoxins are retained within the bodies of the bacteria and are set free only after their death or dissolution. After absorption the bacterial toxins do not affect all organs or tissues equally, but exhibit a selective action, some attacking the red blood-corpuscles and dissolving them, others the tissues of the brain and nervous system.

Toxins, extra- and intra- cellular

One might think, from what has been said, that men and animals are wholly at the mercy of bacteria. Fortunately this is not so, as all are endowed with certain defensive powers that resist the injurious action of bacteria and their poisons. This resistance to disease is called immunity.

Immunity

Many of the diseases that are infectious in man cannot be transmitted to animals and, conversely, some of the infectious diseases of animals do not occur in man.

Natural immunity

Among the races of men variations in the resistance to disease is observed; for example, the negro seems to possess a much greater resistance to infection with yellow fever than the white man. In addition to the variations in resistance among the races of man there are also variations among individuals. The conditions under which people live have much to do

Racial immunity

with their resistance. Unsanitary homes and workshops, fatigue, exposure, poor nourishment, and injuries all tend to lower the resistance to disease. The excessive or continued use of alcohol is a very important factor in lowering resistance, as is shown by the frequency of infectious disease, particularly pneumonia and tuberculosis, among drinkers. Constitutional diseases like diabetes and nephritis also lower the resistance.

Acquired immunity

It is possible to acquire immunity. Following an attack of infectious disease there commonly results an immunity that protects the individual from a second attack. The resistance gained in this way is spoken of as acquired immunity and follows diseases such as measles, mumps, scarlet fever, and typhoid fever. The duration of acquired immunity varies; after scarlet fever it oftentimes lasts during life, while after typhoid fever it may last only a year or two. That immunity could be acquired in this way was known many years ago, and led to the conception of producing immunity artificially without actually causing the individual to pass through the dangers of disease. Although not the first to attempt to produce immunity artificially, the experiments of Jenner, who discovered the protective effects of vaccination, were the most successful. The events leading up to Jenner's discovery are interesting. In England, where smallpox had been a scourge for many years, it was observed that people who had been accidentally infected with cow-pox, a modified form of smallpox in cattle, were not attacked

by smallpox even though they were exposed to it. Jenner reasoned that if an accidental infection with cow-pox could prevent against smallpox it would be a rational procedure to purposely infect with cow-pox. So, acting on the advice of his patron, Dr. John Hunter, he inoculated a boy with pus from a cow-pox pustule in May, 1796, and two months later injected the pus from a smallpox pustule without producing any disease.

When immunity is acquired by introducing into the body the infectious agents in modified form or in small amount, it is spoken of as active immunity because the body tissues take an active part in forming the substances that give protection. Our knowledge of how immunity is produced in this way is due principally to Pasteur, who found that the bacteria producing cholera among fowls became much less virulent after being cultivated for long periods of time on artificial culture media or after cultivation at increased temperatures. By injecting gradually increasing amounts of these attenuated bacteria of chicken-cholera into fowls he was able to immunize them to the disease.

Active immunity

The introduction of dead bacteria or vaccines in increasing doses is often used to develop immunity against those bacteria whose poisons are intracellular. This method has been practised a great deal these last few years, and has been attended with considerable success in some infections. Its most successful appli-

Vaccines

cation has been in the preventive inoculation against typhoid fever in the army.

There is another type of immunity that can be conferred without the body tissues taking any active part in the process. For this reason it is called passive immunity. In 1890 von Behring discovered that the blood-serum of animals that had been immunized to the poisons of diphtheria and tetanus, if injected into other animals, would protect them also. Later Dr. Flexner, at the Rockefeller Institute in New York, made similar observations in connection with the poison of the meningococcus, the organism causing the epidemic form of cerebrospinal meningitis.

Perhaps a brief description of the way diphtheria antitoxin is made will make this type of immunity better understood. The animal used in the commercial preparation of diphtheria antitoxin is the horse. At the start the animal is inoculated with a very small dose of the diphtheria toxin obtained by growing the diphtheria bacillus on large flasks of bouillon. The bacilli are filtered out and the filtrate containing the soluble diphtheria toxin is used for injecting. The effect of the first injection is to make the horse sick, but not fatally so. At the end of a week a second injection is made with the same dose, but the animal is now able to stand the poison without ill effect. Each week the dose is increased until at the end of two or three months the animal is able to withstand enormous doses of the poison without ill effect, due to the protective substances formed in its body.

In other words, active immunity has been established in the horse. At the end of three or four months the animal is bled to the amount of five or six quarts, and the blood is set aside to clot. In the serum that separates from the clot are the same substances that protected the horse from the diphtheria poison. This is the diphtheria antitoxin. It is standardized by determining the smallest amount of antitoxin that will neutralize 100 times the fatal dose of toxin for a guinea-pig weighing 250 grams. This amount is called the antitoxin unit, and enables us to measure the dose of antitoxin.

What the nature of these substances is that enables us to resist infection is not known, and the way in which they act is built up on theory that is complicated and difficult to understand. It is sufficient for us to know that soon after infection occurs the body tissues and fluids begin to protect themselves against the invading bacteria and their poisons. The first defense is made by the white blood-corpuscles, or leucocytes, the scavenger cells of the blood. They are attracted in great number to the point of infection and destroy the invading bacteria by taking them into their cell bodies and digesting them. The fate of infections depends many times on the defense of the phagocytes; if they are sufficient for the needs of the occasion, the infection is checked and localized; if they are not, the infection extends and may become general.

Phago-cytosis

The body, however, does not rely entirely on the phagocytes for protection. Infection stimulates the

tissues to form substances, circulating in the blood-serum, which combine with and neutralize the poisons of bacteria. They are spoken of as antibodies and act in different ways; some, called bacteriolysins, dissolve the bacterial cells; others gather the bacteria into

clumps or clusters; these are called agglutinins; and finally substances may be formed that act on the bacteria in such a way as to make them more readily

digested by the phagocytes; these are called opsonins.

It is an interesting fact, and one of much importance, that the amount of these protective substances formed is, not only sufficient to render an infection harmless, but is greatly in excess of the needs of the moment. They remain stored away in the cells ready to be utilized when the same infective agent again attacks; this is the way that immunity is established.

It has long been known that the blood serum of normal individuals contained substances that destroy bacteria to a variable degree. In individuals made immune to disease this bactericidal power of the blood serum is greatly increased. It developed from experiments made by Bordet that this destructive effect of the blood serum could be reproduced in animals immunized to the red blood corpuscles of other animals. For example, if a rabbit be immunized gradually to the red blood cells of man, the rabbit's blood serum will dissolve or hemolyze the human red blood cells when mixed with them in the proper proportions. It is not, however, one single substance in the rabbit's serum that produces this effect but two substances, one

of which is always present in the blood serum, the other only after immunization has occurred. This latter substance will act only with the substance to which the serum is immune and for this reason is said to be specific. These three substances taking part in the solution or hemolysis of the red blood cells are designated, antigen, complement and amboceptor.

In the example given above the antigen is the human red blood cell, the complement is the substance always present in the blood serum and the amboceptor is the substance present in the blood serum of the rabbit after immunization.

The term antigen is applied to any substance which, when injected into a living animal, causes the formation of antibodies, viz., red blood cells, bacteria or bacterial poisons. The immune substance produced by the injection of the antigen is called the amboceptor. It differs from the complement that is present in all serum by the fact that it is not so sensitive to heat and so is said to be thermostabile.

In the experiment just described with the human red cells and the rabbit's serum immunized to them, it is possible to add just enough corpuscles to use up or fix all of the complement.

Similar experiments may be made with a number of antigens, such as the gonococcus, the treponema pallidum, the typhoid bacillus, the glanders bacillus and others. This principle of mixing antigen, complement and amboceptor in definite proportions so that the complement is fixed is the basis of complement fixation as

applied in the diagnosis of disease. Perhaps the one most used is the Wassermann test for syphilis. The object of the test is to determine whether a patient's blood serum contains the specific immune substance or amboceptor of syphilis.

The antigen may be an emulsion of treponema pallidum or an extract of syphilitic liver. The amboceptor or immune substance of syphilis may or may not be present in the patient's blood serum. For complement the blood serum of guinea-pigs is used. If these three substances, the antigen, the patient's serum and the complement are mixed in the proper proportions, the complement will be fixed if the patient has syphilis. If the patient is not infected with syphilis the complement is still free and unfixed.

To determine this, sheep's corpuscles and the serum of a rabbit immunized to sheep's corpuscles is added after the complement that is always present has been destroyed by heat. If the complement is used up then no hemolysis of the sheep's corpuscles will take place and the test is said to be positive, if it is not it will join with the rabbit serum amboceptor and dissolve the corpuscles and the test is negative.

Anaphylaxis The word anaphylaxis, literally translated from the Greek, means against protection, the exact opposite of prophylaxis, which means for protection. This name has been given to a condition of hypersensitiveness which has been found to exist in certain animals and man. For example, it has been shown that guinea-pigs may be made sensitive to harmless proteids like

egg-albumin or milk. The first injection causes no symptoms, but the second, even when the dose is smaller, may cause shortness of breath, spasms, and death. It requires from ten to fourteen days after the first injection for this hypersensitiveness to develop.

A similar hypersensitiveness has been observed in some human beings to the horse serum in diphtheria antitoxin, and the symptoms of serum sickness have been attributed to it (see Diphtheria, page 94). The reactions following the use of tuberculin and mallein are also believed to be due to anaphylaxis. This condition of hypersusceptibility is sometimes spoken of as Allergy.

CHAPTER V.

THE GROUP OF PYOGENIC COCCI.

In the following chapters the characteristics of the individual species of bacteria associated with the production of disease will be considered. Inasmuch as certain ones are closely related in their growth, morphology, and manner of producing infection, it is convenient to form them into groups; thus there is the group of pyogenic cocci (pus-forming cocci) and the intestinal group, which may also be subdivided into the typhoid and dysentery groups. On account of their wide distribution and the frequency with which they cause infection, the pyogenic group will be considered first.

Staphylo-
coccus
pyogenes

The coccus that most commonly causes infection is the staphylococcus, so named because of its characteristic arrangement into clusters often likened to bunches of grapes. (See Fig. 2, *A*, page 7.) Several varieties are distinguished by the pigment they produce when grown in cultures. The *Staphylococcus aureus* produces a golden-yellow pigment, the *S. citreus* a lemon-yellow pigment, while the *S. albus* grows without forming any color. The *Staphylococcus epidermidis albus* is a variety found in the under layers of the skin. The size of these coccus forms differ, some being larger than others. They do not form spores, all are without motility, and all are Gram positive.

(44)

The *aureus* is the most virulent of all staphylococci. The infections caused by the staphylococci vary with the virulence of the organism and the resistance of the individual infected. The infection may be local like a boil or an abscess, or it may extend to involve large areas of tissue (cellulitis).

General infections, septicemia, and pyemia are very often caused by these organisms. Malignant endocarditis and puerperal fever come under this head. They are usually the cause of infection in wounds, although there are other bacteria that may do this. It is to remove all bacteria, especially the pus-cocci coming in contact with the patient, that the precautions or technique of the operating-room is directed. Since the pus-cocci are so often found on the skin, careful washing and scrubbing of the hands followed by a disinfectant is employed to destroy them. It is important to remember that these precautions cannot be safely performed in a careless manner, as the pyogenic cocci may be located *in* rather than *on* the skin. They are to some degree resistant to disinfectants, and require an exposure of at least ten minutes in a 1 : 1000 solution of bichloride of mercury.

The injury caused in infections by the staphylococci is due almost wholly to the toxins in part set free and in part retained in their cell bodies and liberated in the dissolution after death. The toxins cause the formation of pus and also attack the red blood-cells, dissolving them (hemolysis). This explains the anemia that always accompanies these infections.

The streptococcus is one of the group of pus-forming cocci, characterized by multiplication in one plane, producing strings or chains of cocci. These cocci are Gram positive.

There are many varieties of streptococci which may be divided into two large groups depending on their faculty of dissolving red blood cells, viz. :—

1. The hemolytic streptococci.

2. The non-hemolytic streptococci.

Numerous individual numbers of these groups have been found which vary from one another in their shape, staining peculiarities, virulence, and agglutination reactions.

The characteristics of the hemolytic group include their high degree of virulence and tendency to produce epidemic infections. They are rarely present in the human body under normal conditions.

The non-hemolytic streptococci are widely distributed in the body but they are not so virulent or invasive. They rarely are the primary cause of infection. One member of the non-hemolytic group, the *Streptococcus viridans,* is peculiar in possessing the property of changing hemoglobin into methhemoglobin when grown on artificial culture-media; the colonies have a greenish zone about them.

Infections with the streptococcus include boils, abscesses, erysipelas, puerperal septicemia, septic sore throat, broncho-pneumonia, osteomyelitis, mastoiditis, meningitis, empyema, and endocarditis. Septic sore throat may occur in epidemics and has been traced in

a number of instances to milk infected by some person handling the milk. Acquired immunity following these infections, if it occurs at all, is of very short duration. In animals, however, it has been possible to produce an active immunity in horses and the serum of the animals so immunized can be used to produce passive immunity in human beings.

The results obtained from the use of antistreptococcus serum have been successful in some instances but its action is uncertain. The difficulty lies in the fact that there exists a great many strains of streptococci and unless the serum contains the protective substances for the particular strain causing the infection no successful result can be expected.

The *Micrococcus tetragenus* is a pus-forming organism of low-grade virulence. Its arrangement is peculiar, forming squares of four cocci. It is found frequently in the sputum and causes infection usually in combination with some other micro-organism.

<div style="text-align:right">Micro-coccus tetrage-nus</div>

The gonococcus is the organism causing gonorrhea. It is a diplococcus, always occurring in pairs with the surfaces facing one another flattened like two coffee-beans. It does not stain by Gram. In pus it is found almost always within the bodies of the leucocytes. It is very difficult to cultivate, as it does not grow on the ordinary culture media. By the diplococcus form, coffee-bean shape, situation within the leucocytes, and Gram negative stain, it is identified by direct microscopic examination of pus.

<div style="text-align:right">The gono-coccus</div>

Infection with the gonococcus, or gonorrhea, is

classed as a venereal disease because it is commonly
confined to the genital organs. It is an exceedingly
common disease, and is spread almost always by
sexual contact. In the male the infection starts, after
an incubation period of five to seven days, with a dis-
charge of pus from the urethra. The acute stage lasts
usually from 3 to 6 weeks, and then recedes either en-
tirely or leaves a catarrhal inflammation which may
last and be infectious for an indefinite period. In ap-
proximately half of the cases, however, the infection
extends back to involve the bladder, prostate gland, or
seminal vesicles. When this happens the gonococci be-
come buried in the tissues and frequently remain dor-
mant for years, only to light up again when conditions
favor it. Infection of these organs is most difficult to
eradicate, and a person so infected may be able to
transmit the disease to others over long periods of time.
It is a frequent cause of sterility in the male. In the
female the infection, during menstrual life, starts in
the cervix of the uterus, less often in the urethra. It
frequently involves Skene's ducts about the urethral
orifice and Bartholin's glands beneath the floor of the
vagina. The disease has the tendency to ascend dur-
ing the menstrual period to involve the mucous lining
of the uterus, thence to the Fallopian tubes and ovaries.
When this occurs it nearly always requires surgical in-
tervention. The disease is harder to combat in the
female than in the male, partly because the acute symp-
toms are not so marked, and so the nature of the in-
fection may escape detection, and partly because the

anatomy of the organs infected is such that it is next to impossible to treat the infection thoroughly. The period over which the disease may continue infectious in the female may be years, and if the tubes and ovaries are involved sterility usually ensues.
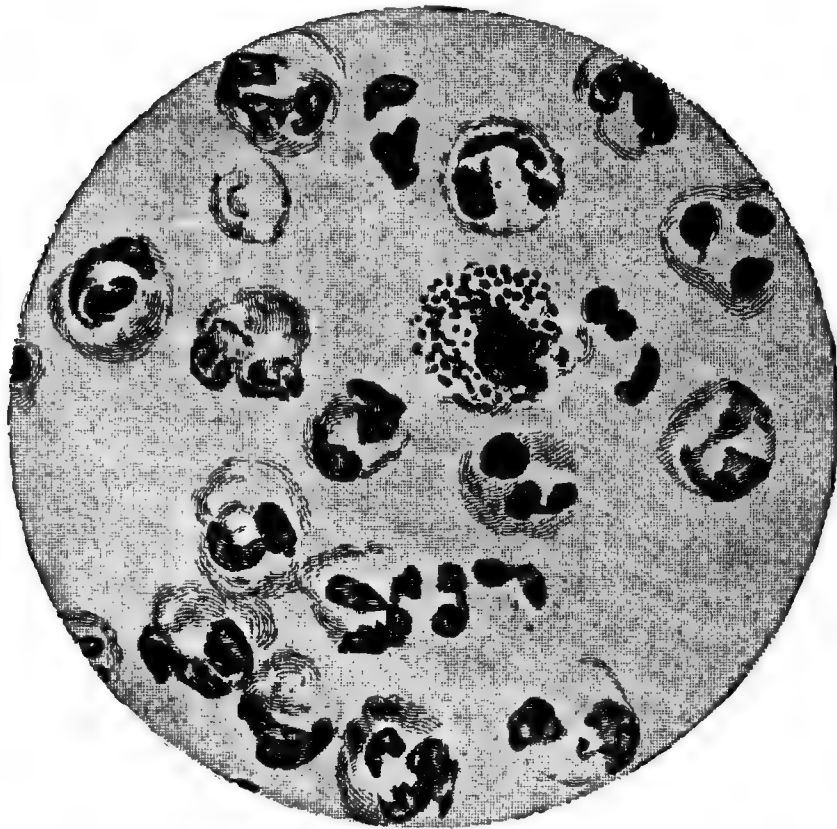

Fig. 5.—Gonorrheal pus, showing gonococci within a leucocyte.

Gonorrheal infection of the eyes is fairly common. It occurs in the newborn most often, and is called ophthalmia neonatorum. Ulcers on the cornea which interfere with vision in later life, or complete destruction of the eyeball, may result. It is the chief cause of blindness in children. The infection gets into the eyes during delivery, and as a prophylactic measure it is advisable to instil a drop or two of 1

Ophthalmia neonatorum

4

per cent. nitrate of silver into the eyes immediately after birth. In adults the infection is usually introduced by infected fingers, handkerchiefs, or towels.

Vaginitis   Among children in institutions gonorrheal infection of the vagina, vaginitis, occurs in epidemic form. It spreads from child to child with great rapidity, and is very difficult to check. The infection starts from one child so infected, and is spread by napkins, towels, or directly from one child to another.

While infections with the gonococcus are generally localized, they may in rare instances become general, causing arthritis, endocarditis, and meningitis. The toxin of the gonococcus is within the body of the organism, and is liberated only after death of the cell body. Dead cultures of gonococci, or vaccines, have been employed in the treatment of the infection, but have proven only partially successful in the complications such as arthritis, epididymitis, orchitis, and the vaginitis of children. Serum obtained from animals that have been immunized with living cultures of gonococci (active immunization) has also been only partly successful, probably because there seems to be a great many different strains or families of gonococci.

Pneumonia is an acute infectious disease caused by a variety of micro-organisms, the chief one being the *Diplococcus pneumoniæ,* or the pneumococcus. Other bacteria, such as the streptococcus, staphylococcus, the influenza bacillus, the Friedlander bacillus, and typhoid bacillus, may also cause pneumonia. The

pneumococcus is a small lance-shaped organism ar-
ranged in pairs. These diplococci may form chains
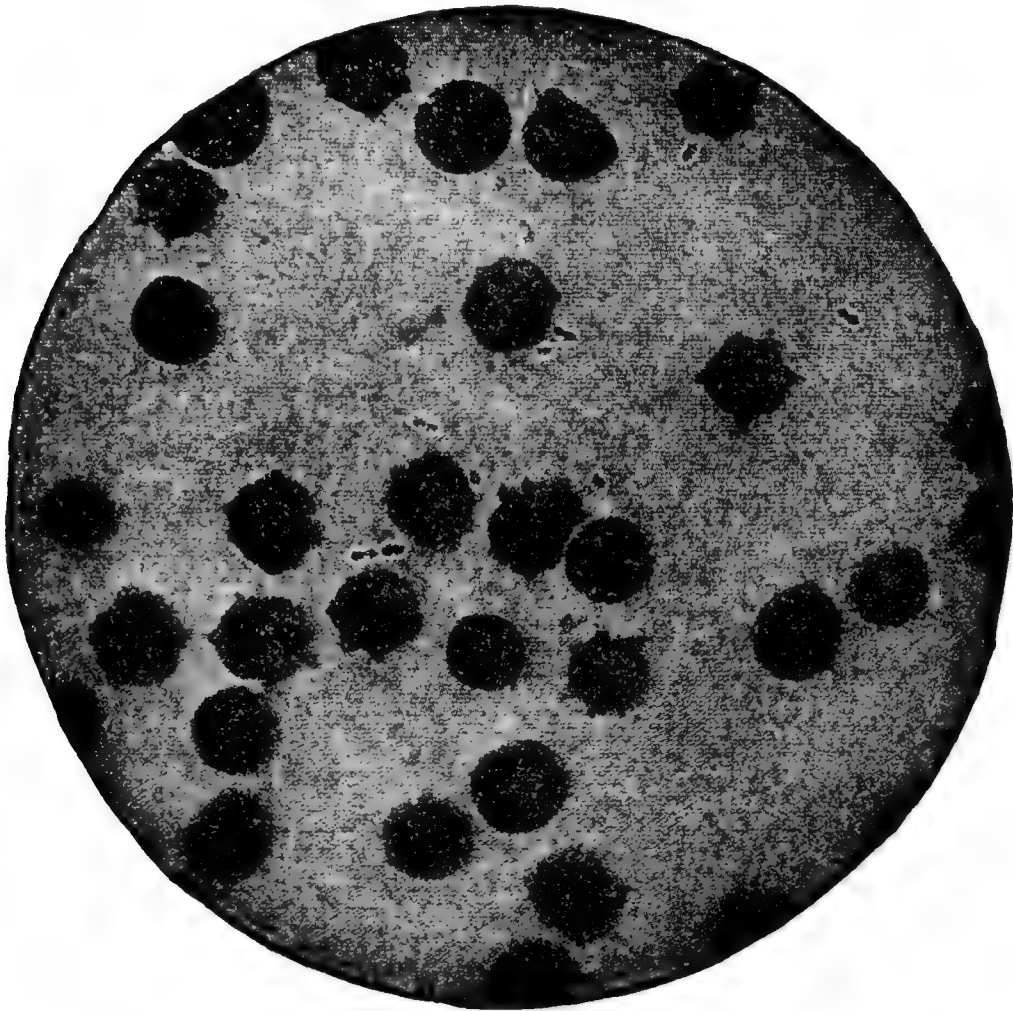not unlike the streptococcus in appearance. It is an

Fig. 6.—Diplococcus pneumoniæ in the heart's blood of a rabbit.
×1000. (After *Fränkel-Pfeiffer*.)

encapsulated diplococcus, the capsule being easily
stained in smears of the fresh sputum.

The pneumococcus grows best at body temperature
on media that contains blood or blood serum. It is
dissolved in bile, while the streptococcus, with which
it is easily confused, is not. It is Gram positive.

Four types of pneumococci are recognized, called Types I, II, III and IV. The first three are distinct, clear cut types, but Type IV is composed of a number of pneumococci, and so far it has been impossible to separate them one from another. The method of determining the type of pneumococcus present in any given case of pneumonia is briefly as follows:—

From the sputum a pure culture of the pneumococcus is obtained either by inoculating mice which are very susceptible to pneumococcus infection, and cultivating the pneumococcus from the mouse peritoneum or by inoculating special media (Avery) with the sputum. With the pure culture of the pneumococcus agglutination tests are made mixing the growth with equal amounts of each of the three types of immune sera. If one of the sera agglutinates or clumps the pneumococci the test is positive for that particular type. If the pneumococcus culture is not agglutinated by any one of the immune sera it belongs in Type IV.

Precipitin tests may also be made. The precipitating substance is contained in the peritoneal washings of mice or in the culture fluid. These are centrifugalized to render them perfectly clear and they are mixed with the immune sera. If precipitation occurs with any one type of serum the pneumococcus belongs to that type.

Type I pneumococcus is responsible for the largest number of pneumonia cases, while Type II is the most fatal. Type IV is frequently found in the throats of healthy people and is the least virulent of all.

Infection with the pneumococcus takes place in two-thirds of the cases from outside the body, either directly from other patients or from infected dust. Carriers may transmit the infection but only to a limited extent.

While the chief point of infection is in the lungs, the pneumococcus can be cultivated from the circulating blood in a large proportion of the cases, indicating a general infection. With this in mind the complications such as otitis media, pericarditis, endocarditis, meningitis, arthritis, and osteomyelitis are readily understood. Infections with the pneumococcus can occur in other parts of the body without pneumonia.

To limit the spread of pneumonia the patient should be isolated at once. In hospital practice the patient should be screened. The sputum should be collected in paper boxes or napkins and burned. The hands of the patient should be kept clean with disinfectant (bichloride of mercury solution 1 : 1000) and the bed clothing disinfected. Rooms and apartments that have been occupied by pneumonia patients should be disinfected before being reoccupied. *Precautions*

The immunity acquired by man during an attack of pneumonia is of short duration. It has been possible, however, to produce an active immunity in horses by inoculating them with cultures of the pneumococcus. The serum of such animals is protective to man only in the case of Type I infections. The type of pneumococcus infection in any given case must be determined for this reason. *Immunity*

The serum is given intravenously. The first dose recommended is 100 cubic centimeters diluted to 250 cubic centimeters with salt solution. This may be repeated every twelve hours for 3 or 5 doses.

The results of serum treatment in Type I infections at the Hospital of the Rockefeller Institute have been favorable. In 107 cases treated with the serum 8 died or 7.5 per cent. The mortality in untreated cases is 24 to 30 per cent. Similar results have been obtained by others.

Active immunity Efforts have been made in the army to immunize troops to pneumococcus infection by the use of vaccines containing many different strains of pneumococci. Favorable results have been reported but the time elapsed is too short to make any very definite statement as to its efficacy.

Cerebrospinal meningitis is an infectious disease in which the agent of infection produces an inflammation of the covering of the brain and spinal cord. The **The meningococcus** infection may be caused by any one of a number of micro-organisms—the pneumococcus, the typhoid bacillus, the influenza bacillus, the tubercle bacillus, the *Streptococcus* or *Staphylococcus pyogenes*. When the meningitis results from infection with these organisms it is generally secondary to an infection elsewhere in the body, as, for example, during pneumonia, typhoid fever, pulmonary tuberculosis, or septicemia.

The primary form of meningitis, the form that frequently occurs in epidemics and is more commonly called spotted fever, is due to infection with the

meningococcus or the *Micrococcus intracellularis men-ingitidis,* and must not be confused with the forms mentioned above, which are always secondary.

The meningococcus was identified and described by Professor Weichselbaum in 1887. The micro-organism was found in the cerebrospinal fluid of patients sick with the disease, and generally within the bodies of the leucocytes. For this reason the term intracellular is used in its description. The coccus occurs in pairs, a diplococcus which in appearance is not unlike the gonococcus. It is Gram negative. It can be cultivated on agar containing blood or ascitic or hydrocele fluid. Three types of the meningococcus are recognized, the *meningococcus* and the *parameningococcus, A* and *B.*

The presence of the disease is detected by finding the meningococcus in the cerebrospinal fluid, which is withdrawn by inserting an aspirating needle into the cerebrospinal canal, at the level of the third or fourth lumbar vertebra. This procedure is spoken of as lumbar puncture, and may be performed by physicians without danger to the patient. The fluid recovered in this manner is usually cloudy and is immediately centrifuged to throw down the cellular elements contained in it. After this has been done the deposit is spread thinly on slides, stained by Gram's method, and examined under the microscope. The meningococcus when present is identified by its shape and arrangement in pairs, and by its location within the bodies of the leucocytes. The micro-organism may be cultivated

from the spinal fluid. In addition to its use as a diagnostic aid, lumbar puncture is very often the means of relieving the symptoms of pressure due to an excessive amount of fluid in the spinal canal, and for this reason it is customary to remove a large amount of the fluid.

The meningococcus is spread by the discharges from the mouth, nose, and ears of patients sick with meningitis, and it is not infrequent to find the organisms in the secretions of the nose and mouth of those attending them. Occasionally they may be found in the nasal secretions of healthy people who may act as carriers of the infection. To prevent the disease from spreading it is essential first of all to remove the patient from contact with others, especially during the first two weeks of the disease, for at this period the infection is most virulent. Then all discharges from the mouth, nose, eyes, and ears should be collected in cloths and paper napkins and burned. Cultures should be made from the nasopharynx of those who have been exposed to the infection. All persons in whom the meningococcus is found should be isolated. Nurses in attendance should use great care to disinfect the hands after handling the patient, and spray the nose and mouth with antiseptic solutions. Children living in the same house should not be permitted to attend school until it is certain that they have not been infected.

Cerebrospinal meningitis in the epidemic form has been attended with a very high mortality in the

Prevention

past, especially among young children. In some epi-demics it has been as high as 90 per cent. The treat-ment with antimeningitis serum, however, has been attended with success, and the excessive mortality has been considerably reduced by its use. In this country this method of treatment was begun by Dr. Flexner and Dr. Jobling at the Rockefeller Institute in New York. The serum is made by injecting horses with slowly increasing doses of meningococci that have been killed by heat. The tolerance of the animals to the poison of the meningococci is gradually increased in this way until they are able to withstand many times the fatal dose. This tolerance depends upon an active immunity due to the formation within their bodies of protective substances that neutralize the poison. After eight or twelve months the horses are bled and the blood-serum containing the protective substances is used for treating patients sick with meningitis.

The extended trial of the serum in a number of epidemics has shown that, the earlier it is used after the onset of the infection, the greater its curative value. For this reason it is customary to inject the serum immediately after the withdrawal of the cere-brospinal fluid by lumbar puncture, without waiting to determine the nature of the infecting organism. The serum should be given every twelve hours in severe cases until the spinal fluid becomes clear and the meningococcus is no longer present. The amount of serum to be given at one dose is dependent upon the

age of the patient and the amount of serum withdrawn. In children 10 to 20 cubic centimeters may be given, in adults 30 to 40 cubic centimeters. It is unsafe, however, to give more serum than is removed by lumbar puncture.

The *Micrococcus catarrhalis* closely resembles the *Meningococcus*, but is much easier to cultivate and grow at room temperature. It is found in the nasal secretions of healthy people and is probably responsible for nasal and bronchial infections similar to influenza. It has been the cause of epidemic conjunctivitis.

CHAPTER VI.

THE BACILLI OF THE COLON, TYPHOID, DYSENTERY GROUP.

THESE organisms are usually grouped together because of the similarity in their appearance and manner of growth upon artificial culture media. All the members of this group are short, rod-shaped, often forming chains, but never forming spores. They are all motile and Gram negative. They are distinguished from one another by the way they ferment sugars and produce acid in culture media.

Under the name of colon bacilli are grouped a number of varieties very closely related, which are usually harmless parasites living in the bodies of man and animals, but which at times become pathogenic and cause infection. The colon bacillus itself, properly called the *Bacillus coli communis,* is a constant inhabitant of the intestine in man and animals. In nature it is commonly found in soil, air, water, and milk. Just what function it performs in the intestine is not known positively, but it probably assists in breaking down food materials into simpler form so that they can be absorbed. Some believe that the colon bacillus elaborates a substance harmful to disease-producing bacteria in the intestines.

Once the colon bacillus has invaded the walls of the intestine, it is capable of setting up an infection. It has been found to be the cause of abscess of the liver, inflammations of the gall-bladder, the urinary bladder, the pelvis of the kidney, and the pancreas. It is frequently the cause of peritonitis in cases of rup-

tured appendix. Occasionally it causes a general infection. The poisons of the colon bacillus are contained within the body of the organism and are liberated only when it disintegrates. The knowledge of this fact has made it possible to immunize against colon infections by injecting the dead cultures, or vaccine, in slowly increasing doses. (See Immunity.)

On account of its constant presence in the intestine of man and animals, the presence of the colon bacillus in water or milk leads to the assumption that they have become infected with intestinal discharges, and so not safe for consumption. On account of the wide distribution of the colon bacillus in nature, this view has been modified to some extent, and now, unless they are present in excessive number, the water or milk is not condemned.

The Bacillus Typhosus.

The typhoid bacillus is the cause of typhoid fever. In recent years we have come to recognize that there are a number of other micro-organisms closely related to the typhoid bacillus which produce a fever and other symptoms that make a clinical picture identical with typhoid fever. It is more accurate therefore to look upon the clinical condition of typhoid as being due to any one of a group of micro-organisms the chief members of which are the typhoid, paratyphoid, and paracolon bacilli, with forms intermediate between each.

The typhoid bacillus is both a saprophyte and a parasite. As a saprophyte it is widely distributed in nature, due to its ability to adapt itself to its environment. It will live in water, ice, sewage, milk, dust, air, and soil. In surface-water typhoid bacilli will live about a week, being rapidly overgrown by other bacteria, but in distilled water they will live for three months. Freezing will kill most of them in a few days. Experiments made by placing typhoid bacilli

Fig. 7.—Typhoid bacilli showing flagella. × 1100 times. (After *Löffler*.)

in ice prove that nearly all are killed in a week, but occasionally they live for three months. The bacillus will retain life for six months in the upper layers of the soil.

Within the body they can resist the action of the gastric juice and multiply in the small intestine, where the greatest amount of damage is done. During the disease the typhoid bacilli may be found in the circulating blood, spleen, mesenteric lymphatic glands, rose-spots, and occasionally in the sputum and vomitus. Typhoid fever therefore should be considered not as a local infection of the intestine, but as a general infection with the organisms present in many

of the organs and tissues of the body. In the bile, urine, and stools the bacilli may persist for months and years after the acute infection has passed. It is for this reason that complications and sequelæ so frequently occur. The persistence of the typhoid bacilli in the bile is an important factor in the production of gall-stones; the bacilli have been found in the centers of stones from ten to fifteen years after the infection.

The typhoid bacillus is a short, rod-shaped organism with twelve or more flagella, and actively motile. It grows on all the ordinary culture media in the presence or absence of oxygen. The colonies on agar resemble grape-vine leaves. It is Gram negative.

The way infection takes place
Infection with typhoid bacilli always occurs by way of the alimentary tract, by infected water or food. Added to the cause of infection there is usually a lowered resistance on the part of the individual.

The infection reaches the alimentary tract, most often through infected water. As we have seen, typhoid bacilli will live for months in the soil; so that the discharges from typhoid patients that have not been disinfected and are deposited in or on the ground may lead to the infection of nearby wells and streams particularly during periods of heavy rain. Water infected in this way may give rise to local epidemics in the case of wells, or to epidemics miles away in the case of streams. The epidemic of typhoid fever in Ithaca, N. Y., in 1903 was caused by the infection of the city water supply by a case of typhoid in a laborer's camp situated on the banks of the stream that

fed the city reservoir; 1500 cases of typhoid occurred in a remarkably short time.

Wells are sometimes infected from privies, cisterns, and open cesspools when they are placed near a well, or when the natural drainage of the soil-water is in the direction of the well. Defective walls or covering that admit surface-water render the infection of wells in this way more likely.

Milk is an excellent culture medium, and typhoid bacilli will grow readily in it. They gain entrance to the milk by washing the milk cans or pails in infected water, or from the hands of persons sick or but recently recovered from the disease. Flies may also carry the infection to milk. There have been some 185 epidemics of typhoid traced to milk. In 1903 a milkman in Boston sick with typhoid spread the disease through the milk, causing an epidemic of over 400 cases.

The infection may be spread by eating uncooked vegetables that have been washed in infected water. Oysters and clams, when they have been grown in water contaminated with sewage, have been known to carry the infection. Along the seaboard laws are now in force that prohibit the cultivation of oysters in water near the outlet of sewers. The importance of flies in the spread of typhoid has been recognized only in the last ten years. When they come in contact with typhoid patients, or with infected discharges, they carry the bacilli on their bodies and deposit them on foodstuffs.

Typhoid
carriers

Finally, typhoid is spread by what are known as carriers, or persons that carry the bacilli in their bodies for a long time after they have recovered from the disease. About 4 per cent. of all typhoid cases become carriers. The bacilli may be voided in the urine or passed in the stools. Dr. Park tells of a cook who was a carrier. During a period of five years she had been employed in six different families in which 26 cases of typhoid fever had developed, all within a month after her arrival in each family. From the experience of recent years the number of typhoid infections resulting from contact with carriers is much greater than was formerly believed.

Prevention

To limit the spread of typhoid fever, precautions should be taken to render all food materials and water free from infection and to destroy the typhoid bacilli in all discharges that may contain them. During times of epidemics special care should be taken to boil all drinking water, to pasteurize all milk to be drunk, and to wash all vegetables to be eaten uncooked in boiled water.

So far as the destruction of the bacilli in the discharges is concerned the disinfection of the urine and stools is of the utmost importance. The stools are best disinfected with a 5 per cent. solution of carbolic acid. The solid parts should be broken up with a stick that can be burned or with a glass rod that can be sterilized after using, in order that all parts of the stool may come into contact with the disinfecting fluid. Stools treated in this way should be allowed to stand

for at least one hour; then thrown into the closet, buried, or burned. In the country they should be thrown into a trench so placed that the surface drainage is away from the well or the nearest water course. Quicklime should cover the stool in the trench and over this dirt should be thrown. The urine should be disinfected with carbolic acid solution in the same manner. All urinals and bed-pans must be disinfected with carbolic solutions after being used.

The patient should have eating utensils and toilet articles for his own exclusive use, which should be marked and kept separate from all others. Remnants of food should be burned or disinfected away from the kitchen.

Nurses and attendants on typhoid patients must always wash their hands after handling the patient in a 1 : 1000 solution of bichloride of mercury. Uniforms and linen that have been worn in the patient's room should be soaked in carbolic solution before being taken to the laundry. Nurses should not eat in the same room with typhoid patients. The direct infection from patient to nurse is not at all uncommon, and the directions just given must be strictly observed.

After recovery the patient should be given a full bath before leaving the room, and the room itself disinfected in the usual way. Chronic carriers should be isolated and every effort made to render them non-infectious.

Infection with the typhoid bacillus is followed by Immunity an immunity to the disease which persists for a variable

length of time, sometimes for life. Instances of rein-fection are rare. The immunity is conferred by the presence in the blood of protective substances known as bacteriolysins and agglutinins. The former are very much increased after typhoid, and by experiment it can be shown that the blood of patients after recov-ering from typhoid has marked power to dissolve the

A.   B.

C.   D.
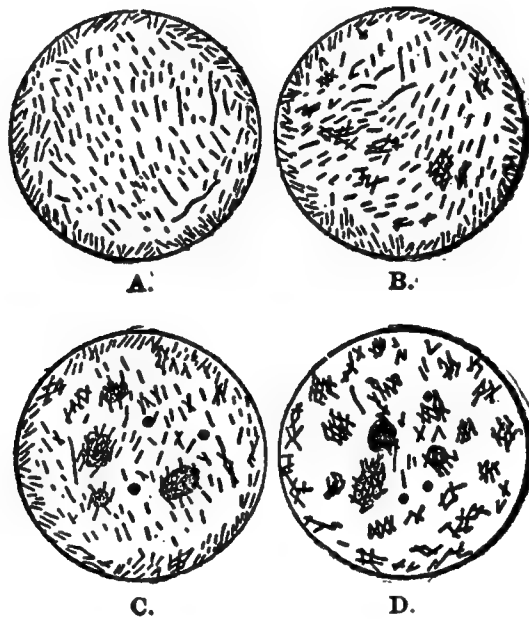
Fig. 8.—Stages of the Widal reaction. (After *Robin*.)

typhoid organisms. The agglutinins possess the power of drawing the typhoid bacilli into clusters or clumps. This phenomenon is made use of in detecting the pres-ence of typhoid fever by what is known as the Widal reaction.

The Widal reaction   It is made in this way: A small amount of blood is drawn into a capillary tube from the patient's ear and allowed to clot. By clotting the serum is sep-arated from the blood. The object of the test is to see if the serum contains any agglutinins of typhoid bacilli.

All blood contains a small amount of agglutinating substance; so the serum is diluted, say, to 1 : 40 or 1 : 80 and mixed with a fresh bouillon culture of typhoid bacilli in equal parts. The mixture is now under the microscope, and if the agglutinins are present the typhoid bacilli will be seen drawn together into clumps
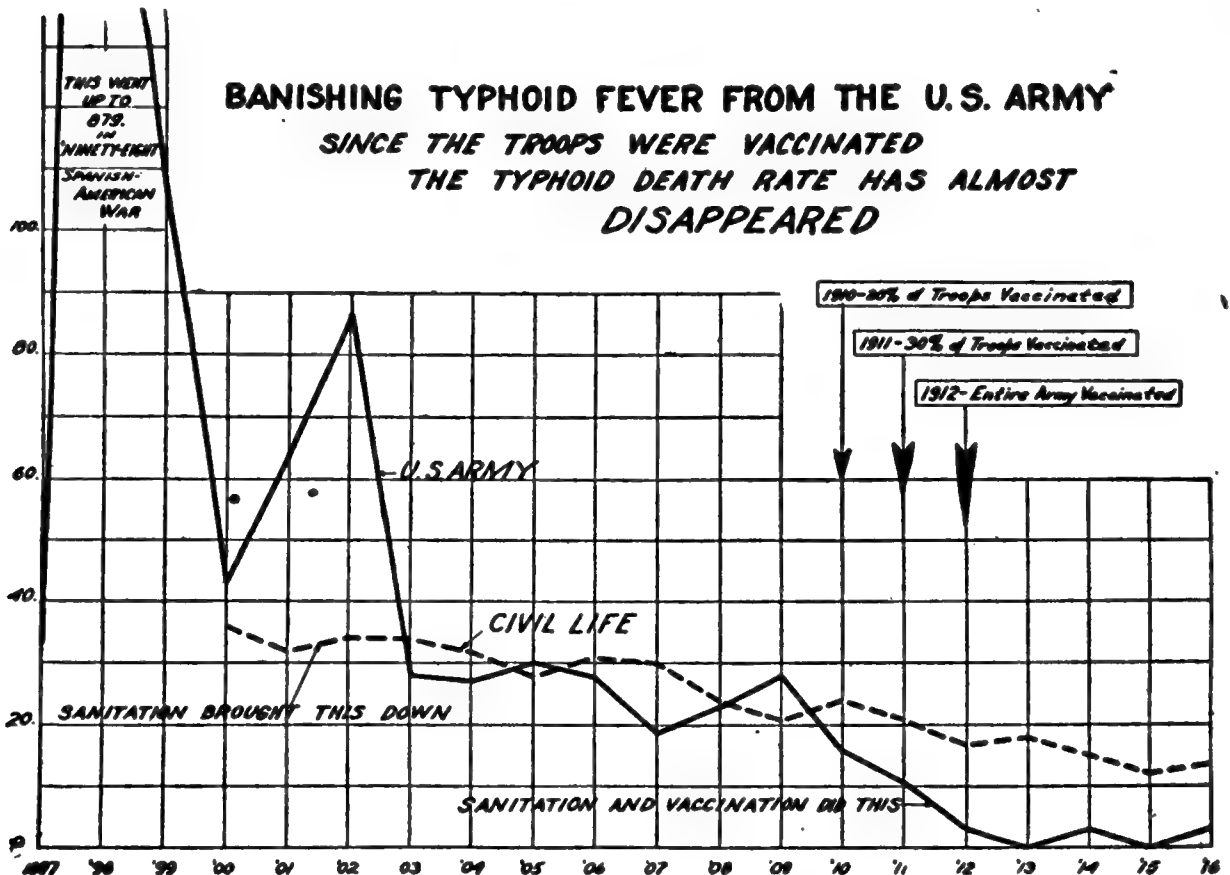
Fig. 9.

or clusters and lose their motility. When clumping is complete the reaction is said to be positive, and means that the patient now has or recently has had typhoid fever. Negative reactions are of no significance, as the reaction is not constant, being present one day and absent the next. A positive reaction, however, is conclusive.

Quite recently the prevention of typhoid has been greatly advanced by what is known as vaccination. As mentioned earlier in the chapter, the poison of the typhoid bacilli is found within the body of the cells, and is liberated only after death and disintegration of the organisms. An active immunity to the disease can be produced by injecting the killed typhoid bacilli, which after disintegration set free their poisons in the blood and stimulate the organs and tissues of the body to form protective substances that prevent infection. The inoculations consist of three injections of vaccine, the first one of 500,000,000, the last two of 1,000,000,-000 bacilli at intervals of one week. The vaccine most used is one containing both the paratyphoid and typhoid bacilli. The inoculations are sometimes followed by a reaction marked by a rise in temperature, headache, and general malaise. This method of creating immunity to typhoid has been practised a great deal in the last two years with very gratifying results.

It was first tried in this country in the U. S. Army maneuver camp at San Antonio, Texas; 8097 men were vaccinated, that is, they were injected with a killed culture of typhoid bacilli on three occasions, the dose being increased each time. Only one case developed among these men, and this one was not fatal.

Among nurses and hospital attendants the anti-typhoid vaccination is being largely practised. In the Massachusetts General Hospital 1381 nurses and attendants were vaccinated with no cases of typhoid developing subsequently.

THE BACILLUS PARATYPHOSUS.

The paratyphoid bacillus in shape and size is very much like the typhoid bacillus. It is differentiated from the typhoid bacillus by its ability to ferment glucose. There are two types of paratyphoid bacilli, called type A and B, which differ slightly in their method of growth. They also behave differently in the agglutination or Widal reaction. The blood of the patients sick with paratyphoid fever will not agglutinate the typhoid bacillus. If the infection is due to paratyphoid A the blood will not agglutinate the paratyphoid B, but only the A.

The agglutination reaction is a very good way to diagnose the type of infection present in all cases of typhoid-like infection.

The course of the fever in paratyphoid infections is somewhat milder and shorter than in typhoid. In the fatal cases coming to autopsy the spleen and mesenteric glands are enlarged, just as in typhoid, but the intestines show little change. Changes in the bowel do occur because hemorrhage sometimes occurs in paratyphoid fever.

Immunity follows an attack of paratyphoid fever just as in true typhoid, but the protection is only against the type of paratyphoid bacillus causing the infection. A case illustrating this point came under the writer's observation in the summer of 1913, in which the patient developed typhoid-like symptoms and fever, although he had had a severe typhoid in-

fection only a few years before. The infection proved to be a paratyphoid type B.

In the immunization against typhoid with killed cultures it is now customary to use the killed bacilli of both typhoid and paratyphoid in order to confer immunity to all types of typhoid-like organisms.

THE BACILLI OF THE DYSENTERY GROUP.

The first member of this group was discovered by Shiga, a Japanese, in 1897. In its size and shape it is very much like the colon bacillus, but does not ferment sugars like the colon bacillus does. It can be grown from the surface of the large bowel or from the stools of dysenteric patients, and cultures when fed to dogs cause dysentery.

In man the dysentery bacilli will give rise to severe diarrhea, accompanied with cramps, tenesmus, and fever. The stools are streaked with blood and contain mucus. The disease spreads rapidly, sometimes through infected water, sometimes from direct contact. It lasts from seven to ten days, and frequently is attended with a death rate of from 5 to 20 in 100.

Numerous epidemics have been reported in the United States; among them an epidemic of 350 cases in the village of Tuckahoe, N. Y., which was studied by the writer, together with Dr. Wm. H. Park. The cause of the epidemic was found to be due to an organism almost identical with the one described by Shiga. From a study of the dysentery bacilli found in this and

other epidemics in this country we find that there are a number of bacilli very nearly alike that may cause these epidemics of dysentery.

Individuals that have been infected with dysentery bacilli develop agglutinating substances in the blood that will clump the dysentery bacilli just as in the case of typhoid and paratyphoid infections.

To summarize what has been said of the colon-typhoid-dysentery group: All the members are bacilli of similar appearance, all are to some degree motile, but they differ one from another in their growth, particularly in their ability to ferment sugars and produce acid in culture media. The colon group, although a constant inhabitant of the intestine, gives rise to no infection unless it gains access to tissues outside the bowel. The typhoid and dysentery bacilli are never present in the body under normal conditions, but when they enter the body they cause a characteristic infection. The blood-serum of all infected individuals develops substances that protect against reinfection, and among these substances are the agglutinins which gather the bacilli together into clumps. The agglutinins caused by infection with the colon bacillus will agglutinate only the colon bacillus; the same is true for the typhoid, paratyphoid, and dysentery bacilli. This peculiarity is made use of in diagnosing the kind of infection present.

The Mucosus Capsulatus Group.

In this group are placed a number of micro-organisms which resemble one another closely in their

morphology and manner of growth. The members of this group differ but little from those of the colon group.

The Bacillus Mucosus Capsulatus.

This bacillus was discovered by Friedländer in 1883, and is often called the Friedländer bacillus. It is a short, plump bacillus, with rounded ends, exhibiting considerable variation in size. It may occur singly, in pairs, or in chains. It is not motile and forms no spores. On all the ordinary culture media it grows readily even at room temperature. The most characteristic feature is the transparent capsule about the organism. Exposure to heat of 60° C. destroys the bacillus in a short time.

At the time of its discovery this bacillus was believed to be the chief cause of lobar pneumonia, but it has since been proved that it is responsible for only a small percentage of the cases. In addition to causing pneumonia, it has been found in suppurations of the nasal sinuses, empyema, pericarditis, and meningitis. No method of immunization has been found as yet.

The Bacillus Lactis Aërogenes.

The *Bacillus lactis aërogenes* is constantly present in milk and, with other micro-organisms, is the cause of souring. It is also present in water, sewage, and feces. It closely resembles the colon bacillus, but differs from it chiefly in being non-motile and having

a capsule. It is not a virulent organism, but has been known to be the cause of cystitis.

THE BACILLI OF THE PROTEUS GROUP.

The members of this group are putrefactive bacteria capable of breaking down complex proteids into simpler compounds. They are widely distributed, being found in water, soil, air, and wherever putrefaction is in progress.

The chief member of the group is the *Bacillus proteus vulgaris,* a large, thick bacillus that grows readily on the ordinary media. It is motile, but forms no spores. It liquefies gelatin in its growth and produces a characteristic odor of putrefaction. It is not a very virulent organism. It occasionally causes peritonitis, endometritis, pyelonephritis, and enteritis. It has been described as the cause of several epidemics of meat poisoning.

THE BACILLUS OF RHINOSCLEROMA.

This bacillus is a short, plump rod, in appearance and manner of growth almost identical with the *Bacillus mucosus capsulatus.* Infection with this micro-organism is located usually in the mucous membrane of the nose, mouth, pharynx, and larynx. It produces hard, nodular, inflammatory swellings. Under the microscope large, swollen cells are found in the tissue which contain the bacilli.

CHAPTER VII.

BACTERIA CAUSING ACUTE INFECTIONS.

THE BACILLUS OF TETANUS.

TETANUS, or lockjaw, as it is more commonly called, has existed for many centuries, but the micro-organism causing the infection was not discovered until 1885, when Nicolaier, a German bacteriologist, was successful in producing the disease in animals by injecting them with small amounts of soil.

Morphol-
ogy
The organism is a bacillus of large size, which forms spores readily. It grows on the ordinary culture media, but only when no oxygen is present. The spores are located at one end of the bacillus, and cause a swelling which gives it much the same shape as a drumstick. The spores are very resistant to harmful influences. They will survive dry heat of 80° C. for an hour and 5 per cent. carbolic acid solution for twelve to fifteen hours. Away from sunlight the spores may live for years.

Its natural home is the soil, especially where it has been cultivated and manured. This is due to the fact that tetanus bacilli are present in the intestines of some animals. In the United States the soil in the Hudson Valley and on Long Island seems particularly infectious.

Infection generally occurs by the contamination

(74)

of lacerated wounds, especially gunshot wounds with
particles of wood, soil, or glass.   A great many cases
in our country have been due to wounds caused by fire-
crackers and blank-cartridge pistols, and has led to a
crusade against their use on Independence Day.   The

Fig. 10.—Tetanus bacilli. Spore-bearing rods from an agar
culture.   Mounted preparations, stained with fuchsin.   × 1000.
(*Fränkel-Pfeiffer.*)

period of incubation is from one to twenty days.   The
muscular spasm generally begins in the muscles of the
face and jaw, making it difficult to chew.   This is the
origin of the popular name, lockjaw.   Gradually
other muscles become tight and stiff until finally all
the muscles of the trunk and extremities are affected.
The least irritation is sufficient to throw all the muscles

into spasm, making the entire body rigid. These spasms are produced by soluble poisons that are formed by the tetanus bacilli at the point of inocula-

Tetanus toxin tion, and seem to have a special affinity for the tissues of the brain and spinal cord. The poisons are also formed in the culture media, and are among the most powerful known; the poison formed in a bouillon culture being sufficient to cause death when injected into mice in doses of 0.0000005 cubic centimeters. Man and the horse are very susceptible to the poison, while chickens are able to resist large doses.

Immunity It is possible to immunize animals against the tetanus toxin by injecting the poison in very small doses and gradually increasing it. After a time the animal can withstand large doses without ill effect. The antitoxin is made by injecting horses with ascending doses of the poison until they are thoroughly immunized; then they are bled and the serum, which contains the protective substance is used to protect human beings. Tetanus antitoxin is used both as a prophylactic and a curative agent. For prophylaxis a dose of 1000 units is given intramuscularly in all cases where wounds have been contaminated with dirt. In

Serum treatment the United States Army during the war all wounded men received tetanus antitoxin at once and another dose after ten days. By this means the incidence of tetanus in the Army was practically *nil*.

For curative purposes tetanus antitoxin must be given intraspinally in doses of 3000 to 5000 units and repeated if necessary. At the same time the antitoxin

may be given intravenously or into the muscles. The prospect of success in cases where tetanus has already developed is not as good as it is in prophylaxis. Park, however, mentions 24 consecutive cases of tetanus with 18 recoveries.

THE GLANDERS BACILLUS (BACILLUS MALLEI).

Glanders is a malady which occurs principally among horses, but dogs, cats, sheep, and swine are also susceptible. In rare instances man acquires the disease. It is caused by the *Bacillus mallei*, a small, rod-shaped organism with rounded ends. It can be cultivated easily on the ordinary kinds of culture media, and stains readily, but unevenly, giving the bacillus a granular appearance much like the bacillus of diphtheria. Heat at 60° C. will destroy the bacilli in two hours and 1 per cent. carbolic acid in thirty minutes. Drying destroys them in a short time. In water they may live for two months or more.

The infection in horses occurs generally in the nose or mouth, from the entrance of the bacilli through cracks or wounds in the mucous membrane. After an incubation period of two or three days there is a nasal discharge with swelling of the nasal mucous membrane, which later ulcerates. The cervical lymphatic glands also swell and may suppurate. The disease frequently terminates in pneumonia. Infection through the skin gives rise to a nodular eruption, the nodules later undergoing suppuration. This is called farcy.

The disease may be transmitted to human beings from infected horses or may pass from man to man. The manifestations of the disease in man are much the same as in the horse. It may assume an acute or chronic course, the former nearly always resulting fatally.

The toxins of the *Bacillus mallei* are within the bodies of the organisms, that is, they are endotoxins and are very resistant to heat. Attempts have been made to immunize animals by the injection of small amounts of the toxin, and have been to some extent successful. It is not possible to immunize man in this way.

Diagnosis   The diagnosis of glanders may be made in several ways. The discharges or the pus may be injected into the peritoneal cavity of guinea-pigs. If the bacillus of glanders is present the testicles become swollen and painful in two to five days. A test may be made for the presence of substances in the blood-serum that will agglutinate the bacilli of glanders. It is done in the same manner as the Widal reaction for typhoid fever. Finally, the toxin of the bacilli made from cultures and called mallein may be injected under the skin of suspected cases. If glanders is present it produces a reaction marked by fever and tenderness about the point of inoculation. The principle upon which this reaction rests is the same as in the tuberculin reaction.

THE BACILLUS OF INFLUENZA.

This organism, described by Pfeifer in 1892, is a very small bacillus, Gram negative, aërobic, and non-motile. It will not grow except on media that contains hemoglobin and so is spoken of as hemophilic. It grows best in the presence of the staphylococcus. Heat kills the bacillus readily; an exposure of a few minutes at 60° C. is sufficient. It is killed quickly by drying.

Influenza or grippe is a highly infectious disease affecting the nose and accessory sinuses, the throat and lungs, and occasionally the meninges. It rarely causes pneumonia by itself. During the winter of 1912 the writer isolated influenza bacilli from the circulating blood of a case of septic endocarditis. The infection is spread by personal contact.

To prevent the transmission of the infection the discharges from the nose and mouth should be collected and destroyed. The bacilli, however, remain in the secretions of the nose and mouth for long periods of time after recovery. They have been found also in healthy persons. This probably explains the sporadic cases. The immunity following influenza is of very short duration and reinfection is common.

The epidemic of 1918, spoken of as the Spanish influenza, was a very virulent infection characterized by a high percentage of bronchopneumonic infection, which was extremely fatal.

The cause of this epidemic disease while called

influenza, has so far baffled discovery. The influenza bacillus was isolated from the sputum in a large percentage of cases, but other organisms were also, notably the *Hemolytic streptococcus,* the pneumococcus (all types), the *Friedländer bacillus,* and the *Micrococcus catarrhalis.* It has been impossible for bacteriologists throughout the world to reach any conclusion as to which one of these organisms, if any, was the primary cause of the disease.

The results of efforts to immunize against the infection by means of vaccines containing the various organisms known to be present in the sputum are not conclusive, some believing them to be of value, others not.

THE BACILLUS OF WHOOPING COUGH.

The bacillus causing whooping cough was first described by two French bacteriologists, Bordet and Gengou, in 1900. It is very small, oval, and Gram negative. It shows bipolar staining and resembles the bacillus of influenza in growing best on culture media in which there is blood or its coloring matter.

The infection localizes itself in the throat, nose, and bronchial tubes and is spread by the secretions from these parts. It is transmitted from one child to another, chiefly by direct contact, less often through dwellings and schools that have been infected.

One attack generally protects during life; so cases of reinfection are very rare. The toxins of the bacillus are within the bodies of the bacterial cells

(endotoxins). Efforts have been made to immunize against the disease and to modify its course by injecting the killed bacteria. The results have been fairly successful.

THE KOCH-WEEKS BACILLUS.

This organism is the cause of acute infectious conjunctivitis, commonly called "pink eye." It resembles closely the bacillus of influenza, but differs from it in growing on media that does not contain hemoglobin.

THE DUCREY BACILLUS.

This bacillus is of very small size, and has a tendency to form chains. It is not motile and does not form spores. It stains with all the ordinary dyes, but more deeply at the ends. It will grow only on media containing human blood.

Infection with this organism is the cause of chancroid, or soft chancre, an acute, inflammatory, ulcerating sore which occurs generally on the genitals and surrounding skin. It begins as a small pustule which ruptures and becomes an ulcer, having a tendency to spread. The bacilli frequently extend along the lymphatic vessels and involve the adjacent glands of the groin, which may undergo suppuration. The bacilli can be found in the pus and discharges from the ulcers. Infection results generally from sexual contact, rarely from infected dressings, towels, and instruments.

THE MICROCOCCUS MELITENSIS (MALTA FEVER).

Malta fever occurs among the people living on the shores of the Mediterranean Sea, in some parts of South America, and in the West Indies. It is similar to typhoid fever, but is not so severe, and the mortality rate is not so high. The *Micrococcus melitensis,* the cause of the infection, is readily cultivated on the ordinary laboratory culture media and stains easily. It appears under the microscope in groups and short chains. The infection is spread in the milk of goats, which is the chief source of the milk-supply in Malta, and probably by the mosquito.

Patients sick with Malta fever develop in their blood agglutinins for the micrococcus, which may be utilized in detecting the disease. The use of vaccines made from killed cultures of the micrococcus has been attended with good results.

THE BACILLUS OF ANTHRAX.

Anthrax is primarily a disease of cattle and sheep, although horses, dogs, and goats are susceptible. The infection is usually transmitted directly to man from infected hides or wool. The disease has existed chiefly in Europe until recently. During the training of the Army both in this country and in England numerous infections occurred from the use of infected shaving brushes. On account of the great demand for shaving brushes by the army, bristles were imported from China which were not properly disinfected. Anthrax

bacilli were isolated from the brushes in several instances.

The anthrax bacillus was the first micro-organism definitely proved to be the cause of a specific disease by Davaine in 1863. It is a large straight rod with square cut ends, is non-motile, stains by Gram's method and forms spores. It is aërobic. Its growth is characteristic. On solid culture media the colonies are composed of tangled strands which give them the appearance of a dishevelled mass of hair and in fluid media they grow in long strings. The spores are extremely resistant and retain their vitality for years.

In animals the infection is usually intestinal or cutaneous. In man the cutaneous infection is in the form of a malignant pustule or malignant edema. The malignant pustule is characterized by a circumscribed swelling, with edema and a black central eschar. It is frequently surrounded by a ring of vesicles.

The malignant edema frequently affects the eyelids, lips, and tissues of the neck and chest. It frequently results in gangrene. Anthrax septicemia frequently follows the cutaneous infections.

Intestinal infection is known to occur from the use of infected meat or milk. Several instances of anthrax meningitis have been recently reported.

A pneumonic form of anthrax, known as woolsorter's disease, occurs from the breathing in of spores from dust.

Among animals immunity may be conferred by the injection of attenuated anthrax bacilli. Recently ex-

Immunity

cellent results have been obtained by the use of Sclavo's serum and Eichorn's serum given intravenously.

THE BACILLUS OF PLAGUE (BACILLUS PESTIS).

The bacillus of bubonic plague was discovered by both Kitasato and Yersin during the epidemic in China in 1893. It is a short, thick, Gram negative, bacillus with rounded ends. In old cultures atypical forms are found, some like cocci, others club-shaped like the diphtheria bacillus. It is not motile and does not form spores. It will grow only in the presence of oxygen. In dark, moist places the organism will live for months or years. In the sputum and pus from patients it lives for one or two weeks. In cadavers they may live for several weeks. Dry heat destroys the bacillus in one hour, boiling in a few minutes. Direct sunlight requires four or five hours. Carbolic acid (5 per cent.) and bichloride of mercury (1 : 1000) destroy them in ten minutes.

The plague raged from the sixth to the seventeenth century, and in the fourteenth century the black death, as it is called, destroyed one-quarter of the population of Europe. The great plague in London in 1665 destroyed 70,000 people. The disease subsided then and remained practically dormant until 1894, when it broke out in Hong Kong. It spread thence to other countries, and a small epidemic occurred in San Francisco in 1907. In India the disease is endemic and annually causes the death of 500,000 people.

The infection may enter through the skin or by

way of the respiratory tract, and the symptoms of the disease manifest themselves after an incubation period of three to seven days. The symptoms following infection through the skin are characterized by headache, high fever, stiffness in the limbs, restlessness, and anxiety. Collapse frequently follows. The lymphatic glands are enlarged, particularly those in the inguinal region, which are called buboes. Infection by way of the respiratory tract begins abruptly with pneumonia. The mortality rate for this disease is very high,—80 to 90 per cent.

The bacilli of the plague are present in the swollen lymphatic glands, the sputum, urine, and intestinal discharges, and the infection may be spread directly from these sources. The chief way, however, in which the infection is spread is from the bites of the rat-flea, which transmits the disease from rat to rat and from rat to man. Unsanitary conditions have little to do with the occurrence of the plague, except that they favor infestation with rats. To prevent the disease from spreading, all patients must be quarantined, all discharges destroyed, and all articles that have come in contact with the patient disinfected. To prevent rats from breeding, all stables and outhouses should be cleaned up, and all possible sources of food-supply cut off. Dwelling-houses should be made rat-proof as far as possible. The importation of the disease into ports not infected should be guarded against by fumigating ships from infected countries and the isolation of suspected cases during the period of incubation.

The way the disease is spread

Ways of prevention

The toxins of the *Bacillus pestis* are both endo- and extra- cellular. It is possible to immunize animals and, in their blood, substances that will agglutinate the bacilli are found. They may be used in the diagnosis of the disease. In human beings an immunity develops after one attack. A vaccine has been used against the disease, and is said to reduce the mortality rate 20 to 25 per cent.

THE BACILLUS PYOCYANEUS.

The discharges from open wounds occasionally have a green color, the cause of the color in these cases being due to a pigment formed by the *Bacillus pyocyaneus*. It is a short, actively motile rod, Gram negative, having a tendency to form chains in fluid media. It can be readily cultivated in the presence of oxygen, and is easily identified because it stains the media upon which it grows a brilliant green. It forms no spores.

This organism possesses no great virulence, and may live without producing injury on the skin, and in the respiratory and intestinal tracts of animals and man. It may, however, be the cause of otitis media and diarrhea and gastroenteritis in children. Cases of general sepsis, liver abscess, and pericarditis have been attributed to it.

The pigment produced is of two kinds; one is called pyocanin, soluble in chloroform; the other is a fluorescent pigment soluble in water. In old cultures a ferment-like substance is formed called pyocyanase, which has the property of dissolving some of the other forms of bacteria. It has been used to destroy diph-

theria bacilli that persist in the throat after recovery. The toxins formed by the bacillus are both endo- and extra- cellular. Immunity in animals is produced with much difficulty, but in man no way of producing immunity has been devised.

THE SPIRILLUM OF ASIATIC CHOLERA.

The micro-organism causing cholera is a small, curved rod, often shaped like a comma, and therefore called the comma bacillus. When two are placed end to end they are S-shaped. True corkscrew forms occur, particularly in cultures in fluid media. The spirillum was discovered by Professor Koch in 1884. It is motile, being propelled by a single flagellum placed at one end, and grows on all the laboratory media in the presence of oxygen. No spores are formed. It is Gram negative.

Cholera exists constantly in India and countries of the Orient. It has been carried occasionally to other countries, causing epidemics. A very bad epidemic occurred in Hamburg in 1892. In this country the disease has been imported on several occasions, but no epidemic has developed since 1873. Strict measures are taken at the chief ports,—New York, New Orleans, and San Francisco,—to quarantine all suspects among the immigrants. *Distribution of the disease*

Infection always takes place by way of the alimentary tract, from infected water and food. While infected water is the most common cause, the infection may be carried on vegetables that have been washed in infected water, particularly those used as salads. *Path of infection*

Flies can deposit the infection on bread, butter, meat, and other foodstuffs. Direct infection from handling soiled bed-linen is not uncommon, as is shown by the greater frequency of the disease among washerwomen during epidemics. The onset of cholera, following an incubation period of two to five days, is sudden, with frequent watery stools, high fever, and great prostration. In the severe cases death may occur in eight to twelve hours. The infection localizes itself in the intestine. The spirilla are never found in the circulating blood, consequently the stools alone are infectious and may continue to be for months after recovery. People who carry the spirilla of cholera in the intestine after recovery are called cholera carriers.

Prevention   To prevent the disease during epidemics all drinking-water and milk must be boiled, and no meat or vegetables eaten unless cooked. Great care must be taken to exclude flies from contact with foods. Bed-linen, clothing, and utensils used by patients should be soaked in 5 per cent. carbolic solution, and subsequently boiled in the laundry. Attendants upon cholera patients should be careful to disinfect the hands after handling the patients. The stools are best disinfected with 5 per cent. carbolic solution, and the disinfection should be continued for some time after recovery.

The constitutional symptoms that accompany cholera are due to the toxins formed by the spirilla in the intestines. They are partly thrown out by the organisms, that is, soluble toxins, and partly retained

in the body of the bacterial cells and set free only after their death. It is possible to immunize animals against cholera by injecting small amounts of the killed culture or very small doses of the living organisms. The blood-serum of animals immunized in this way contains substances that dissolve the spirilla-bacteriolysins, and substances that clump them—agglutinins. The agglutinins are made use of in diagnosing cholera in the same way as in the diagnosis of typhoid fever (see Widal reaction). Human beings that have recovered from cholera are immune to the disease, but they remain so only for a few months. Efforts to protect human beings by injecting the killed cultures have been made in India on a large scale, but the results have been only partially successful.

The Bacillus of Diphtheria.

Diphtheria is an infectious disease caused by the diphtheria bacillus, sometimes called the Klebs-Löffler bacillus, after the two men who discovered it. The word diphtheria is derived from a Greek word meaning a membrane, because of the characteristic false membrane that forms in the throat. The bacillus causes infection most frequently in the throat or nose, although it may grow on the gums or about the teeth. It is possible for diphtheria bacilli to cause infection of the middle ear, the sinuses of the nose, and the lung (pneumonia). Rarely it extends to the skin about the mouth, or to the genitalia or rectum. The diphtheria bacillus is one of the few types that can be identified by its appearance under the microscope because its

shape is different from other bacteria. Three fairly distinct forms are recognized:

A. The granular type, the granules generally at the ends.

B. The barred type, the granules so arranged that the cell looks cross-striped like a barber's pole.

C. The solid type, with ends often club-shaped. They will grow on most of the laboratory media, but thrive best on media that contains blood-serum.

It stains readily with dyes, is not motile, and forms no spores. Outside the body direct sunlight kills the bacilli in half an hour but in the dust they will live for months. On slate-pencils, cups, glasses, or toys such as children put in their mouths they will live for weeks. In the nose and throat the bacilli caused, by the poison made by them, a death or necrosis of the mucous membrane. The membrane may extend into the nose and larynx causing an obstruction to breathing. By far the greater damage is caused by the poisons that are absorbed and affect the various organs and tissues, particularly the muscle of the heart, the kidneys, and the nervous system. The effect of the poisons upon the heart results sometimes in sudden death, following even slight exertion like sitting up in bed. Paralysis may follow diphtheria when the nervous system has been attacked.

Diphtheria in the throat and nose is detected by finding the bacilli in the wipings made from the membrane. **Diagnosis** It is not safe to rely solely upon the presence and appearance of a membrane, because membranes

may be due to infection with micro-organisms other than the diphtheria bacilli, such as the staphylococcus and streptococcus. In order to say whether a membrane is due to diphtheria or not, a sterile cotton swab
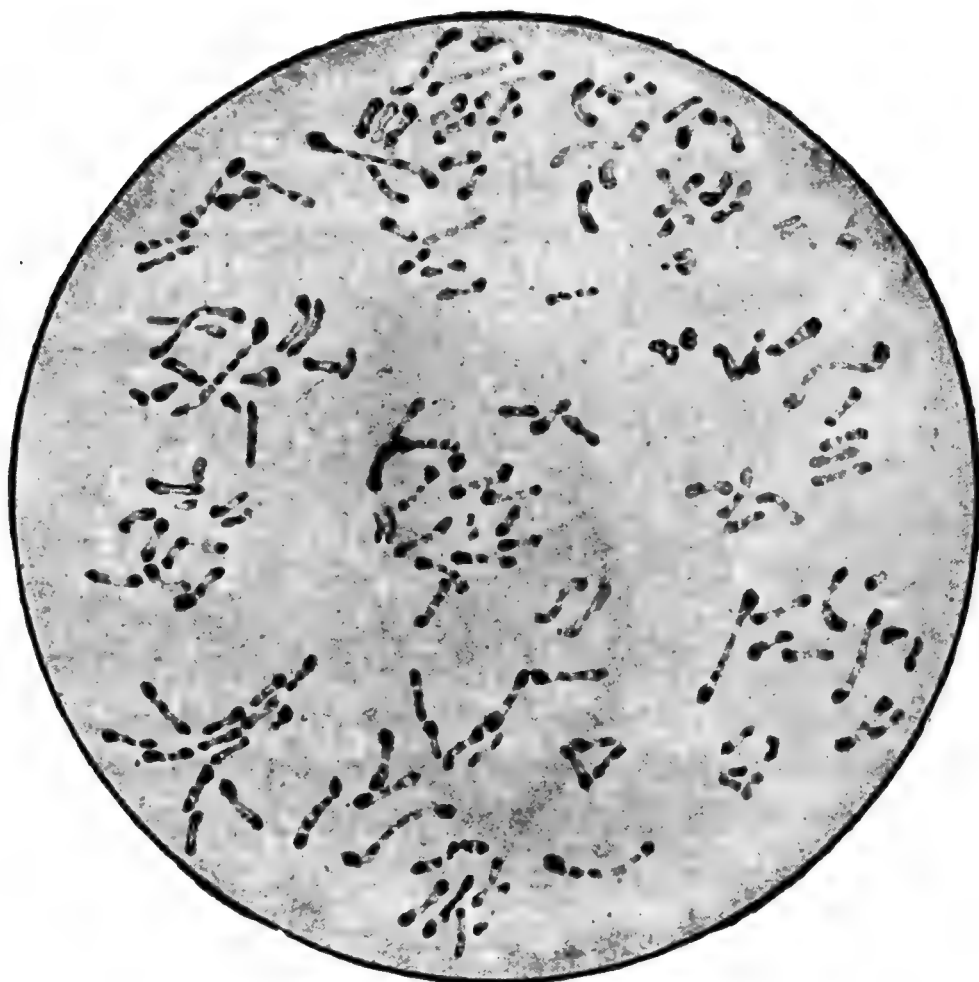
Fig. 11.—Bacillus diphtheriæ. ×1000. (Drawing by *E. L. Oatman, M.D.*)

is rubbed over the membrane, and then rubbed on the surface of a tube containing coagulated blood-serum. The tube and swab are now sent to the laboratory and incubated at body temperature from twelve to twenty-four hours in order to allow the bacteria present to multiply. The growth is now smeared on glass slides,

stained, and examined under the microscope. If diphtheria bacilli are present they can be readily identified by their appearance. (See Schick test.)

Spread of
the disease   The disease is spread to others chiefly by means of the bacilli thrown from the nose or mouth by coughing and sneezing. The sputum contains the bacilli in large number. Indirectly the disease is spread from the sputum by means of drinking-cups, handkerchiefs, door-knobs, and among children from pencils, chewing gum, toys, and other things that are handled and passed about. Cats, rats, and mice may carry the infection, and flies may deposit it on food and milk. Infected milk has been the cause of a number of epidemics.

The most important and first precaution to be taken in limiting the spread of diphtheria is isolation. This means the complete isolation of the sick person. The length of the isolation cannot be determined by the condition of the patient or by the appearance of the throat, because it is possible and frequently is so, that although the patient is apparently well and the throat clear, the bacilli of diphtheria are still there. In order to tell when the bacilli have disappeared a wiping of the throat is made just as described in making the diagnosis, incubated, and examined.

Two such cultures free from diphtheria bacilli are considered sufficient evidence that the patient is no longer able to transmit the disease to others. In some cases virulent bacilli persist in the throat for months. Even in healthy persons, particularly attendant upon

diphtheria patients, the bacilli may be carried in the throat for long periods of time without causing any of the symptoms of the disease. These diphtheria carriers may be the starting points of epidemics if they are not detected. The writer traced a serious outbreak in an orphan asylum to a boy, apparently healthy, whose duty it was to carry food from the kitchen to the children.

Fig. 12.—Organisms of Vincent's angina, showing spirillum and fusiform bacillus.

All discharges from the nose and mouth should be collected on paper napkins and burned. A paper napkin should be held over the nose and mouth while coughing or sneezing. All bed-linen and utensils used by the patient should be soaked in a 5 per cent. solution of carbolic acid and boiled. The sickroom must be fumigated and cleaned after the manner described under Disinfection. All well persons, including the

Disinfection

nurse, should receive an immunizing dose of antitoxin.

The curative property of antitoxin was discovered by von Behring in 1894. By the use of antitoxin the fatal cases have been reduced 75 per cent. The antitoxin should be given in all suspected cases and in large amount. In urgent cases it may be given directly into the veins, but under ordinary circumstances it is given into the muscles. The greatest effect is attained with a large first dose, for as the disease progresses the toxin unites with the cells and is then unaffected by the antitoxin. The immunizing dose protects from two **Serum sickness** to six weeks. Occasionally the injection of antitoxin is followed after a few days by a feeling of malaise, skin eruption, vomiting, albuminuria, and swelling of the lymphatic glands. This condition is due to an increased susceptibility on the part of the patient to certain constituents of the antitoxin, probably the horse-serum. A few cases of sudden death following the injection of diphtheria antitoxin have been attributed to anaphylaxis.

In epidemics the Schick test gives information which is of the greatest value in checking the spread of **Schick test** the disease. It is well known that a considerable number of people are normally immune to diphtheria. If a minute quantity of diphtheria toxin is injected into the skin of such people no effect is produced while in those not immune a local reaction results in twenty-four hours which is characterized by an area of redness and infiltration $\frac{1}{2}$ to 1 inch in diameter.

CHAPTER VIII.

BACTERIA CAUSING CHRONIC INFECTIONS.

THE BACILLUS OF TUBERCULOSIS.

TUBERCULOSIS is an infectious disease caused by the tubercle bacillus, which was discovered by Professor Koch in 1882. The organism is widely distributed over the world, and is pathogenic for the lower animals as well as for man. It is frequently found in cattle, less often in goats and swine, rarely in sheep, horses, dogs, and cats.

The bacillus is a slender rod, slightly curved, with rounded ends. It is purely parasitic, that is, it will not grow or multiply outside a host. It is never found save in the bodies and discharges of animals affected by the disease, or in the dust or upon articles which the discharges have contaminated. It is not motile, does not form spores, and is cultivated on artificial culture media with difficulty. It cannot grow without a liberal supply of oxygen, and only at body temperature. It is killed by moist heat at 70° C. in ten minutes, but dry heat at 100° C. requires one hour. Direct sunlight destroys them in two hours, but when protected from sunlight they can live for a year.

Morphology

There are four kinds of tubercle bacilli: the human; the bovine, chiefly found in cattle; the avian, found in birds, and the reptilian. The human tubercle

bacillus is only slightly infectious for cattle, but the bovine bacillus is infectious for human beings, particularly young children, who may become infected from the milk of tuberculous cattle.

Staining   The tubercle bacillus does not stain readily, but once stained it is difficult to decolorize it with acids. For this reason it is said to be acid-fast. The method employed in staining is as follows: The suspected material is spread thinly on a glass slide and dried. The preparation is then covered with fuchsin, a red dye to which has been added a small amount of carbolic acid solution and steamed, the heat quickening the staining. Then the preparation is washed off in water and decolorized with a 5 per cent. solution of nitric acid. This is allowed to act until all the red color is removed. After washing again in water the preparation is again stained with a methylene-blue solution. The picture produced by this method shows the tubercle bacilli unaffected by the acid decolorizer and stained red, while all other organisms are stained blue. In this way the tubercle bacillus may be detected in discharges from suspected cases.

Tubercle bacilli in urine   In collecting urine for examination for tubercle bacilli it is important to know that the smegma bacillus, a non-pathogenic organism found in the secretions about the genitalia, possess the same staining peculiarities as the tubercle bacillus; so that great care must be used to exclude it from the urine by careful cleansing of the external genitalia and collection of the urine by catheter. In fluids like urine, pleural effu-

sions and ascitic fluid the number of tubercle bacilli is always small; so to detect them the inoculation of **Exudates** guinea-pigs with the fluid is often practised. If tubercle bacilli are present in the fluid injected, the disease develops in the animal after a period of three to six weeks. In tuberculous meningitis the spinal fluid is often clear and the tubercle bacilli difficult to find. If, however, the fluid is allowed to stand ten to twelve hours a film or clot forms in which the tubercle bacilli can be found. The tubercle bacillus may cause infection by entering the body in the following ways:—

Hereditary transmission, long believed to be a **Path of infection** common occurrence, has not been proven among human beings. In very rare instances the bacilli may pass from the mother to the child in the uterus, but this depends upon some injury or disease of the placenta.

Respiratory: This is the most common way that infection takes place. The sputum of consumptives is the direct carrier of the infection. Deposited in houses, on floors and streets, the bacilli become incorporated with the dust which is breathed in by those in close contact with the patients.

Intestinal: This is more common in children than in adults. The bacilli gain entrance through the milk from tuberculous cattle or food infected by consumptive people. The habit children have of putting everything into their mouths is responsible for many infections, particularly in houses where consumptives are living. The bacilli resist the action of the acid in the stomach, and in the intestine may penetrate the

wall and lodge in the mesenteric glands. From this point they may be carried to remote tissues or organs.

Cutaneous: The bacilli may enter the skin through injuries or abrasions, giving rise to the disease known as lupus vulgaris.

Tubercles Once in the body, the tubercle bacilli may become localized in any tissue or organ, and there proceed to multiply. The result is the formation of a nodule or tubercle, from which the disease takes its name. The tubercles are about the size of a millet-seed, and at first are distributed separately in an organ. As they grow larger the central portion is poorly supplied with blood, so that it degenerates, softens, becomes cheesy, and finally may ulcerate. Tubercles that are placed close together may coalesce and go on to ulceration, causing large abscesses. If the tubercle bacilli reach the circulating blood they may be carried to many organs and tissues, at once causing a tuberculous septicemia or miliary tuberculosis. In such cases at autopsy the miliary tubercles are found everywhere in the body.

It is well to distinguish between the words "tubercular" and "tuberculous," as they are often used incorrectly. The word tubercular means nodular and has no reference to the nature or cause of the nodule. Tuberculous, on the other hand, is an adjective used to indicate tissues infected with tubercle bacilli.

Toxins The damage done in tuberculosis is due almost entirely to the absorption of the toxins formed by the tubercle bacillus. These are of two kinds: an extra-

cellular or soluble toxin, to which is attributed the fever, headache, loss of appetite and so on, and an endotoxin which causes an irritation of the tissues leading to the formation of the tubercle. The absorption of these toxins causes the formation of anti-bodies but not in sufficient amount to cause immunity. The toxins of the tubercle bacilli may be obtained from cultures, and are used under the name of tuberculin in the diagnosis and treatment of the disease. The tuberculin reaction used in the diagnosis is based upon an observation made by Professor Koch, that animals having tuberculosis were very sensitive to the poison, and when injected with even a small amount of tuberculin developed fever, headache, nausea, vomiting, and general malaise, while the diseased tissues became temporarily more inflamed. Healthy animals were unaffected. This method has been employed among tuberculous patients, using from 1 to 10 milligrams of the tuberculin subcutaneously. Simpler methods have more recently been used, such as the von Pirquet test, in which the tuberculin is introduced into the superficial layers of the skin with a scarifier, and the Moro test, in which the tuberculin is rubbed in, in the form of an ointment. In the first method a positive reaction is manifested by fever, headache, and so on, as described above, but in the cutaneous tests there is only a local redness about the point of inoculation. A positive test means that tuberculosis is present in the body, but it does not tell us where or whether it is active or not. In children, a positive reaction usually means active disease.

Tuber-
culin
reaction

Tuberculin administered in increasing doses, too small to cause a reaction and at fixed intervals, develops a tolerance for the poison, and so an immunity. This method of treatment is being widely used, while the results are not prompt, the consensus of opinion is that it exerts a beneficial effect on the course of the disease in some cases.

During the last ten years great efforts have been made to check the ravages of the disease; in fact, a crusade has been carried on that has become world-wide. Among the measures that have been advocated are the registration of all cases of tuberculosis by departments of health, the establishment of institutions sufficient to care for the advanced cases, dispensaries where suspected cases may be examined and subsequently visited by nurses who instruct the sick in the proper way to disinfect the sputum, stools, and urine, and the disinfection of all houses occupied by tuberculous patients before being reoccupied. More general measures, such as better sanitary conditions in factories, schools, and dwellings, have been brought to the attention of the public, and have created a public sentiment that is now bearing fruit. As a result of this crusade, it is not too much to expect that the death rate from tuberculosis will be materially reduced, and that the spread of the disease will be checked.

THE BACILLUS OF LEPROSY.

The bacillus causing leprosy was found by Hanses, a Norwegian, in 1871, in the nodules of leprous

patients. It is a short rod about the size of the tubercle bacillus, which it resembles closely both in appearance and in staining peculiarities. It takes stains with difficulty, but once stained it resists decolorizing with acids. For this reason it is spoken of as being acid-fast. It is very difficult to cultivate on the culture media at our disposal. Efforts to transmit the disease to animals have not been successful.

Leprosy is one of the oldest diseases known, and Dr. Osler says it existed in Egypt three or four thousand years before Christ. It is referred to many times in the Bible, but there is reason to believe that other diseases were included under the same name. The disease has continued to exist to the present time, but was particularly prevalent in the Middle Ages. At present it exists in Iceland, Norway, Sweden, Russia, Spain, Portugal, England, West Indies, China, India, and the Philippines. In the United States small numbers of cases are to be found in Louisiana, Minnesota, Florida, and Texas, with isolated cases widely scattered.

Distribution of the disease

The disease manifests itself either as tubercular leprosy or as anesthetic leprosy. In the former, nodules develop in the skin which soften and finally form discharging sores. In the anesthetic form the nerves are principally affected, and this leads to loss of sensation in the skin. Both forms may exist at the same time.

The way that infection takes place is not positively known, but many believe that it enters the skin

or mucous membranes through close personal contact. While hereditary transmission cannot be denied, no instance has so far been recorded. The infectious material is found in the discharges from the open sores, in the urine, milk, blood, sputum, and nasal secretions. The last are especially infectious.

The spread of the disease is checked by the segregation of the lepers in the communities where the disease prevails. Attendants upon leprous patients should know that the disease is one of the most difficult to contract of all the infectious diseases, and that it is very rare for nurses to be infected while attending cases. Careful attention should be given to disinfecting the nasal discharges and sputum.

CHAPTER IX.

THE DISEASES CAUSED BY THE MOLDS, YEASTS, AND HIGHER BACTERIA.

REFERRING back to the classification of the fungi given in chapter ii, there still remains to be considered the hyphomycetes, or molds, and the blastomycetes, or yeasts. Under the head of higher bacteria are organisms having characters that make it difficult to classify them either as molds or yeasts. The most important of the diseases caused by the higher bacteria is:—

ACTINOMYCOSIS.

This is an infection generally running a chronic course, caused by the actinomyces, or ray fungus. It prevails chiefly among cattle; but sheep, dogs, cats, horses, and swine are also susceptible. It occasionally occurs in man.

The parasites can be seen by the naked eye, in pus from the abscesses, as minute, yellow masses, often called sulphur granules. If the granules are examined under the microscope they are found to be made up of a central thick mass of filaments which radiate at the periphery. It is because of this radial arrangement that the parasite is called the ray fungus. The ends of the filaments are often club-shaped.

The infection is located most often about the

mouth or in the throat. It starts as a nodule, hard at first, but later undergoes softening and finally suppurates, causing a discharging sinus. Infections of the skin, lungs, intestines, and appendix have been described. The parasite is supposed to enter the body
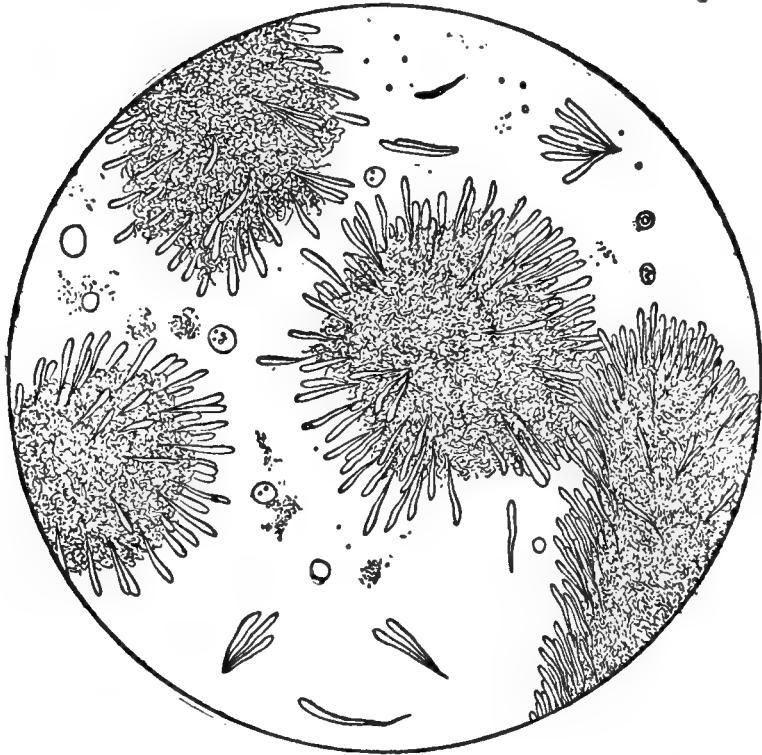
Fig. 13.—Actinomyces hominis (lung). × 350.
(*Lenhartz-Brooks.*)

in grain, oats, barley, or rye, and in cattle from hay or straw.

The disease is not highly infectious, and all danger is removed by careful disinfection of the discharges containing the pus.

YEASTS.

Yeast-cells are much larger than bacteria; they are oval in shape and have a thick cell-membrane.

The protoplasm contains vacuoles and one or more nuclei. The manner of reproduction is characteristic; the capsule protrudes and forms a bud and contains a part of the protoplasm and a half of the nucleus. It gradually grows larger, and is eventually pinched off to become another cell. The cells frequently contain spores, which are liberated when the cell disintegrates.

The most important property of yeasts is the fermentation of sugars whereby the sugar is changed into ethyl alcohol and carbon dioxide. Commercially the yeasts are used in a variety of ways, but chiefly in the manufacture of beers and wines. Few of the yeasts are infectious for man, and but one will be mentioned.

BLASTOMYCOSIS.

This infectious disease is caused by a yeast called the blastomyces. In appearance it corresponds to the yeast-cells described above, having a thick cell-wall, with one or more nuclei in the protoplasm, and vacuoles. Occasionally it forms threads called mycelia (sing. mycelium).

The skin is most often affected. Small nodules form, which soften and discharge a yellow pus. They spread slowly and sometimes involve a considerable area of skin. Infection of the lungs is more serious and often leads to pneumonia. A few cases of general infection have been reported with abscesses in the liver, spleen, and lungs.

Where the organisms that cause the disease come

from is not known, but in skin infections it is presumed that they enter along the hairs or through small abrasions. It is not a very infectious disease, and the infection of others may be prevented by disinfecting the pus discharged.

Fig. 14.—Microsporon furfur. (After *Lenhartz*.)

Molds.

The molds in their structure are much more complex than the yeasts. They are characterized by the formation of mycelial threads and terminal organs of reproduction called hyphæ. They may be seen growing on decomposing substances, and look like little pieces of cotton. Of the many kinds of molds, but a few are pathogenic for man.

THRUSH.

This occurs in infants and young children, causing sore mouth. It is caused by a mold called the *Oidium albicans.* The mucous membrane is red and dotted with small, white flakes, which contain the organism.
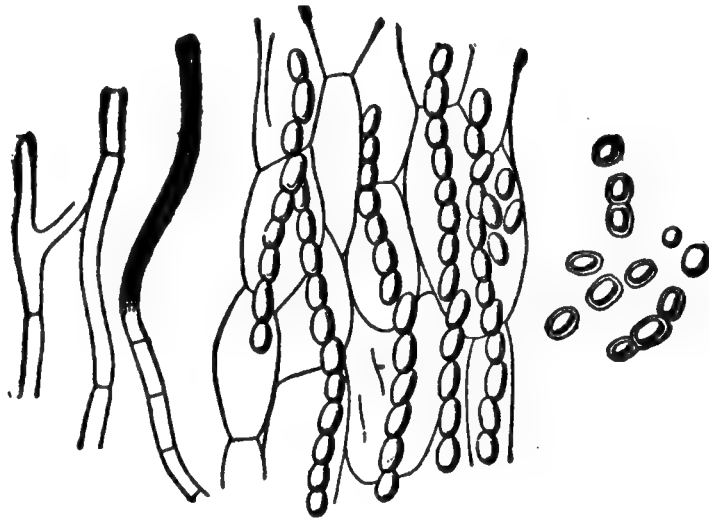
Fig. 15.—Trichophyton tonsurans.   (After *Bizzozero.*)

PITYRIASIS VERSICOLOR.

The infectious mold here is the *Microsporon furfur,* which lives on rather than in the skin. It produces yellowish, scaly patches on the chest, back, or abdomen, which may spread over large areas of the skin. When scratched, the growth can be removed in fine scales which contain the mold. It affects chiefly the uncleanly.

FAVUS.

The mold causing favus is called the *Achorion Schönleini,* after its discoverer. It attacks the hair-fol-

licles, especially of the scalp, and forms yellow crusts about the base of the hairs. If the crusts are removed and examined under the microscope, the parasites can be found in them. The disease is very resistant to treatment.

RINGWORM.

This is a very common affection among children, and is caused by the *Tinea trichophyton.* There are three types of the parasite: the *Tinea tonsurans,* which attacks the hairs of the scalp; the *Tinea sycosis,* which attacks the hairs of the bearded part of the face, and the *Tinea circinata,* which attacks the skin. It starts as a slightly elevated, scaly spot, which gradually widens, forming a red, scaly patch, with raised edges. The hairs invaded by the parasites break off and leave the center devoid of hair. The disease spreads from one person to another by direct contact.

CHAPTER X.

THE BACTERIA IN WATER AND MILK.

The Bacteria in Milk.

From its appearance and taste little can be known of the bacterial content of milk. It may be teeming with bacteria, yet give no indication of their presence. In fact, ordinary market milk contains from 100,000 to 1,000,000 bacteria in every cubic centimeter.

How do these bacteria get into the milk? In the udder of the healthy cow the milk is practically free from bacteria, but they live in the milk-ducts in the teats, and get into the milk as it is drawn. The chief source of bacteria in milk lies in the uncleanly methods of collecting it. Many get it from the dust-laden air of the stable, from the dirt on the hide of the cow, unclean milk-pail and from the dirty hands of the milkers. It is a true saying that the number of bacteria in milk is an index of the cleanliness with which it has been collected. Once in the milk, the bacteria multiply with great rapidity, for milk is an excellent medium for the cultivation of bacteria. The temperature of the milk for some time after it is drawn also favors their development.

To prevent the contamination of milk with excessive numbers of bacteria, all that is required is cleanliness,—clean stables, clean cattle, milkers with clean

Prevention of contamination

(109)

hands, and clean milk-pails. Immediately after the milk is drawn, it should be cooled to 5° C. (40° F.) and kept at this temperature until sold.

The State Department of Health of New York, recognizing the importance of clean milk and the various purposes for which it is used, has established several grades of milk and cream with the requirements for their production.

Grade A—raw milk. The cows must be tested with tuberculin at least once a year. Milk must not contain more than 60,000 bacteria per cubic centimeter and cream not more than 300,000 bacteria.

Grade A—pasteurized. The number of bacteria per cubic centimeter must not be more than 30,000 in milk and 150,000 in cream.

Grade B—raw. The number of bacteria must not exceed 200,000 per cubic centimeter in milk and 750,-000 in cream.

Grade B—pasteurized. The number of bacteria per cubic centimeter must not exceed 100,000 in milk and 500,000 in cream.

Grade C—raw and pasteurized have no limit placed on the number of bacteria. These grades are intended for special purposes. For infant feeding, Grade A raw or pasteurized should be used; for ordinary table use, Grade B raw or pasterized; and for cooking Grade C.

Pasteurization is accomplished by heating the milk to 60° C. (140° F.) for thirty minutes or 65° C. (158° F.) for fifteen minutes. The milk is imme-

diately cooled to 5° C. (40° F.) and kept at this temperature until used. Milk to be used in feeding infants should be modified and poured into the nursing bottles before being pasteurized. It should be used within twenty-four hours. The pasteurization kill all the bacteria, but not the spores. If the milk is cooled as directed, the spores will not develop.

The bacteria usually present in milk are harmless in so far as they are able to produce specific disease; but while they may be considered harmless for healthy adults, they may be very dangerous for infants and sick persons. The great loss of life among infants under 2 years of age from intestinal or diarrheal diseases show this. During the summer months, when the number of bacteria is more than at any other time of the year, the milk undergoes chemical changes which lead to disturbances in digestion and infection of the intestines.

Diseases other than these caused by the ordinary dirt bacteria may be spread in milk. Many epidemics of scarlet fever, typhoid fever, and diphtheria have been traced to infected milk. The infection is introduced into the milk at the dairy, usually by someone sick with the disease in question.

Disease transmitted by milk

The transmission of tuberculosis in the milk from tuberculous cattle is believed to be of common occurrence, particularly among infants. The tubercle bacilli may pass through the walls of the intestine without causing any disease of the intestinal wall itself, and lodge in the mesenteric lymphatic glands. They may

lie dormant for years and later on, when the resistance is lowered by disease or by unsanitary conditions of living, become active and cause tuberculosis in whatever organ or tissue they may be lodged. The milk from cattle having tuberculosis of the udder is the most dangerous but even when the udder is healthy and the disease located in other organs, the milk may contain tubercle bacilli. Not only is the milk from tuberculous cattle infectious, but also the products—butter and cheese—made from the milk. From what has been said, it is easy to see the danger of using raw cows' milk for infant feeding without positive assurance that the cows have been tuberculin tested and are free from tuberculosis.

The Bacteria in Water.

Water as it falls in the form of rain is free from bacteria. It begins to be contaminated with bacteria when it reaches the dust-laden air above the earth, and after it reaches the ground the number of bacteria is greatly increased from the soil. As it drains from the surface of the earth or percolates through it, it is classed either as surface water, of which ponds, lakes, or rivers are examples, or as ground water, which feeds wells. Surface water always contains large numbers of bacteria, but the water in wells contains only a few on account of the filtering action of the soil. While the number of bacteria in surface water is large, there is going on constantly processes of purification which keep the number in check.

First, there is sedimentation or the sinking of impurities by reason of their weight. The effect of sedimentation can be seen after floods, where the mud and dirt is found over the flooded areas. Sedimentation takes place slowly; so in streams that are flowing fast it cannot be relied upon to remove much of the impurities. Aëration is another factor. This means the mixing of water with air, as takes place, for example, in water-falls. It does not destroy the bacteria but it removes objectionable odors. Sunlight exerts a powerful destructive action on the bacteria in water, provided the depth of the water is not too great for the sunlight to penetrate. Unfortunately, the penetrating power of sunlight is not great; so its action is limited to the upper layers of the water. The ground water is purified by the filtering action of the soil, which is very efficient, provided the amount of water to be filtered is not too great and it is not required to work continuously.

The ordinary soil bacteria in water are harmless. It is only the pathogenic bacteria in the soil from human excreta, like the typhoid and dysentery bacilli and the cholera spirilla, that get into the water and cause disease. In testing the water to see whether it can transmit these diseases or not, it is almost useless to look for the disease-producing bacteria themselves, because they are extremely difficult to find. The presence of intestinal bacteria is looked for, particularly the colon bacillus, and when they are found in large numbers the water is condemned for drinking pur-

poses: first, because drinking-water should not contain substances excreted from the intestines of man or animals, and, secondly, water that does contain such substances is constantly open to infection with bacteria that produce disease.

Artificial methods of purification

Nowadays practically all surface waters are contaminated with human sewage. To render these waters safe for drinking purposes in cities, the natural process of water purification cannot be relied upon, and artificial methods, based on filtration, are employed. The water may be made to percolate through beds made of fine gravel and covered with a thick layer of fine sand. The dirt and slime in the water cling to the small particles of the sand, and only the water free from its impurities is permitted to pass through. About 90 per cent. of the bacteria in water can be removed by sand filtration. In mechanical filtration, a chemical substance like alum is added to the water in sufficient quantity to coagulate the solid and extraneous materials, which sink and carry the bacteria with them. In the home, water may be rendered pure by filtration through porcelain filters, and, where these are not available, by boiling. The flat taste of boiled water may be removed by passing the water from one container to another so that air may be mixed with it.

CHAPTER XI.

DISEASES CAUSED BY PROTOZOA.

In the classification of micro-organisms in Chapter II, they were divided into two great classes: those belonging to the animal and those belonging to the vegetable kingdom. So far we have studied only the vegetable micro-organisms—the molds, yeasts, and bacteria. The protozoa (sing. protozoon) represent the lowest form of animal life, and are composed of a single cell made up of a nucleus surrounded by a mass of protoplasm. The protoplasm is concerned with the nutrition of the cell, while the nucleus controls the vital functions, particularly reproduction. Comparatively few of the many species of protozoa are known to be pathogenic for man. The life cycle of the protozoa is peculiar in that part may be lived in the body of some animal, and part outside the body. During the cycle they may take on various shapes and sizes.

AMEBIC DYSENTERY.

This is a chronic form of dysentery, frequently associated with abscess of the liver, which is especially prevalent in the tropics, in fact the disease is sometimes called tropical dysentery. It occurs frequently in the southern part of the United States. Two cases, one with abscess of the liver, have come under the observation of the writer. In both instances the patient

(115)

had not been outside of the State of New York in several years.

Two species of amebæ are found in man, one is pathogenic, the *Entamœba hystolitica,* the other is harmless, the *Entamœba·coli.* They exist in both a vegetative and encysted form. The vegetative form is not so infectious as the encysted form, the latter being much more resistant.

Structure　　In structure the ameba, in the vegetative form is composed of an outer clear zone and an inner granular zone of protoplasm which contains the nucleus. The protoplasm frequently contains cavities called vacuoles. It moves by extending a portion of the outer clear zone, called a pseudopod, into which the rest of the cell body flows. These pseudopods may also embrace small particles of food and take them into the body of the cell.

In the encysted stage the outer layer of protoplasm becomes dense and forms a cyst wall. There is no motility in this stage.

Reproduction takes place either by simple division or by budding, in which a portion of the nucleus and the protoplasm protrude from the margin and are eventually pinched off to make a new cell.

The infection with amebæ comes chiefly from chronic carriers. Those having to do with the preparation of food are especially dangerous. It is in the encysted form that the ameba is most infectious.

The ingested amebæ lodge in the intestine and cause changes leading to ulceration. They frequently find their way into the liver to cause abscess formation.

The stools contain the amebæ and to prevent the disease from spreading, they should be disinfected with a 5 per cent. solution of carbolic acid. Carriers should be isolated.

The diagnosis of amebic dysentery is made by finding amebæ in the stools. This is done by examin-
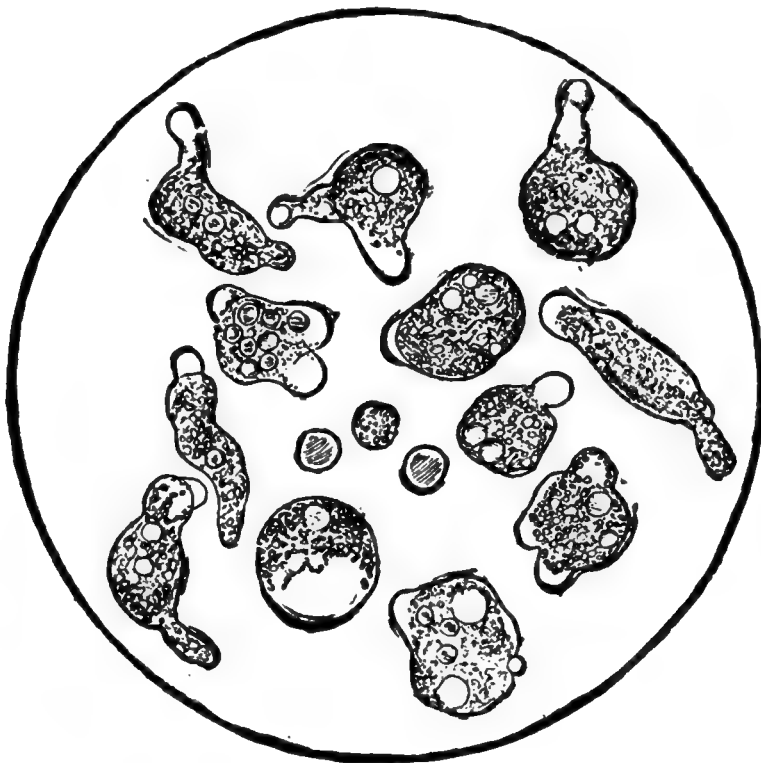
Fig. 16.—Ameba coli. From dysenteric stool. (Zeiss Apochr., 1; oil immersion, ¹⁄₁₂.) (After *Lösch.*)

ing the mucus or pus in the stool under the microscope. If the vegetative form is looked for the material must be kept warm in order to preserve the motility. The encysted form is seen best in stained preparations. The disease is of long duration but much success follows the ingestion of ipecac or its active principle, emetin.

SYPHILIS.

This disease is caused by the *Treponema pallidum* belonging to the class of protozoa and characterized by having no undulating membrane and having a flagellum at each end. It is a very delicate spiral having from 3 to 12 turns. It is actively motile.

The organism was discovered by two German investigators, Shaudium and Hoffman in 1905, and in 1912 Dr. Noguchi at the Rockefeller Institute was successful in cultivating them.

Path of infection
The infection takes place through small injuries or cracks in the skin or mucous membranes, and is spread, in the vast majority of cases, through sexual intercourse. On this account, syphilis has been termed a venereal disease. It is quite possible to become infected in other ways. People with syphilitic sores in the mouth may transmit the infection to others by kissing or from drinking-glasses or eating-utensils that they have used. Wet-nurses may become infected by nursing a child that is infected. Physicians may become infected in the performance of professional duties, as in the examining of patients and in the attendance of women in confinement. Nurses can be infected from the sores of patients under their care. This kind of infection is, fortunately, not very common, and may be prevented entirely by careful disinfection of the hands after attending such cases, or by the use of rubber gloves. Children may be infected in the uterus or, during labor from sores in the vagina.

Infection manifests itself first by a sore called a chancre, which develops from three to six weeks after exposure. It may be located anywhere on the body, but is always at the point where infection entered. The organisms are at first localized in the primary sore, but very soon spread to the glands near by, and then to
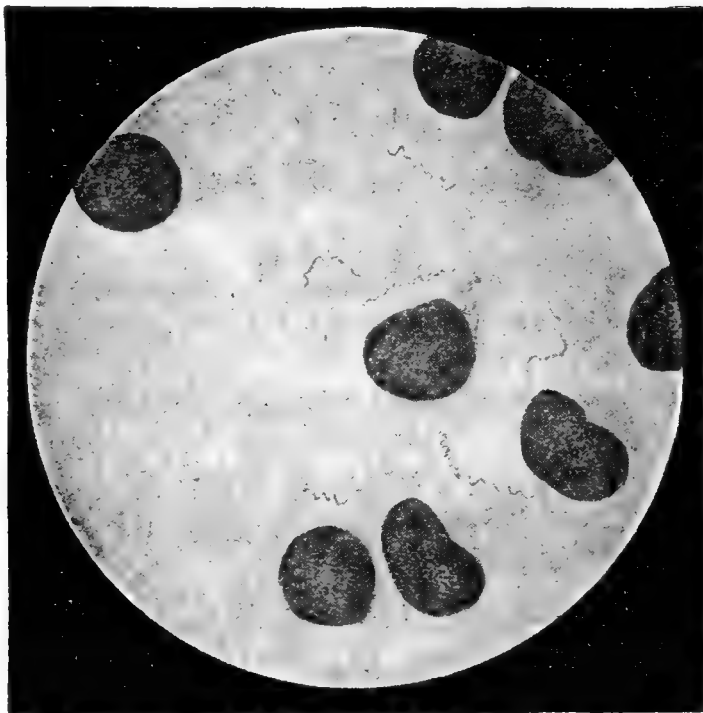
Fig. 17.—Treponema pallidum in smear from secretion of a fresh, hard chancre. The dark spots represent the red blood-cells; the light, wavy lines the spirochetes. ×1000. (After *Lenhartz*.)

the blood, causing a general infection. The result is a general skin eruption, sore throat, fever, and anemia,— symptoms that develop in from six to twelve weeks after the chancre, and mark the beginning of the secondary stage. Later the spirochetes become localized in certain tissues, particularly the brain and spinal cord,

and often lead to the formation of nodules which have a tendency to become soft and cheesy. A nodule of this sort is called a gumma and is characteristic of the tertiary stage of syphilis. The very late manifestations of syphilis affecting the brain and spinal cord are most serious; two of them, general paresis and locomotor ataxia are always fatal.

The presence of syphilis may be detected by examining the serum from the sores for treponema. This may be done by mixing the serum with a drop of India ink or, better, by the dark field illumination. In either of these methods the treponema appears very brilliant in a dark background. This method is particularly valuable during the first stage while the infection is localized.

After the infection has been existent for two weeks or more the blood serum may be tested by complement fixation or Wassermann test. (See Chapter IV, page 42.)

Luetin reaction   Killed cultures of the spirochetes may also be utilized in diagnosis by injecting a very small amount of the culture into the superficial layers of the skin. This is called the luetin test, and was devised by Dr. Noguchi. A successful or positive test is shown by the development of a hard, inflamed, nodule, at the point of injection, and is due to the hypersensitiveness of the skin to the syphilitic poison. The test is of value only in the later stages of the disease, when the complement-fixation test is frequently not successful.

THE SPIROCHETE OF RELAPSING FEVER.

The cause of relapsing fever is a group of spirochetes, the individual members of which differ in minor details in the various countries where the disease prevails. The spirochetes are long, delicate, threads with four to ten spirals and an undulating membrane which
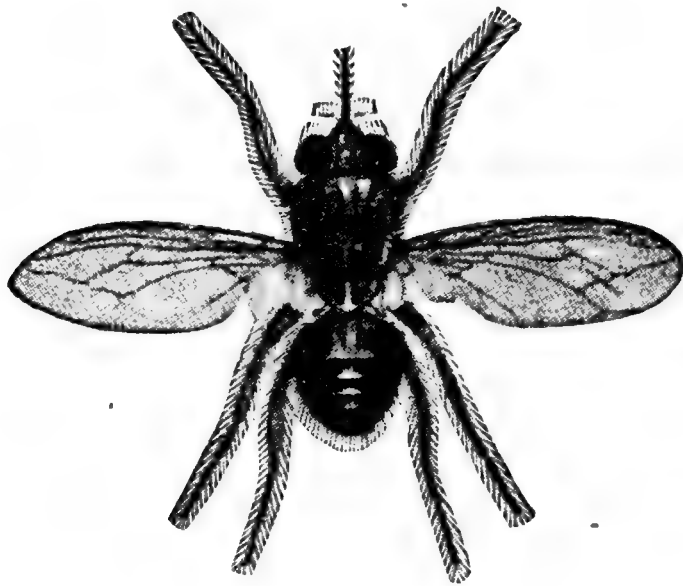
Fig. 18.—The tsetse fly.

propels them about actively. They can be found in the blood of those sick with the fever by dark field examination or in stained smears. At present the infection is most widespread in India and Africa, but sixty to seventy years ago epidemics occurred in this country.

People infected with spirochetes develop a fever of relapsing type. First there is a period of fever lasting from five to seven days, then a period of remission of the same duration. It is spread by the bites of lice and ticks which become infected by sucking the blood of

patients having the disease. One attack usually confers immunity. In preventing the spread of the disease it is important to isolate the patient and disinfect the bedding, clothing, and apartments. Particular attention should be given to the extermination of lice and ticks.

Vincent's Angina.

This is an infectious disease of the gums, mouth, or throat, characterized by the formation of a membrane which may be identical with the diphtheritic membrane, or by ulcerations which have a punched-out appearance. In smears made from the membranes or ulcers, large, fusiform bacilli, broad in the middle, with tapering ends and long spirilla, are constantly found and are supposed to be the cause of the infection. It is the belief now that the spirilla are but a later stage in the development of the fusiform bacilli. As both forms are difficult to cultivate, the diagnosis must be made by examining smears made directly from the throat. These organisms may be present with the bacilli of true diphtheria, and are said to aggravate the infection. (See Fig. 12, page 93.)

The disease is usually mild and responds fairly promptly to local treatment, but in some cases where the nature of the infection has not been recognized and properly treated, the ulceration and destruction of tissue in the throat may be extensive. It is spread directly from person to person through the secretions from the mouth. The danger of becoming infected is not great.

MALARIAL FEVER.

Malarial fever is an acute infection caused by a protozoan parasite. It is characterized by intermittent chills and fever and sweats, and accompanied by anemia. There are three types of the fever caused by three species of the parasite: the tertian type, with chill and fever every third day; the quartan, with
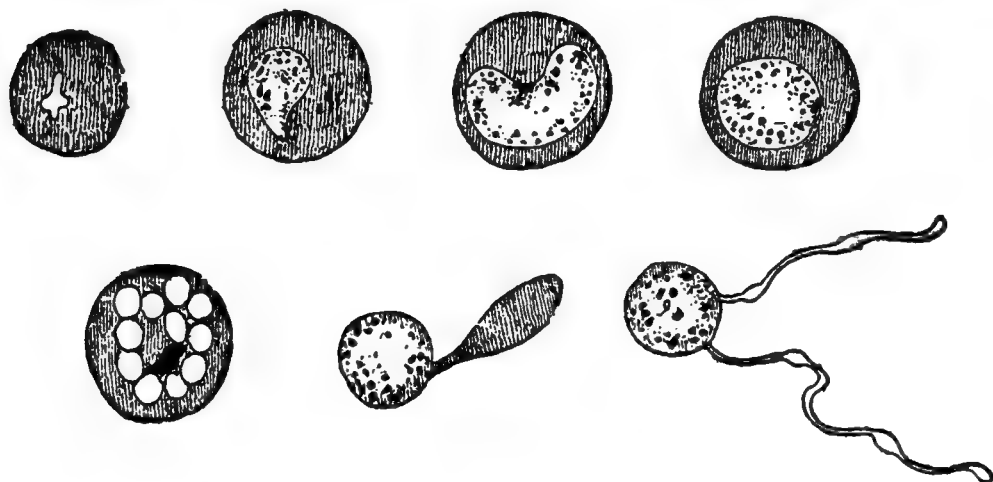
Fig. 19.—Plasmodium vivax, parasite of tertian fever. In the upper row and on left of lower row, various stages of intra-corpuscular development; the two last figures in lower row are free sexual individuals, microgametocytes (sperm cells), which are about to set free the microgametes, or males. (After *Reinhardt*.)

chill and fever every fourth day; and the estivo-autumnal, with an irregular fever like typhoid.

The disease is transmitted from one person to another by the female mosquito of the genus Anopheles. They can be distinguished from the ordinary mosquito, the Culex, by their position when they alight. The body of the Culex is always parallel to the surface, while the body of the Anopheles forms a sharp angle with it. When the Anopheles feeds on

infected blood the malarial parasites are taken into the stomach and undergo reproduction. After seven to ten days they find their way to the salivary glands. When the mosquito bites man the parasites are excreted with the saliva into the wound. In the blood the parasites enter and develop within the red blood-cells. As they grow they fill more and more of the corpuscle and finally become segmented into smaller bodies that are to become parasites. When this development is complete, requiring forty-eight or seventy-two hours, depending upon the type of parasite, the red blood-corpuscle is ruptured and the segments and a toxin are set free in the circulating blood, causing the chill and fever that are so characteristic of the disease. In this way more and more blood-cells are attacked and destroyed, which explains the anemia.

The diagnosis is made by finding the parasites in the blood. They can be found by examining either fresh preparations or stained specimens. In the former the parasites can be seen inside the red blood-corpuscles as colorless bodies containing granules of pigment that are in active motion. In the stained specimens the parasites are motionless, but are much more distinctly seen.

The spread of malaria is controlled by all measures that aim at the extermination of the mosquito. As the mosquito lives and breeds in swamps and ponds, attention should be directed to these places first. The larvæ from which the mosquito develops live and grow near the surface of stagnant water. If oil is spread

on the water the larvæ cannot hatch out into mosquitoes. Swamps, when it is practical to do so, should be drained or filled in. In districts where malaria is known to exist, the house should be screened.

TRYPANOSOMES.

A trypanosome is a long micro-organism with spirally twisted body. On one side is a membrane the edge of which is cord-like and extends beyond the body to form a whip or flagellum. The wave-like movements of the membrane and the movements of the flagellum propel the trypanosome about. The protoplasm is granular and contains two nuclei. Reproduction takes place by a longitudinal splitting of the whole cell body. The life cycle is not clear, but in some species at least there is development in an intermediate host, generally some species of fly.

There are about 60 species of trypanosomes, many of which are pathogenic for animals but only two are known to cause disease in man. The *Trypanosoma gambiense* is the cause of the Sleeping Sickness, a disease prevalent in equatorial Africa.

One of the natural hosts of the parasite is the crocodile and a species of fly, the *Glossura palpales,* that feeds on the blood of these animals and transmits the infection to human beings. Trypanosomiasis or the sleeping sickness, is a chronic disorder marked by fever, wasting and lethargy. The parasites can be found in the blood but more often in the cerebrospinal fluid. No way of establishing immunity is known.

CHAPTER XII.

DISEASES CAUSED BY UNKNOWN MICRO-ORGANISMS.

UNDER this head are placed a number of diseases in which no micro-organism has been definitely demonstrated as the cause.

SCARLET FEVER.

The infection almost always occurs from direct contact; entering the sickroom may be exposure enough to cause the disease. Objects which the patient has touched will transmit the infection such as linen, clothing, furniture, and playthings. Physicians and nurses sometimes carry the infection, although they themselves may not be affected. Milk has been known to carry the infection and cause serious epidemics. The milk in such cases is infected at the dairy by someone who has the disease. The infection may be transmitted at any time during the disease by the secretions from the nose and mouth and from the skin, during the period of desquamation.

In order to prevent it from spreading, the sick room in private homes should be as far away as possible from the room occupied by other members of the family. Admission to the room should be denied to everyone except the physician and the nurse. The physician should wear a gown and cap when entering

(126)

the room, and should pass directly out of the house after visiting the patient. The nurse, too, should wear a gown over the uniform and a cap over the hair, both being removed when it is necessary to go to other parts of the house. During the period of desquamation skin should be kept anointed with plain or carbolized vaselin, as preferred, in order to keep the particles of skin from spreading about. Quarantine may be raised when the desquamation has completely ceased. Before the patient is discharged a full bath in weak bichloride of mercury solution, 1 : 10,000, should be given, taking particular care to cleanse the hair. The room and contents should be disinfected after the manner already described.

Immunity is conferred by one attack. Some success in the treatment of the disease has resulted in the transfusion of blood from patients recently recovered.

MEASLES.

Measles is a contagious and infectious disease that generally occurs during childhood, although adults may contract it. It spreads with great rapidity and generally in epidemics. The specific agent of infection is probably inhaled, causing the first symptoms to appear in the nose and throat.

The infectious material is undoubtedly in the secretions of the nose and throat of the sick patients. It may be spread by the attendants on the patient, by furniture, hanging, carpets, by flies and insects. In preventing the spreading of the disease special atten-

tion should be given to destroying the secretions from the nose and throat. These should be collected in paper bags and burned. The patient should be quarantined until the skin and mucous membranes are clear. After recovery the room should be disinfected.

Rubella, or German Measles.

The infection is very much like measles, but is usually not so severe. In preventing its spread the same precautions should be taken as in measles.

Variola, or Smallpox.

Smallpox is an acute infectious disease characterized by a skin eruption that passes successively through the stages of papule, vesicle, pustule, and crust, and usually leaves a depressed scar. The infectious agent is in the pustules, secretions, excretions, and in the breath. The scales are particularly infectious, forming a part of the dust in the room and becoming attached to the furniture, hangings, and clothing. The poison is very tenacious and remains virulent for months.

In caring for smallpox patients the first thing to do is to isolate them, preferably in a building removed from other dwellings, because of the possibility of the virus being carried in the air. The strictest quarantine should be enforced not only of the patients, but of the attendants. Everyone that has been exposed to the contagion should be vaccinated and kept under obser-

vation for sixteen days. During the illness the discharges from the mouth, nose and intestines should be disinfected. The quarantine must be maintained until the skin is entirely free from crusts and scales.

The methods and principles of immunization to smallpox have been described under the subject of immunity.

CHICKEN-POX, OR VARICELLA.

This is an acute infectious disease of children. It is spread in the same manner as smallpox, but to prevent its spreading the precautions need not be so rigidly enforced because it is not so serious an infection. The patient is kept from contact with other children, and after the recovery, the room should be disinfected.

RABIES, OR HYDROPHOBIA.

Rabies is a disease common among animals, particularly dogs, although cats, cattle, and horses may be infected. It is transmitted from one animal to another, and to man through the saliva from the bites of rabid animals. The poison acts upon the tissue of the brain and spinal cord, being carried there along the nerve trunks. The incubation period is usually from forty to sixty days.

In animals the disease begins with a stage of excitement and restlessness, followed by depression, difficulty in swallowing, and paralysis. In man there is first headache and depression, later difficulty in swal-

lowing, and spasm of the muscles of respiration. The spasms are very painful and may be induced even by the sight of water. This is the origin of the name hydrophobia, which means fear of water.

All efforts to find the cause of the infection in the brain and spinal cord have been fruitless. Peculiar bodies, called Negri bodies, are quite constantly found in the brain and spinal cord, which many believe are parasites belonging to the animal kingdom, and classed as protozoa. The diagnosis of rabies can be made either by finding the Negri bodies or by reproducing the disease in rabbits by inoculating them in the brain with portions of the spinal cord of rabid animals.

Immunity
It is due to the studies of Pasteur that we are able to immunize against rabies. He found that the virus of rabid dogs could be intensified by inoculating a series of rabbits until the inoculation period could be shortened to six or seven days. The spinal cords of rabbits inoculated in this way contain the virus in its most concentrated form, and is spoken of as the fixed virus.

The fixed virus may be attenuated by drying the spinal cords and, if human beings are now inoculated with portions of the tissue, beginning first with the most attenuated and then with more and more virulent tissue, an active immunity is established. This is the method now in use in the treatment of persons who have been bitten by rabid dogs, and it can be applied during the forty- to sixty- day incubation period. It has proven very successful. In the last ten

years 50,000 people have been immunized in this way, with failure in only 1 per cent. In cases of dogbites where there is a suspicion that the animal is rabid the wound should be cauterized with pure nitric acid. The animal should not be killed but kept in confinement. If it is rabid it will develop unmistakable symptoms and die in five or six days. The whole head of the dog should be sent at once to the nearest laboratory where the diagnosis can be made.

Yellow Fever.

This is an acute infectious disease the cause of which is unknown, but it has been proved that the infection may be transmitted by a certain kind of mosquito called the *Stegomyia fasciata*. The blood of yellow fever patients contains the virus for a period of three days during the sickness, and as the stegomyia feeds on the blood of the patient during this time, it becomes infected. The mosquito cannot transmit the infection at once; not until twelve days have elapsed.

Yellow fever is primarily a disease of the tropical climate, particularly of the Spanish-American countries. It is occasionally imported to the temperate climate, as numerous epidemics in the seaport cities of the United States testify. To prevent the spread of the disease efforts must be directed to the destruction of the breeding places of the mosquitoes, and to prevent them from biting yellow fever patients. The former means the complete cleaning up and draining of the swamps and marshes. All yellow fever patients must

Distribution

Prevention

be screened to prevent the mosquitoes from biting them. In countries where the infection prevails all houses should be screened. Such measures as these rendered the Panama Canal Zone, formerly a hotbed of yellow fever, a safe place in which to live.

ACUTE ANTERIOR POLIOMYELITIS.

This is an acute infectious disease affecting the gray matter of the spinal cord, causing paralysis of groups of muscles. It occurs in epidemic and sporadic form. It affects children particularly, and while the mortality rate is low the deformities resulting from the paralysis are very disfiguring.

Recently Drs. Flexner and Noguchi, at the Rockefeller Institute in New York, have been successful in cultivating an organism from the spinal cords of fatal cases of this disease. By inoculating monkeys with the cultures, they have reproduced the disease, and, after the death of the animals, have recovered the organism from the spinal cord.

How the infection is spread is not known. It is assumed that the discharges from the nose and throat are infectious; so they should be collected and destroyed. As an added precaution the patient should be isolated.

The treatment of the patient with the blood serum of recently recovered cases has been attended with some degree of success. The serum is introduced directly into the spinal canal by lumbar puncture. The earlier in the disease the serum is given the better is

the prospect of success. This treatment seems to arrest the paralysis but has no affect on it after it has once developed.

ACUTE RHEUMATIC FEVER.

This disease is generally conceded to be infectious, but the cause is as yet unknown. Several kinds of bacteria, among them the streptococci and staphylococci, have been described as its cause. They have been cultivated from the joints, blood, tonsils, and heart-valves of rheumatic-fever patients. An infection very much like rheumatic fever has been produced by inoculating animals with the cultures. It is not certain, however, whether these organisms are present as the actual cause of the disease, or only as secondary invaders.

MUMPS.

This is an acute infectious disease affecting the salivary glands in infants and young adults. It is contagious, being spread directly from one patient to another. The infectious agent is unknown.

TYPHUS FEVER.

In 1914 Plotz described a Gram positive organism isolated from the blood of typhus fever cases. It will grow only in the absence of oxygen and in shape may be curved, straight, or coccoid. The same organism has also been isolated from the blood of guinea pigs and monkeys that have been infected with typhus blood. It has not as yet been accepted as being the cause of typhus.

CHAPTER XIII.

THE TECHNIQUE OF PREPARATIONS FOR AND THE COLLECTION OF MATERIAL FOR BACTERIO- LOGICAL EXAMINATION.

IT is not strictly a part of the nurse's work to collect specimens for bacteriological examination, but sometimes the occasion arises when the nurse can render valuable assistance by knowing how to do these things. On the other hand the preparation of the patient for bacteriological procedures, such as punctures for aspirating fluids and the making of cultures from the circulating blood, is quite properly within the duties of the nurse. The directions that follow will serve as a guide, but may need to be modified or changed according to the ideas of the physician in attendance.

THE COLLECTION OF URINE.

The collection of specimens

A sterile test-tube plugged with cotton is used to collect the urine, and the urine must be obtained by catheter. The usual technique is followed in preparing the patient, the catheter introduced, and the first part of the urine allowed to escape. The cotton plug is now twisted out of the tube, the mouth of the tube passed through the flame of an alcohol lamp, and the urine allowed to fill the tube one-half or three-fourths full. The stopper is then replaced and the tube kept in the upright position.

(134)

Sputum.

Specimens to be examined for tubercle bacilli should be collected in clean, wide-mouthed bottles that can be tightly corked to prevent leakage. If the outside of the bottle has been soiled by the sputum, it should be washed off with a 5 per cent. solution of carbolic acid. Sputum to be examined for the pneumococcus, influenza bacillus and other organisms should be collected in sterile wide mouthed bottles. Only sputum coughed up from the lower air passages and unmixed with saliva, should be sent.

Feces.

The stool may be passed directly into a sterile fruit jar or into a sterile bed-pan and then transferred to the fruit jar. The specimen may be transferred either by pouring or with a sterile wooden spatula. If the stool is to be examined for typhoid or dysentery bacilli, dip a sterile cotton swab into the stool and place into a sterile test tube plugged with cotton. If amebæ are suspected the stool should be kept as near body temperature as possible and submitted to the laboratory with as little delay as possible.

Blood for Widal Reaction.

The blood is obtained best by pricking the lobe of the ear with a needle having a cutting edge. The skin should be cleansed with alcohol, and the needle must be sterile. The best way to collect the blood is in a

capillary glass tube by placing one end in the drop of blood and lowering the other end enough to allow the blood to flow in easily, until the tube is one-half full. If a capillary tube is not at hand, the blood may be collected on a glass slide or on glazed paper, like a calling card. The blood drops should not be smeared out but allowed to dry as drops.

Throat Cultures.

Outfits for making throat cultures are supplied by the Bureau of Health in most cities, and consist of a sterile swab in a test-tube and a tube of culture medium. The patient is placed in a good light, the tongue held down by a tongue-depressor or spoon-handle, and the swab rubbed over the inflamed part of the throat. The material on the swab is then rubbed directly over the surface of the culture medium. After use the swab may be burned or replaced in the tube and sent with the culture.

Pus.

When the amount of the pus is sufficient, it may be collected directly into a sterile test-tube. If cultures are made, the swab and culture tube of a throat-culture outfit may be used. The pus is collected on the swab and then rubbed over the culture medium, just as in making a throat culture.

Milk and Water.

Specimens should be collected in glass-stoppered bottles, of 4- or 6- ounce capacity, which are sterile. Specimens of milk should be well mixed before the sample is taken. Specimens of both milk and water must be kept cold and, if it is necessary to send them any distance, they must be packed in ice.

All kinds of specimens should be labeled with the names of the patient, the physician, the date, and character of the examination desired.

Aspirations and Blood Cultures.

The preparation of the patient for the aspiration of fluid from the body cavities, for lumbar puncture, and cultures from the blood must be performed with the greatest care, to insure the patient against infection and to prevent the contamination of the specimen with other bacteria, particularly those in the skin.

For aspirations of the chest or joints and for lumbar puncture, the skin should be cleansed with benzene and then tincture of iodine applied. In taking cultures from the blood this method is not always suitable, because the tincture of iodine discolors the skin so much that the veins cannot be seen clearly. The veins usually selected are at the bend of the elbow. The skin is cleansed first with green soap and water, then with alcohol and ether. A towel wet with bichloride of mercury is placed over the skin and allowed to remain for one hour. Before the culture is taken the

Technique of making preparations

skin is again washed with ether. A bandage or piece of rubber tubing is placed somewhat above the elbow, and tight enough to cause the veins to stand out so that they can be more readily punctured. The blood is drawn into a sterile glass syringe and introduced directly into the culture media.

Specimens of spinal fluid should be delivered to the laboratory as quickly as possible in order that the leucocytes, which degenerate quickly may be counted.

Fluid aspirated from the chest, joints, or peritoneal cavity should be well shaken to prevent the fluid from clotting.

GLOSSARY.

Abrasion. A spot rubbed bare of skin or mucous membrane.

Accessory sinuses. Cavities in the bones of the skull, some containing blood and some air.

Aërobic. Requiring air or free oxygen for growth.

Agglutinin. An antibody that has the power of clumping bacteria.

Allergy. Hypersensitiveness of the body to foreign protein.

Amboceptor. A thermostabile substance which on combination with complement and antigen produce cytolysis.

Anaërobic. Able to live only in the absence of free air or oxygen.

Analine dyes. Colors derived by chemical process from coal tar.

Anemia. A condition in which the blood is lacking either in quality or quantity.

Animalcules. Very small animal organisms.

Antibody. Substances that protect from an infecting agent.

Antigen. Any substance that produces antibodies.

Antitoxin. A proteid substance developed in the body of man or animals that has the power of neutralizing poisons.

Arthritis. Inflammation of a joint.

Attenuation. The diminished power of an organism to produce disease.

Anaphylaxis. The induction of disease, as opposed to prophylaxis.

Bacillus (pl. bacilli). A rod-shaped organism belonging to the vegetable kingdom.

Bactericidal. Possessing the power of destroying bacteria.

Bacterins. Killed bacteria suspended in fluid and injected under the skin in the treatment of some diseases. Also called vaccines.

(139)

Bacteriology. The study of bacteria.

Bacteriolysins. Substances developed in the body which are capable of dissolving bacteria.

Bacterium (pl. bacteria). A unicellular organism belonging to the vegetable kingdom.

Binary fission. The method of multiplication of bacteria in which the organism splits in half.

Carbohydrates. A compound composed of carbon, hydrogen, and oxygen.

Carrier. A person, not sick with any disease, who carries disease-producing organisms in the body and is capable of infecting others with them.

Cell. The smallest unit of structure in plant and animal life.

Cellulitis. An inflammation in the soft tissues of the body

Chancre. The primary sore at the point of infection in syphilis.

Coccus. A bacterium having a spherical shape.

Colony. A mass of micro-organisms of the same kind that has developed from one organism.

Contagion. The transmission of disease by mediate or immediate contact.

Culture. A mass of micro-organisms growing on laboratory culture media.

Cystitis. Inflammation of the urinary bladder.

Deodorant. A substance that destroys objectionable odors.

Disinfectant. A physical or chemical agent that destroys bacteria.

Empyema. A collection of pus in the pleural cavity.

Endocarditis. An inflammation of the lining of the heart.

Endotoxin. A poison retained in the body of a bacterium and set free when the bacterium disintegrates.

Enzyme. An unorganized ferment formed in the bodies of plants and animals capable of splitting complex substances into simpler forms without being changed itself.

Erysipelas. An acute spreading infection in the skin.

Etiology. The study of the causes of disease and the way disease is transmitted.

Fermentation. The decomposition of complex substances into simpler forms by the action of a ferment.

Flagellum (pl. flagella). A whip-like process extending from the body of a bacterium which propels the organism about.

Filtration. The passage of fluid through a filter to remove the solid particles.

Hemoglobin. The coloring matter contained in the red blood-corpuscles which gives the blood its red color.

Hemolysis. The solution of red blood cells.

Immunity. The resistance of the body to disease.

Incubation. The period between the entrance of disease-producing bacteria into the body and the signs and symptoms of disease.

Infection. The entrance into the body of bacteria resulting in injury or disease.

Inhibition. The arrest or restraint of bacterial growth.

Inoculate. To put infectious material into the body to produce disease or into culture media to produce bacterial growth.

Larva (pl. larvæ). The stage of insect development after it leaves the egg in which it resembles a worm.

Lesion. An abnormal condition of any tissue or organ due to injury or disease.

Leucocyte. The white blood-corpuscle of the blood.

Luetin reaction. A skin test for the detection of syphilis.

Lumbar puncture. The introduction of a needle into the space around the spinal cord for the removal of the cerebrospinal fluid.

Medium (pl. media). The material used for the cultivation of bacteria.

Meningitis. An inflammation of the membranes covering the brain and spinal cord.

Morphology. The study of the form and structure of bacteria.

Mycelium. The thread-like processes of fungi.

Necrosis. The death of tissue.

Negri bodies. Minute bodies found in the brain of persons and animals infected with rabies.

Nucleus (pl. **nuclei**). The spherical body found in cells which controls its life and activity.

Opsonin. A substance in the blood-serum which makes bacteria more easily absorbed by the leucocytes.

Orchitis. An inflammation of the testicle.

Organic. Relating to substances derived from living organisms.

Osteomyelitis. An inflammation of the medullary cavity of bone

Otitis media. An inflammation of the middle ear.

Papule. A small, solid elevation of the skin.

Parasite. A plant or animal that lives on or in another living organism.

Pasteurization. The arrest of bacterial growth by heat.

Pathogenic. Disease-producing.

Phagocyte. The white blood-corpuscle of the blood that envelops and destroys bacteria.

Pericarditis. An inflammation of the covering of the heart.

Pseudopod. A transient protrusion of the protoplasm of an ameba.

Protozoön (pl. **protozoa**). A unicellular animal organism.

Prophylaxis. The prevention of disease.

Pyogenic. Pus-producing.

Puerperal fever. An infection starting in the uterus after childbirth.

Pustule. A small elevation of the skin containing pus.

Quarantine. Isolation on account of suspected contagious disease.

Saprophyte. An organism capable of living on dead matter.

Septicemia. The condition resulting from the invasion of the body by bacteria and the absorption of the poisons produced by them.

Spirochete. A spiral or corkscrew-shaped organism.

Spores. A form assumed by some bacteria to resist unfavorable influences.

Sterile. Free from micro-organisms.

Suppuration. The formation of pus.

Tenesmus. Ineffectual straining at stool.

Tuberculin. A preparation made from tubercle bacilli and containing their toxins.

Vaccine. See bacteria.

Vesicle. A small elevation of the skin containing serum.

Vacuole. A cavity in the protoplasm of a cell.

Virus. An animal poison capable of producing disease.

Virulence. Malignity; especially of a microbe.

Wassermann reaction. A blood-test for the detection of syphilis.

Widal reaction. A blood-test for the detection of typhoid fever.

INDEX.