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APPLIED BACTERIOLOGY FOR NURSES

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PREFACE

Bacteriology dominates so large a part of the art of nursing that a correct understanding of the more important facts and principles of that science is an indispensable part of every nurse's mental equipment. In the following pages emphasis has been laid on the immediate application of the subject to nursing, and only enough general bacteriology has been introduced to give the student a clear conception of the principles underlying her work. A perusal of the various chapters will show that a study of all the ordinary modes of transmission of infection has been presented. Many pathogenic bacteria have been omitted, because their discussion would have added little or nothing to the presentation of the principles already laid down. While there is no gainsaying the value of individual laboraatory exercises in the study of bacteriology, the writers feel that, so far as instruction to nurses is concerned, simple practical demonstrations by the teacher may very well be substituted for individual laboratory work. Suggestions for such demonstrations have been added at the end of the chapters.

New York City, *April*, 1913.

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GENERAL BACTERIOLOGY

CHAPTER I

HISTORIC

The fact that many diseases are caused by tiny living organism called bacteria is so universally accepted nowadays that it is hard to realize our real knowledge of bacteria is less than fifty years old. The discovery of the relation between bacteria and disease has revolutionized medical practice, and has resulted in the saving of countless lives which formerly were lost.

It is true that, as far back as the seventeenth century, Leeuwenhoek, of Delft, Holland, had succeeded in constructing a strong magnifying glass by which he observed tiny, living organisms in tartar scraped from the teeth, in cheese, rain-water, decayed meat, feces, etc. And, although it was suggested that these minute organisms were the cause of a large number of diseases, no one succeeded in proving this relationship. Finally, in 1863, Davaine, a famous French physician, demonstrated that anthrax, a disease common in sheep and cattle, was caused by a bacterium If we seek for the reason why some two hundred years elapsed between the discovery of bacteria by Leeuwenhoek and the recognition of their rôle in the production of disease, we find that this was due to the mechanical imperfections of the microscope and to the difficulties surrounding the isolation and cultivation of these minute organisms. Thanks to the genius of Pasteur and of Koch these difficulties were successfully overcome, and the foundation of modern bacteriology securely laid. Prior to this, however, Lister, who had carefully followed Pasteur's work on fermentation, became convinced that infections following surgical operations were due to the introduction of bacteria. He accordingly devised what is known as "antiseptic surgery," whereby it was sought to kill all the germs which might gain access to the wound at the time of operation and at the subsequent dressings, and at once caused an almost complete disappearance of surgical infections.

Following the splendid work of Pasteur and Koch progress in bacteriology was marvelously rapid. The bacillus of typhoid fever was discovered by Eberth in 1880; the bacillus of tuberculosis, by Koch in 1882; the spirillum of cholera, by Koch in 1884; the diphtheria bacillus, by Klebs and Löffler in 1883; the bacillus of lockjaw, by Kitasato in 1889, and so on.

We have already mentioned that following Leeuwenhoek's discovery of bacteria these organisms were held to be the cause of a great variety of diseases. In fact, for some time people seemed "bacteria mad." We now know that bacteria are associated only with a certain group of diseases which we call *infectious diseases*. An infectious disease is caused by a living germ, though not necessarily by a bacterium.[1] For example, typhoid fever, diphtheria, tuberculosis, and pneumonia are caused by bacteria; malaria and syphilis, by tiny germs known as protozoa[2]; while certain diseases of the hair and skin are caused by fungi.[3] The great importance attaching to infectious diseases as a class arises from the fact that they are communicable. Moreover, if the germ of a particular disease is known, the possibility is given of devising means to prevent the spread of the disease, *i. e.*, the transmission of the germ to others. For this reason it is important that nurses should have some knowledge of the nature and characteristics of germs. The study of germs is called bacteriology, and this usually includes not merely bacteria, but also protozoa and fungi. The term "microbe," so frequently used by the laity, is synonymous with the term "germ," and is usually taken to include the three classes of micro-organisms just mentioned.

[1] BACTERIA are microscopic, unicellular *vegetable* organisms that multiply by transverse division.

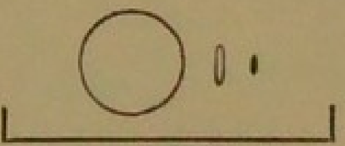
[2] PROTOZOA are microscopic, unicellular *animal* organisms.

[3] FUNGI are microscopic, multicellular *vegetable* organisms.

CHAPTER II

CHARACTER OF BACTERIA

BACTERIA are extremely minute living organisms. Seen under a powerful microscope they appear as little rods, spheres, or spirals. It is difficult for one unaccustomed to the use of a microscope to conceive of the size of these micro-organisms. They vary in size from $\frac{1}{50,000}$ to $\frac{1}{1000}$ inch, so that a tiny drop of pus often contains many thousand bacteria. Even a minute dust mote floating in the air may carry them. Bacteria are one-celled organisms, *i. e.*, each cell is a complete individual. There is no head, no tail, and not even the



$\frac{1}{1000}$ inch

Fig. 1.—Comparative size of human red blood-corpuscle, typhoid bacillus, and influenza bacillus (Jordan).

most powerful microscope reveals any special organs within the cell. The mode of life of bacteria is the simplest that can be conceived. Placed in suitable surroundings, a bacterium after a time divides and forms two bacteria. Each of these grows a little until of the size of the parent, and then, in turn, it also divides, forming two. And so the process goes on, each division giving rise to two bacteria in the place of one. Under proper conditions certain bacteria multiply very rapidly, division taking place about every twenty minutes. The number of bacteria produced from a single parent bacterium in twenty-four hours thus becomes enormous. It is perfectly obvious that this rate of growth cannot continue for very long, else the entire world would long ago have become merely one huge mass of bacteria. We shall study the conditions governing the growth and multiplication of bacteria in a subsequent chapter; suffice it here to say that further growth after a time ceases, owing to the accumulation of waste-products, the exhaustion of the food supply, etc.

In form, bacteria are more or less spheric, rod shaped, or spiral shaped. We call the first *cocci* (singu-

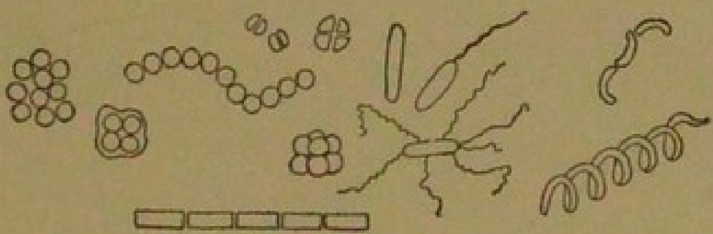


Fig. 2.—Forms of bacteria (Jordan).

lar *coccus*); the second, *bacilli* (singular *bacillus*), and the third, *spirilla* (singular *spirillum*). The first group is still further subdivided according to the manner in which the individual organisms tend to group themselves when multiplying. Thus a large class of cocci divide always in a single plane, and so give rise to a string of cocci appearing like a string of beads. Cocci growing in this manner are termed *streptococci*. In another large class the organisms divide in every plane, so that there is produced a mass having somewhat the appearance of a bunch of grapes. Cocci growing in this manner are termed *staphylococci*. Other cocci, on multiplying, arrange themselves in groups of two each, and these are termed *diplococci*, while still others arrange themselves in groups of fours, and these are termed *tetrads*. In medical bacteriology besides *bacilli* and *spirilla*, the *streptococci*, *staphylococci*, and *diplococci* play an important rôle.

In a preceding paragraph it was stated that bacteria multiplied when placed in proper surroundings. On the other hand, there is considerable variation in the

Fig. 3.—Bacillus tetani, showing spores. Pure culture on agar. Fuchsin stain (Kolle and Wassermann).

behavior of different species of bacteria when placed in unfavorable surroundings. Many quickly perish; others live for some time, and then gradually die off. Still others undergo a peculiar transformation into a highly resistant form known as spores. A *spore* is a round or oval body, usually highly refractive, and *possessing a high degree of resistance* against various destructive agents. Spores, as such, do not multiply, and may, therefore, be compared to seeds. A bacterium produces only a single spore. Spore formation is limited to the bacilli. The fact that spores are so resistant is practically important, and necessitates a careful study of the principles underlying sterilization. Among the spore-forming bacilli encountered in medicine may be mentioned the bacillus of tetanus (lockjaw), the bacillus of anthrax, and the bacillus of malignant edema.

Some bacteria possess the power to move about. They are, therefore, spoken of as being *motile*. By employing suitable methods the motile bacteria are seen to have little hair-like appendages, called *flagella* (singular *flagellum*), which act as swimming arms. Some bacteria have but a single flagellum, others have a little tuft at one or both ends, while still others have flagella on all sides. The typhoid bacillus is a good example of a motile bacterium; it has flagella on all sides.

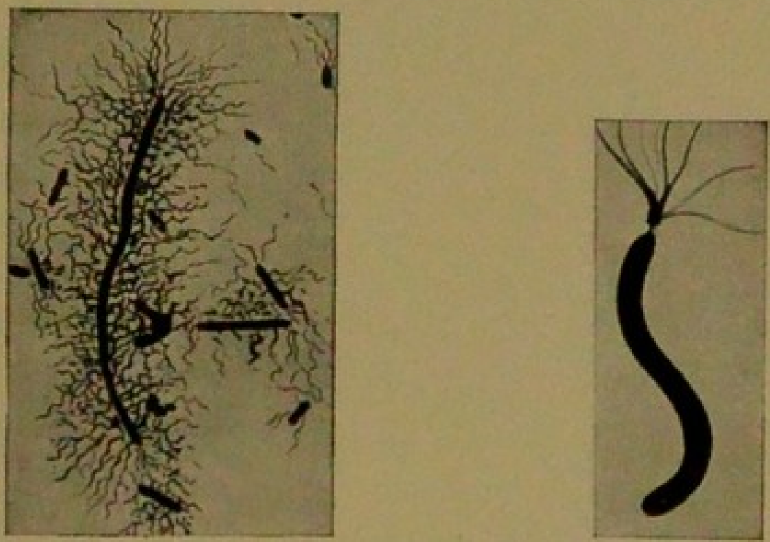


Fig. 4.—Flagella: Proteus vulgaris and large spirillum belonging to the group of sulphur bacteria (Zettnow).

It is well to remember that not all bacteria produce disease. In fact, those that do (the so-called *patho-*

genic bacteria) are only a small proportion of the bacteria thus far known. Many bacteria are very important in preparing food for plants, breaking down complex chemic substances into simpler substances suitable for plant absorption. Still other bacteria are useful in producing fermentations, in disposing of refuse, liquefying sewage, etc. Bacteria are found almost everywhere—in the air, in water, in the soil, and on everything we touch. Most of the bacteria of the air, however, are entirely harmless, although at one time it was believed that they caused the infection of wounds during surgical operations. Lister used to have a spray with dilute carbolic acid playing about the operating room during an operation in order to kill the bacteria which might be in the air. We have since found out that this is unnecessary.

It was stated above that bacteria multiplied enormously when placed under proper conditions. These conditions relate mainly to food supply, to the presence of a suitable temperature, sufficient moisture, absence of much light, presence or absence of oxygen, etc. We shall take up the points in the order named. In supplying living creatures with food, it is always well to have the composition of this as nearly as possible like that of their natural food. In the case of bacteria pathogenic for man and animals it is obvious that the food should have a composition resembling that of the animal body. This is accomplished by making use of broths, milk, blood-serum, and the like. The same principle applies to the temperature at which the bacteria are cultivated. Just as certain tropical plants require a different temperature to grow than do hardy northern plants, so do some bacteria require a warmer or a colder environment than others. Bacteria accustomed to grow in the body of warm-blooded animals usually grow best at a temperature near 100° F. On the other hand, the bacteria normally growing in water, for example, usually grow best at a temperature of about 60° F. Certain bacteria, growing in manure, grow best at a temperature considerably above 100° F.

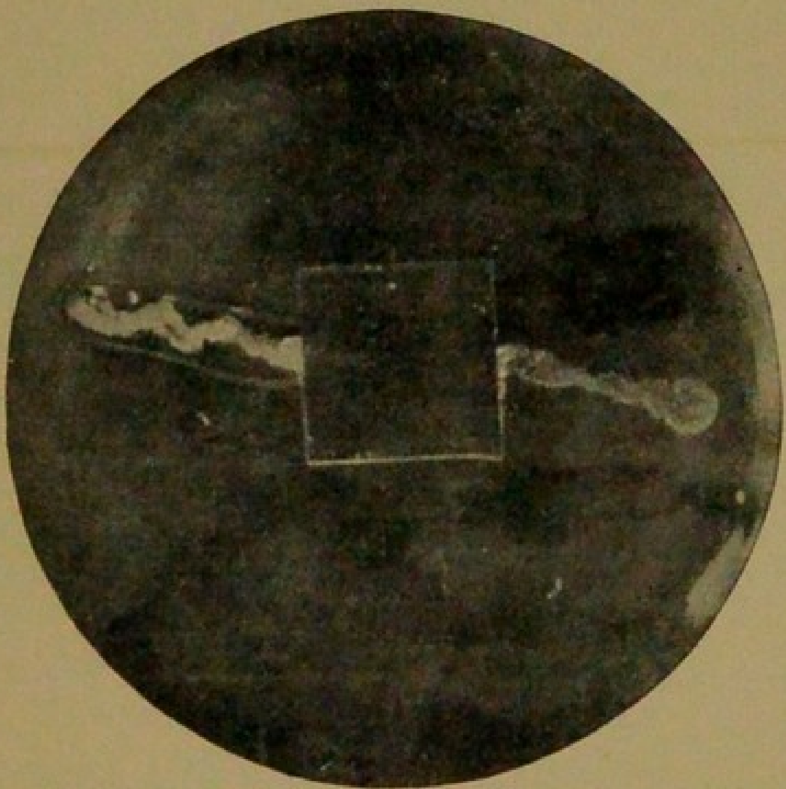


Fig. 5.—Streak culture of the potato bacillus (natural size), showing an aërobic organism which will not grow under a cover-glass (Williams).

All bacteria require a certain amount of moisture for their growth. Moreover, many bacteria die if they are allowed to dry.

The necessity for protecting bacteria which we wish to cultivate against an undue amount of light, particularly against sunlight, is understood when one recalls that certain of the light rays exert a destructive action on bacteria. In fact, so resistant a germ as the tubercle bacillus may be killed by several hours' exposure to direct sunlight.

So far as the effect of oxygen on the growth of bacteria is concerned, it is interesting to note that there are three large classes of bacteria, namely, those which require oxygen for their growth, those which will not grow if oxygen is present, and those which will grow

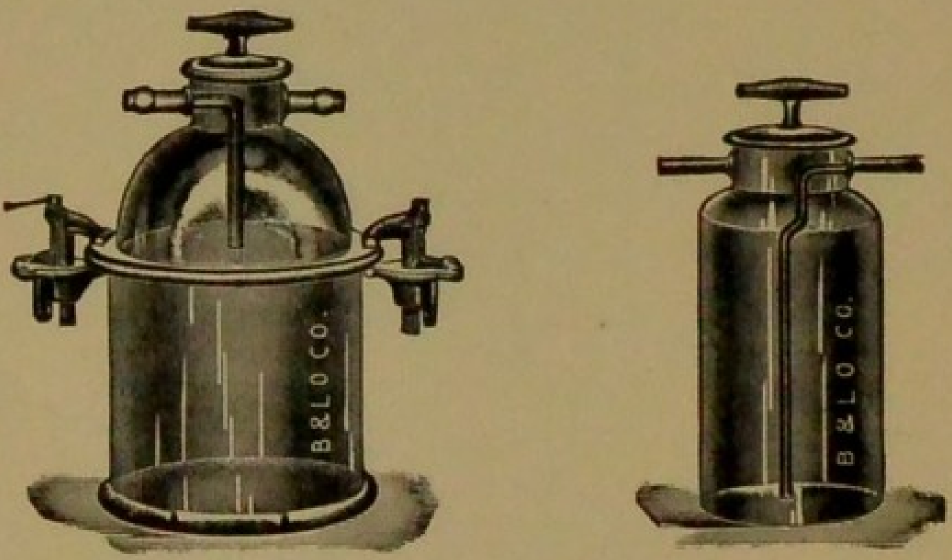


Fig. 6.—Novy's jars for anaërobic cultures.

whether oxygen is present or absent. The bacteria belonging to the first class are called *aërobes,* those belonging to the second class are *anaërobes,* and those belonging to the third class are called *facultative anaërobes.* The bacillus of diphtheria is an aërobe, so is that of tuberculosis; the bacillus of tetanus and that of malignant edema are anaërobes; the colon bacillus and the bacillus of anthrax are facultative anaërobes. Anaërobic cultures are conveniently grown in an atmosphere of hydrogen in a Novy jar, or they may be grown in an atmosphere of air from which the oxygen has been abstracted by means of chemicals.

Demonstration.—Moldy pieces of bread. A throat culture on Löffler serum, one or two days old. Teeth scrapings, under a cover-glass and magnified, unstained. Hanging-drop preparation, preferably of a motile organism (hay bacillus). Be careful that the objective of the microscope is not pushed through the cover-glass. Spores (an old culture of hay bacilli).

CHAPTER III

METHODS OF STUDYING BACTERIA

While bacteria can be seen with high-power magnifying glasses, it is impossible to study their form without a compound microscope. Such an instrument is shown in Fig. 7.

It consists of a heavy foot or base bearing an upright post, to which the stage and the tube are attached. The object to be examined is placed on the stage, and light is thrown up from the mirror beneath, through the object, and into the series of lenses in the tube. The tube is moved up and down by means of two screws, one called the coarse adjustment, the other called the fine adjustment. Fitting into the upper end of the tube are various eye-pieces or oculars. These are of varying power and are usually numbered from 1 to 5. Attached to the lower end of the tube is a so-called nose-piece, carrying two or three "objectives," each objective consisting of a series of lenses mounted together. The objectives are usually distinguished by numbers (3, 5, and 7) or by fractions ($\frac{2}{3}$, $\frac{1}{4}$, and $\frac{1}{8}$ inch). When using the higher powers of the microscope it is important to have strong illumination from the mirror. In order to bring this about a series of lenses, called the condenser, is placed between the mirror and the stage. But even with this equipment it is difficult to study the finer details of bacterial structure. This can only be satisfactorily accomplished by staining the bacteria and examining them by means of very high-power objectives, which dip into a drop of cedar oil placed directly on the specimen to be examined. Such objectives are spoken of as oil-immersion objectives; the one

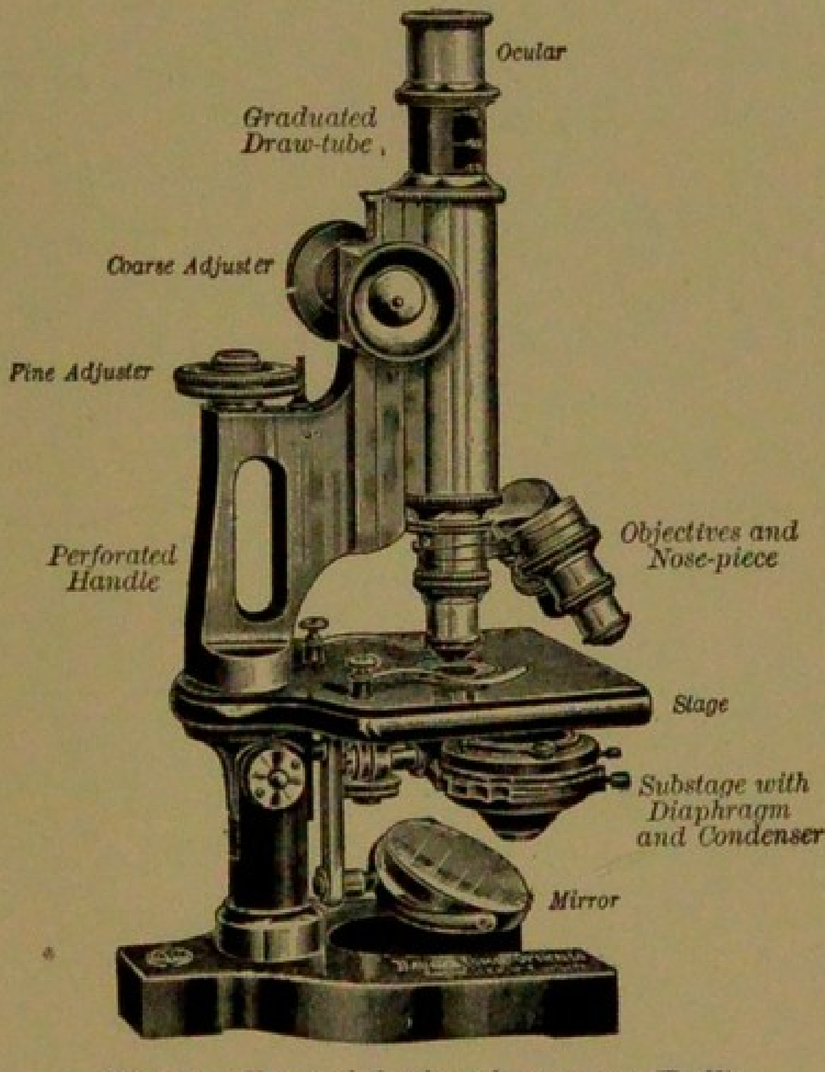


Fig. 7.—Bacteriologic microscope (Ball).

in common use, the $\frac{1}{12}$ inch, when used with a No. 5 eye-piece, magnifies about 1200 times. For the staining of bacteria we usually employ some of the coal-tar dyes, such as methylene-blue, fuchsin, gentian-violet, etc. The appearance of such stained bacteria is well shown in Plate 1. The use of these stains has a further value, in that it often helps to differentiate bacteria from one another. This will be seen when we study Gram's stain and the stain for tubercle bacilli (p. 26).

Demonstration.—Show a reading glass, and a high-power magnifying glass such as is used to count threads in a woven fabric. (Image erect.)

Demonstrate the compound microscope. (Image inverted.)

CHAPTER IV

PREPARATION OF STAINED SMEARS

In preparing bacteria for microscopic examination a tiny bit of the material (pus, sputum, exudate, culture, etc.) is thinly spread on a glass slide and allowed to dry. Then the slide is passed several times through the flame in order to "fix" the preparation. By this is meant the drying, killing, and coagulating of the material, so that it will remain fixed to the slide and not wash off in the staining fluid. For the ordinary examination the preparation is next flooded with the staining fluid—*e. g.*, watery solution of methylene-blue—and allowed to stain for several minutes. The stain is poured off, the slide washed in water, dried with blotting-paper and in air, and is then ready to be examined. The simple stains in common use are watery solutions of methylene-blue, of gentian-violet, or of fuchsin. Some bacteria, however, do not take these simple stains readily, and it is necessary to add something to the staining fluid to cause the stain to "bite in." The substance thus added is called a *mordant*. Carbolic acid is an excellent mordant, a solution of carbolic acid and fuchsin being extensively used to stain tubercle bacilli.

It was said above that stains were also used in identifying bacteria. Most bacteria, for example, when stained and then treated with acids quickly lose their color. Some, however, withstand the action of acids, retain-ing their color even after prolonged contact. These are spoken of as "acid-fast" bacteria. This test is extensively used in identifying tubercle bacilli, for these belong to the acid-fast group. (See Plate 1.)

Another staining method largely used in identifying bacteria is one devised by Gram. This is carried out as follows: The bacteria, spread and fixed on the slide in the usual way, are stained with a solution of gentian-violet with the aid of a little heat. At the end of several minutes the stain is poured off, and, without washing, the slide treated with a solution of iodin. Following this, the preparation is washed with absolute alcohol and then with water. When treated in this way certain bacteria are found to retain the original violet stain, while others lose it during the alcohol treatment. This is a very valuable reaction, and is extensively used in identifying the germs of meningitis, gonorrhea, etc. Bacteria which retain the violet stain when treated according to Gram's method are called "Gram-positive," while those which lose their stain are called "Gram-negative."

In passing we may say that, in addition to these ordinary staining methods, special procedures have been devised for the demonstration of flagella in motile bacteria and for staining spores, capsules, etc.

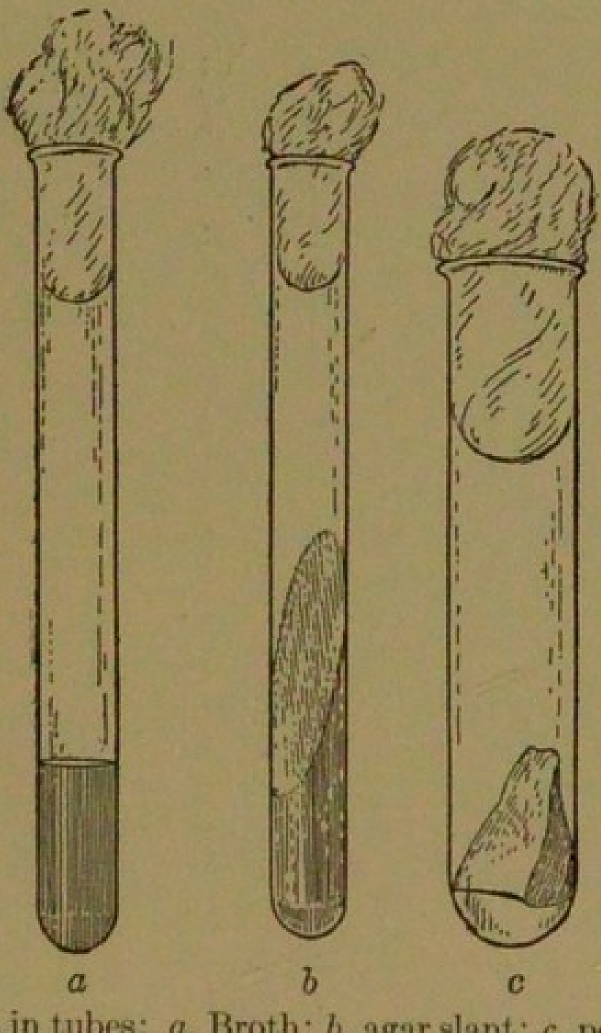
The teacher is to demonstrate simple staining, explaining the various steps, tubercle staining (Ziehl's method), and Gram's stain.

For this exercise let the students examine as many stained specimens as possible, to fix in their minds the appearance and relative size of bacteria.

CHAPTER V

CULTIVATION OF BACTERIA

In order to properly study bacteria it is absolutely essential that they be grown by themselves, *i. e.*, not



a *b* *c*

Fig. 8.—Media in tubes: *a*, Broth; *b*, agar slant; *c*, potato (Hiss and Zinsser).

mixed with a lot of other bacteria. In other words, it is necessary to obtain a pure culture. We shall assume that we have such a culture; let us now consider the methods by which we continue to grow the same. Our first step is to plant the bacteria either in a fluid culture-medium, such as beef-broth, milk, etc., or on the

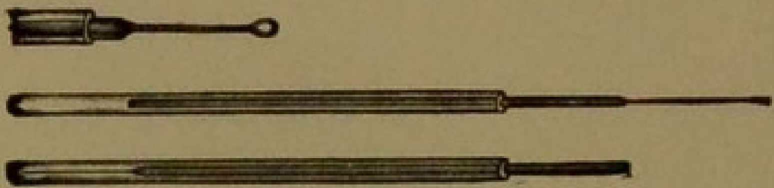


Fig. 9.—Platinum wires for bacteriologic use.

surface of a solid medium, such as gelatin, agar, solidified blood-serum, potato, etc. It is obvious that these culture-media must be absolutely free from other germs, *i. e.*, they must be perfectly sterile. In planting the

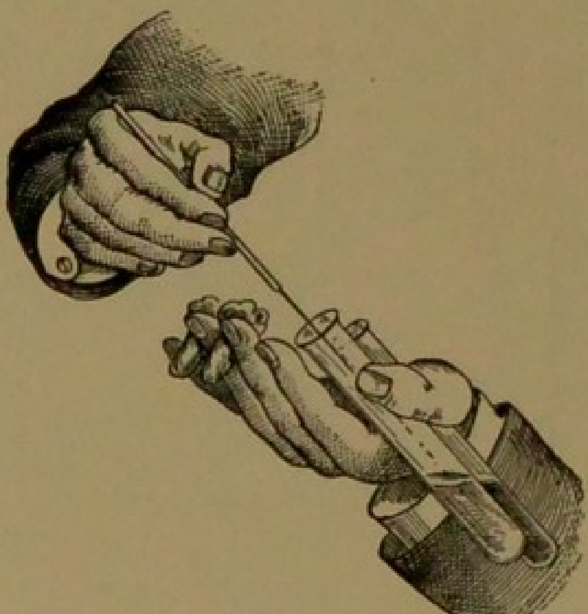


Fig. 10.—Method of holding tubes during inoculation (McFarland).

culture, we have at hand the tube containing our original pure culture and a tube of the sterile medium, *e. g.*, sterile broth, closed at the top with a cotton plug. All we need to do is to transfer a little loopful of culture by means of the platinum wire loop to the tube of sterile broth. In order to avoid carrying along other germs, however, we first hold the wire loop in the flame until it glows, thus destroying any germs that may have

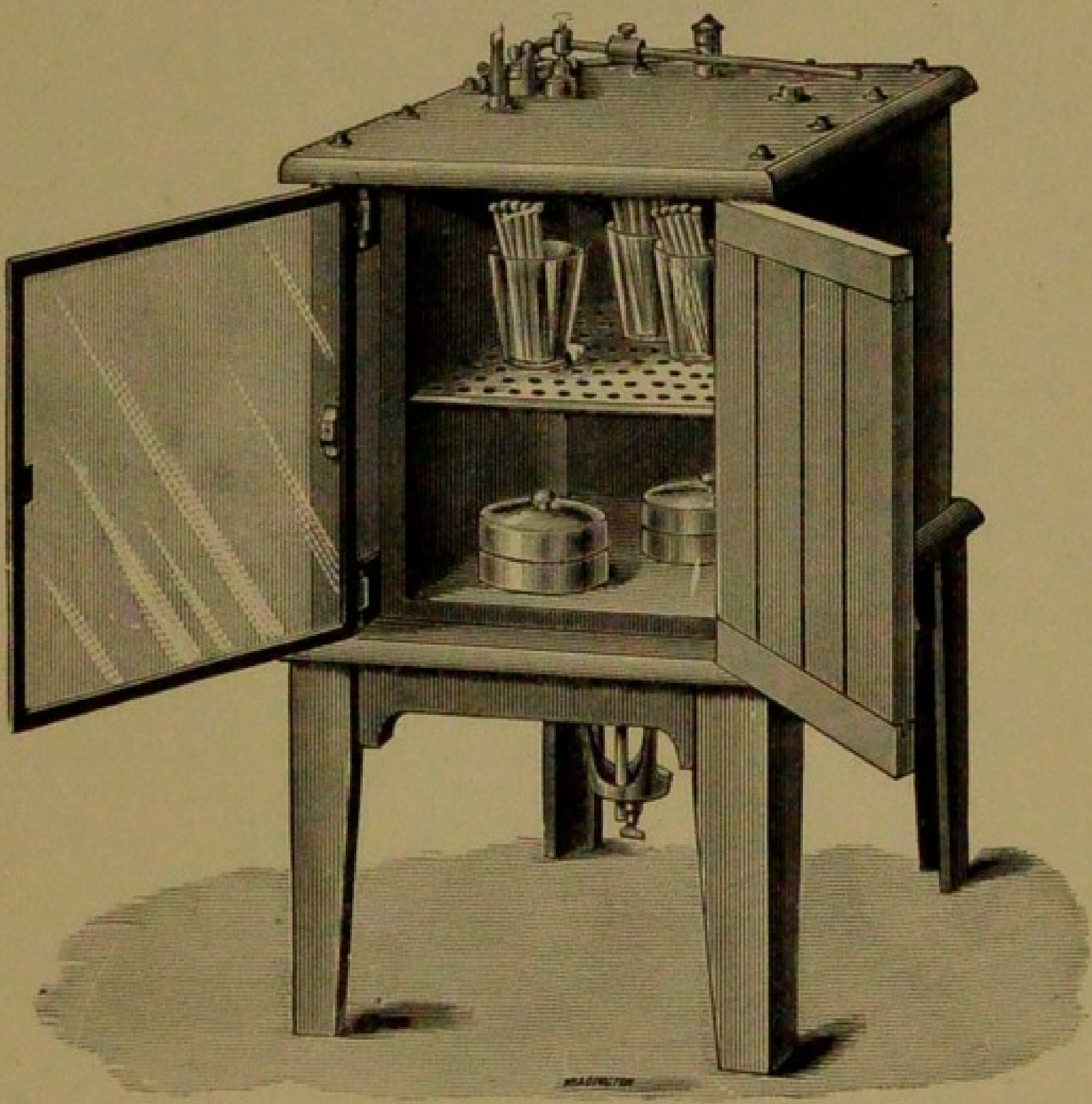


Fig. 11.—Incubator (Eyre).

lodged on the wire. The loop cools in a moment, the culture is transferred, the tubes are again closed with the cotton plugs, and the wire is at once passed through the flame before being laid down. Thus all danger of spreading the germs about is avoided.

The freshly planted culture is now placed in the incubator. This is a kind of oven whose walls are filled

Fig. 12.—Streptococcus pyogenes, culture on agar. Slightly enlarged (Williams).

with water, and whose interior is kept at a uniform temperature by means of a lamp or gas flame controlled by a suitable heat regulator. For the ordinary pathogenic bacteria the incubator is set to maintain a constant temperature of about 99° F.

In studying the bacteria of water, a temperature of 60° F. is usually employed. The general type of incubator is shown in Fig. 11, page 29.

Fig. 13.—Streak plate. (From Hiss and Zinsser, "A Text-Book of Bacteriology," D. Appleton & Co., publishers.)

After remaining in the incubator for twelve to twenty hours it will be noticed that the appearance of the beef-broth has changed. Originally perfectly clear, it now is more or less uniformly cloudy, or it may have a cloudy sediment or be covered with a scum. If the culture was planted on sterile agar (a kind of gelatin) it will now be found to be covered with a peculiar, more or less slimy mass, or with a number of small, rounded spots, This cloudiness in the fluid culture, or this slimy mass on the solid cultures, is the new growth, and is made up of millions of tiny bacteria. Just as in planting seed in the ground, a plant arises from each seed; so, in planting bacteria on the surface of a solid medium, wherever a single bacterium was deposited a whole group of similar bacteria develop. These groups become visible to the naked eye, forming usually more or less rounded

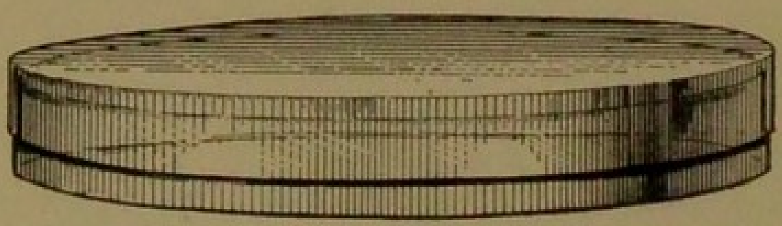


Fig. 14.—Petri dish for making plate cultures (McFarland).

masses, varying in size from that of a pin's head to disks ½ inch in diameter. Such masses of similar bacteria, the offspring of a single individual, are spoken of as "colonies." The number of colonies developing is thus an index of the number of living germs in the material planted. If the bacteria originally planted were very numerous, the colonies developing are so closely crowded that they form one continuous film, in which it is impossible to distinguish separate colonies. It is apparent that we can discover the number of living germs in a specimen of fluid by planting a known quantity of the fluid on a solid medium, growing the culture, and then noting the number of colonies which develop. This is facilitated by using shallow flat glass dishes, called "Petri dishes" or "plates." This "plating" method is extensively used to determine the number of living bacteria in milk and in water.

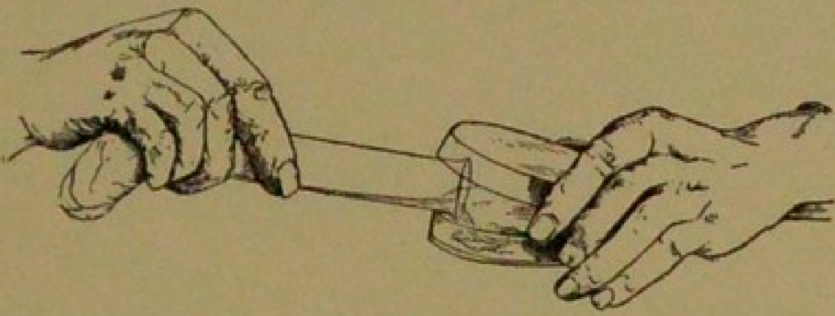


Fig. 15.—Pouring plates (Eyre).

Plate cultures are also employed in isolating bacteria in pure cultures. Without entering into the details of

Fig. 16.—Appearance of colonies on gelatin in Petri dish (Williams).

the method, we may say that in general it consists in the preparation of a number of plate cultures from the material to be examined, selecting the plate on which the colonies are not too closely crowded, and then, by means of a sterile straight platinum wire, carefully transferring some of the bacteria from a single colony to a tube of sterile medium. This process is spoken of as "fishing" a plate. It is obvious that, even though the original material contained many different kinds of bacteria, the cultures obtained by "fishing" will each contain but a single kind in pure culture.

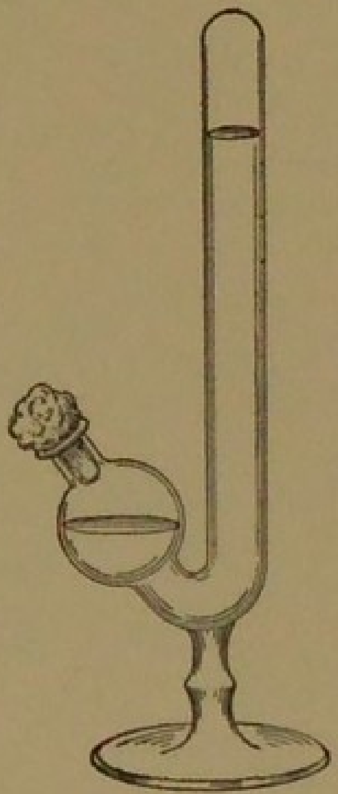


Fig. 17.—Smith's fermentation-tube (McFarland).

The cultivation of bacteria on different media constitutes an important means of studying and identifying the various species. For example, certain bacteria when grown in gelatin cause the gelatin to become fluid, while others do not. Certain bacteria cause milk to turn sour and coagulate, some cause it to become putrid, while others apparently leave it unchanged.

In media-containing sugars some bacteria ferment the sugars with the production of acid, others with the production of gas and acid, while still others do not ferment the sugar at all. In studying the production of acid we can add a little litmus to the medium and note whether the blue color changes to red. The formation of gas is best observed by growing the culture in a fermentation-tube.

Demonstration.—The teacher should inoculate various media, both liquid and solid, using organisms growing both at room temperature and body heat (*e. g.*, hay bacillus), and organisms growing only at body heat (*e. g.*, pneumococcus). Some of the latter variety should be inoculated in duplicate, and the duplicate kept at room temperature, to show that there will be no growth under these conditions. Agar-plate cultures should be made from milk (diluted) and from tap-water.

Streak-plate cultures may be made from the throat or from teeth scrapings.

CHAPTER VI

RELATION OF BACTERIA TO DESTRUCTIVE INFLUENCES

Disinfectants and Antiseptics

In a previous chapter it was pointed out that bacteria required a certain degree of heat in order to thrive. For most pathogenic bacteria this is about 100° F. Higher temperatures, on the other hand, exert an injurious action on bacteria, so that even a short exposure to the temperature of boiling water quickly kills most pathogenic bacteria. Destruction of bacteria can also be effected by *prolonged* exposure to temperatures considerably less than the boiling-point of water. This is spoken of as "pasteurization," after Pasteur, who first applied this method of killing bacteria. The effect of low temperatures on bacteria varies considerably with different species. Bacteria accustomed to grow at body temperature usually cease to grow or grow very slowly at ordinary room temperatures. There is practically no growth at all at 40° F. At freezing temperature many bacteria die off, but even the low temperature of liquid air does not certainly kill all forms.

Bacteria also vary in their resistance to drying, the vegetative forms usually drying quickly, while certain spore forms appear to resist drying indefinitely. As has already been pointed out, direct sunlight exerts a destructive action on bacteria. The combination of heat, drying, and sunlight is extremely efficacious in killing bacteria.

The study of chemicals which exert a destructive influence on bacteria (disinfectants) is of great practical importance. Depending on the intensity of their action, we usually speak of these substances as being either "germicides" (germ killers) or "antiseptics" (preventing germ growth). Every germicide in diluted form is an antiseptic. The conditions under which the disinfectant acts is of the greatest practical importance. Thus, carbolic acid acts better in 5 per cent. solution than in higher concentrations, and the efficiency is increased by the addition of salt, but diminished by the presence of alcohol. The rate of penetration into bacterial cells decreases as the concentration increases above a certain limit. The temperature at which the process is carried on also has a marked influence on the rate of disinfection. The presence of albuminous substances largely interferes with the action of certain disinfectants, notably with mercury bichlorid. The following are some of the more commonly used disinfectants:

Mercuric chlorid, also called corrosive sublimate, bichlorid of mercury, or, for short, "bichlorid," while strongly germicidal, has the disadvantage of being extremely poisonous, of forming insoluble and inert compounds with albuminous substances, and of acting on metals. Despite these drawbacks, however, this is one of the most commonly used disinfectants at the present day. It is employed largely in the form of ready made tablets, containing usually sufficient "bichlorid" to make a solution 1:1000 when one tablet is dissolved in a pint of water. Most of the tablets contain either citric or tartaric acid or ammonium chlorid to prevent the formation of insoluble compounds with albuminous matter. Many of the tablets also contain some harmless blue, pink, or yellow coloring-matter to aid in identifying the solution. For ordinary use solutions of 1:1000 will suffice, when brought into contact with bacteria, to kill the vegetative forms within fifteen minutes. Stronger solutions, however, must be employed when much organic matter is present. Mercuric chlorid should not be employed to disinfect metal instruments, as it quickly ruins them by its action.

Carbolic acid, or phenol, is a white crystalline substance readily liquefied by heat. It can be kept liquid by the addition of 5 per cent. water or glycerin, making what is sold in the drug stores as "pure carbolic acid." For disinfecting purposes it is ordinarily used in the form of a 5 per cent. solution in water, and, while it is less powerful than mercuric chlorid, it has the advantage of being only slightly affected by albuminous material, and of not acting on metals. Its efficiency is increased by the addition of common salt up to saturation: 1:400 kills the less resistant bacteria, and 1:100 kills the remainder. A 5 per cent. solution kills the less resistant spores within a few hours, and the more resistant in from a day to four weeks.

Crude carbolic acid consists mainly of cresols and very little phenol. By saponification of mixtures of cresols and neutral tar oils a product is obtained which makes an emulsion with water. *Creolin* is a type of numerous preparations of this character. They are all poisonous and sensitive to albuminoids. Moreover, these emulsions have the disadvantage of being opaque. *Lysol* is mainly a solution of the cresols in fat or linseed oil saponified with addition of alkali. It gives a clear solution with water, having marked germicidal powers and considerable solvency for grease. It is extensively used in the form of a 1 per cent. solution in gynecologic and obstetric practice. *Tricresol*, a refined mixture of the three cresols, is soluble in water to the extent of 2.5 per cent. It is about three times the strength of carbolic acid.

Quicklime, used in the form of freshly slaked lime suspended in water, is a powerful disinfectant. A 1 per cent. watery solution of the freshly slaked lime kills bacteria which are not in the spore form within a few hours. A 3 per cent. solution kills typhoid bacilli in one hour, while a 20 per cent. solution, added to equal parts of feces or other filth and thoroughly mixed, will completely sterilize them within one hour.

Chlorid of lime, so called (really chlorinated lime), depends for its efficacy on the chlorin it contains, and, as this is readily lost on exposure to the air, it is important that chlorid of lime be kept in tight containers. A solution in water containing 0.5 to 1 per cent. of chlorid of lime will kill most bacteria in one to five minutes. A 5 per cent. solution usually destroys spores within one hour. Chlorid of lime is particularly useful in the disinfection of stools. Together with washing-soda it is also extensively used as a hand disinfectant by surgeons.

Sulphur dioxid gas, produced by burning sulphur in air, was formerly extensively used as a disinfectant for sick rooms, but has now been largely discarded in favor of formaldehyd. Ordinarily 4 pounds of sulphur are burned for each 1000 cubic feet of air space, and the room is kept sealed for at least eight hours. In order to be efficacious the air in the room in which the sulphur is burned should be moist. Sulphur fumigation is still largely used to kill rats and vermin in combating the spread of plague.

Formaldehyd is a gaseous compound having an extremely irritating odor. It is most conveniently used in the form of a watery solution containing about 40 per cent. of the gas, and known commercially as "formalin." A 2 per cent. watery solution of formalin destroys the vegetative forms of bacteria within five minutes. In the form of the gas formaldehyd is extensively used in the disinfection of sick rooms. At least 4 ounces of formaldehyd should be allowed for each 1000 cubic feet of air space. The details of such disinfection are discussed on p. 147.

Iodin, in the form of tincture of iodin, is extensively used as a disinfectant of the skin for surgical operations.

Peroxid of hydrogen (H_2O_2) is an energetic disinfectant. A 20 per cent. solution (a good commercial hydrogen peroxid) will quickly destroy the pus-producing cocci and spore-free bacteria. It combines with organic matter, becoming inert. It is prompt in its action and not poisonous, but apt to deteriorate if not properly kept. It is extensively used to wash out abscess-cavities and purulent sinuses, and also as a gargle and mouth-wash.

Demonstration.—The teacher should inoculate a loopful from a twenty-four-hour broth culture of typhoid (or colon) bacilli into the following tubes: and make subcultures from each of these tubes at

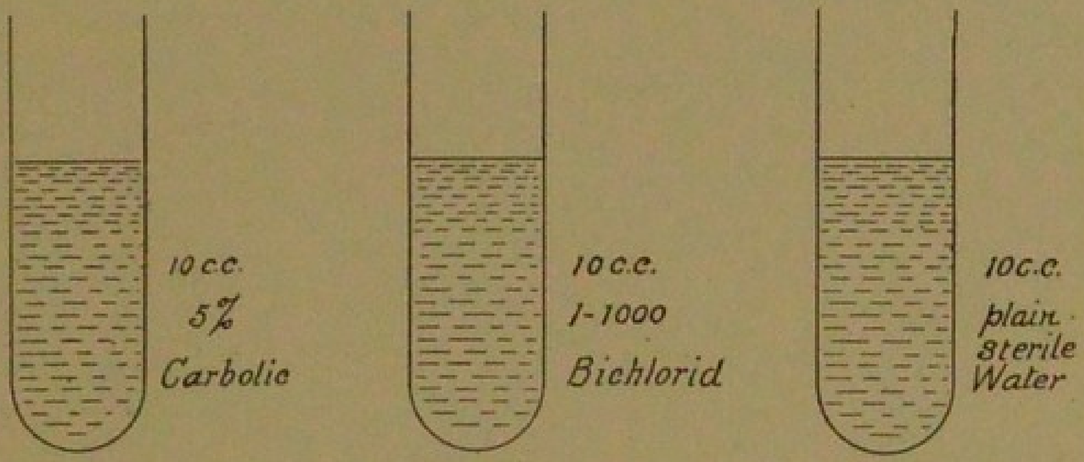


Fig. 18.

the end of one minute or five minutes by inoculating a loopful from these tubes into plain sterile broth.

Instead of making broth subcultures, agar poured plate cultures can be made.

CHAPTER VII

STERILIZATION BY HEAT

In making use of heat to destroy bacteria the method employed depends largely on the character of the material to be sterilized. Heat may be used in the form of fire, *i. e.*, the naked flame, or as dry heat, or as boiling water, or live steam, or live steam under pressure.

(1) *Fire.*—Many infected articles which it is desired to be rid of can be burned in the fire, thus absolutely destroying the infectious bacteria. Infected mattresses, rugs, books, papers, and magazines, toys, pus-soaked dressings, paper sputum cups and paper handkerchiefs, and other similar articles are often best disposed of in this way. In an emergency it is sometimes very convenient to sterilize a knife or other surgical instrument by passing it through the flame, or by dipping it into alcohol and then lighting the alcohol.

(2) *Dry Heat.*—In many instances the use of fire is out of the question. In such cases we may often employ dry heat to advantage. In bacteriologic laboratories special ovens are constructed for sterilizing glassware, etc., by means of dry heat. In the home the oven of the kitchen stove will usually answer equally well. The temperature of the oven should range about 300° F., and the articles should remain exposed for about an hour.

(3) *Moist Heat.*—It has been found that the presence of moisture markedly increases the destructive effect of heat. The simplest method of combining these two factors is to boil the articles to be sterilized in water. Surgical instruments are usually sterilized in this way,

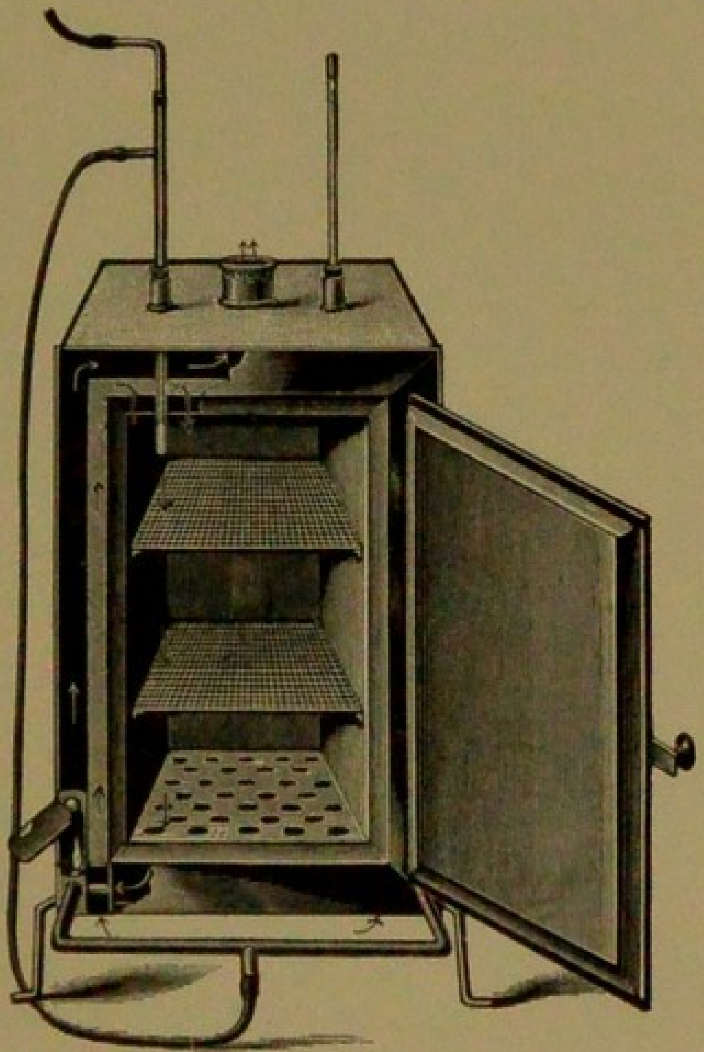


Fig. 19.—Hot-air sterilizer (McFarland).

and so are catheters, douche-nozzles, hypodermic needles, etc.

(4) *Live Steam.*—Another method of using moist heat is by means of live steam in a steam sterilizer. The accompanying figure shows the construction of the

Arnold steam sterilizer. This consists of a very shallow boiling pan, a steam chamber, which is surrounded by the removable hood, and a large pan, which catches the drip water. The large pan is connected with the small pan by a number of small openings, thus constantly keeping a supply of water in the boiling pan. The advantage of this design is the rapidity with which steam

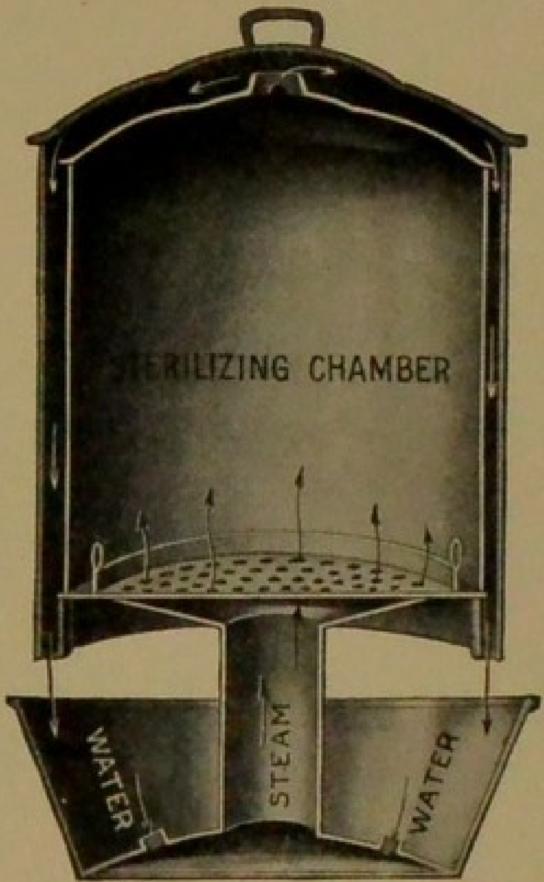


Fig. 20.—Arnold steam sterilizer (Fowler).

is developed and the little attention the apparatus requires when in operation. The temperature within the steam chamber is approximately that of boiling water, 212° F. This form of sterilizer is extensively used to sterilize the various nutrient media used for growing bacteria. In order to be certain that sterilization has been complete it is customary to sterilize these in the Arnold sterilizer for an hour on each of three consecutive days. This makes certain the destruction of

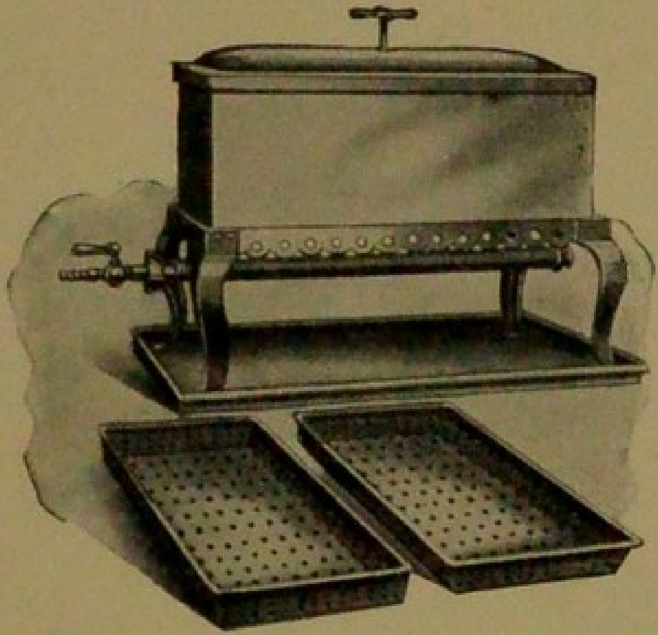


Fig. 21.—Instrument sterilizer.

all spores. Surgical dressings may also be sterilized in this form of sterilizer.

(5) The destructive action of steam can be enormously increased by employing it under pressure. For this a special form of apparatus is required. It is impossible to heat water, in an open vessel or in an Arnold sterilizer, to more than 212° F. As soon, however, as we heat the water in a tightly closed vessel, which will not allow the steam to escape, we can raise the temperature beyond this. The higher the pressure of the steam, the higher the temperature. It is mainly because of this fact that the use of steam under pressure is so much more effective in sterilization than the use of live steam not under pressure. Another reason is the

greater penetration secured by having the steam under pressure.

The accompanying figure shows a common type of steam sterilizer.

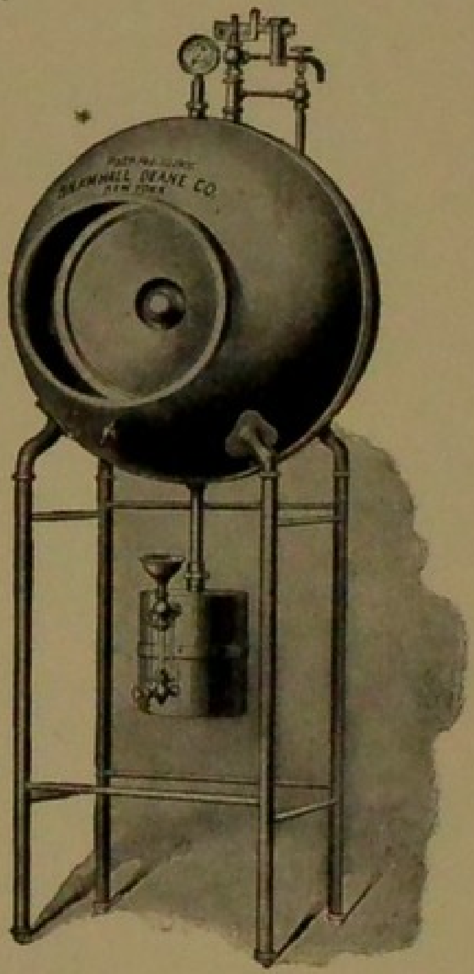


Fig. 22.—A pressure steam sterilizer. The steam jacket entirely surrounds the chamber, to which the steam is admitted through a valve. Pressure may be continued on the jacket while the dressings are removed. The safety-valve is set to relieve at 15 pounds.

The teacher should demonstrate the use of heat for sterilization by inoculating six broth tubes with a well sporulated culture of hay bacilli, and heating two in an Arnold sterilizer for five minutes, two others in a pressure steam sterilizer for five minutes (pressure of 15 pounds), leaving two unheated. After this, all six tubes are placed in an incubator over night.

CHAPTER VIII

THE RELATION OF BACTERIA TO DISEASE

We have already called attention to the fact that only a small proportion of the known bacteria are producers of disease, *i. e.*, are pathogenic. In order to prove positively that a disease is due to a certain bacterium it is absolutely necessary that this bacterium be always found in the disease. Furthermore, it must be possible to reproduce the same disease by the injection of pure cultures of the bacterium, and from the diseased tissues thus produced it must be possible to again isolate the germ.

The manner in which the various bacteria produce disease, their entrance into the body, the part of the body commonly attacked, all these differ considerably with the different micro-organisms. Some, like the bacillus of diphtheria and the bacillus of tetanus (lock-jaw), secrete very powerful poisons, and, while these bacteria do not themselves penetrate deep into the body tissues, their poison is absorbed and gives rise to severe symptoms. In the case of other bacteria, for example, the tubercle bacillus, the germs penetrate deep into the body tissues and there multiply. In their growth they give off poisons which cause the gradual destruction of the tissues in which they lodge. In this way the tubercle bacillus causes large parts of the lung to be destroyed or bones to be eaten away, etc.

Most germs, for some obscure reason, affect by preference certain parts of the body. The typhoid bacillus usually lodges in the wall of the small intestine; the meningococcus prefers the lining of the brain and spinal cord; the gonococcus is very prone to attack the mucous membrane lining the genital organs, and also the conjunctival membrane (outer lining of the eye). The pneumococcus affects chiefly the respiratory organs; the diphtheria bacillus, the throat and nasal passages.

The extent and kind of disease produced by the same bacterium also varies greatly. This, of course, depends largely on the size of the dose introduced, but also on the degree of resistance of the patient. We shall have occasion to speak of this later. (See p. 54.)

The more important pathogenic bacteria are the bacillus of tuberculosis, the typhoid bacillus, diphtheria bacillus, dysentery bacillus, spirillum of cholera, the pneumococcus, the streptococcus, the staphylococcus pyogenes, the meningococcus, the gonococcus, the bacillus of tetanus, of anthrax, of glanders, of bubonic plague, and of malignant edema. The germs of malaria, syphilis, and sleeping-sickness are tiny organisms called protozoa.[1] The germs of ringworm and of barbers' itch are fungi.[1] The germs of smallpox, chickenpox, scarlet fever, measles, yellow fever, and hydrophobia have not yet been discovered, though there is no doubt whatever of the germ nature of these diseases. Several alleged "cancer germs" have been described, but not only has their relation to cancer not yet been proved, but there is still considerable doubt whether cancer is a germ disease.

[1] See Definitions, page 13.

CHAPTER IX

THE TRANSMISSION OF INFECTIOUS DISEASES

No[*] theory has been more generally accepted, both by the medical profession and the public at large, than the belief that infectious diseases are commonly transmitted by clothing, baggage, money, rags, and innumerable other articles, which are supposed to convey pathogenic organisms in their active state from one person to another. These alleged agents are known as "fomites." Since the discoveries of Pasteur and Koch, and particularly during the past ten or fifteen years, practical sanitarians have been slowly but surely accumulating conclusive evidence of the fallacy of the fomites theory. Not so long ago malaria was attributed to the presence of "miasma," or poisonous vapors emanating from swamps; now we know that this disease is transmitted from man to man through the bite of a mosquito. Up to within a few years, yellow fever was held to be transmitted by "fomites," and the medical history of the South is rich in statistics which presume to offer conclusive proof that the clothing of those who had been exposed to yellow fever was responsible, at various times, for outbreaks of this disease. Yet we now know that yellow fever is transmitted only through the bite of a particular species of mosquito. Satisfactory evidence has been given us that plague, which was believed to be caused by almost anything in tne nature of "fomites," is conveyed to man by the rat, through the medium of fleas which infest these animals. It would be difficult to find a text-book, except perhaps the most recent, which does not in positive terms state that typhus fever is transmitted by clothing, baggage, and other articles. Yet careful investigations, particularly the recent work of Goldberger and Anderson in Mexico, indicate that the disease is transmitted by the body louse and not by fomites. With regard to two common diseases of childhood, namely, measles and scarlet fever, public health authorities are coming more and more to believe that desquamation of the skin is a negligible factor, and that these diseases are conveyed from person to person by the infected discharge of the mucous membrane involved.

It is only within comparatively recent years that we have appreciated the importance and danger of mild, ambulant, or irregular cases of infectious diseases, and the frequency with which they occur. They are undoubtedly one of the most common and dangerous factors in the transmission of infection because they often pass unrecognized. More recently we have learned of "carriers," or persons who, while themselves well, harbor the specific micro-organism, and may transmit it to others. These undoubtedly play an important rôle in the spread of infectious diseases.

All these observations have served to discredit the fomites theory, and, while there is no doubt that in some rare instances clothing, rags, books and toys, etc., may act as a medium of infection, we should devote our attention principally to the usual or common means of infection. The knowledge we now possess on this subject proves that infectious diseases are transmitted by persons rather than by things—by contact with others, by certain discharges of those who are infected, and by insects and vermin.

The question which at once arises is as to the need of room disinfection in infectious diseases. If such diseases are not carried by fomites, why go to all the trouble of room disinfection? In the first place, so long as there is any real danger from transmission by fomites, this danger should be guarded against. In the second place, much of the terminal room disinfection now practised can well be omitted, and attention directed to more important matters, with a considerable gain to the public health. The attitude of the best sanitary authorities in the world is well shown in the following extract, defining the position of the Board of Health of the City of New York with respect to disinfection in cases of diphtheria:

" . . . .

"**Disinfection.**—Experience has shown that diphtheria bacilli, as a rule, die out in a short time after drying and exposure to light, and that when a person suffering from diphtheria has completely convalesced and the throat is free from diphtheria bacilli there is little likelihood of any infection from the sick room. Conditions, however, are quite different when the patient is removed from the sick room at the height of the illness, or when death occurs at this time. Under these conditions it is probable that fresh discharges are present and that these contain living diphtheria bacilli.

"The action of the Department, therefore, depends on the manner and the time when the case is terminated:

"(1) If the patient completely convalesced in the sick room, the Department does not perform disinfection, but insists that the apartment be thoroughly cleaned and aired. After recovery of the patient at home, the woodwork of the room in which the patient has been isolated must be thoroughly scrubbed with hot soda solution ($\frac{1}{2}$ pound to 3 gallons) and the room thoroughly aired for at least twenty-four hours before being again occupied. Goods will be removed to the Department of Health Disinfection Station for sterilization and then will be returned.

"(2) If the patient is removed from the sick room during the height of the illness or dies at this period, the room with its contents will be disinfected, and all goods exposed to the contagion will be removed to the Department of Health Disinfection Station and returned after disinfection by steam. Bedding or other infected goods from such infected rooms must not be taken from the house or thrown into the street by the owner. After the goods have been removed and the premises reinspected, if conditions are found satisfactory, the inspector will issue the necessary school permits. Children in the family are not allowed to attend school until they have received a certificate from the Department of Health."

Insects as Carriers of Infectious Diseases

Before leaving this subject, it will be well to devote a little attention to the rôle played by insects and vermin in the transmission of infectious diseases. This rôle may be non-specific (merely mechanical) or specific. Thus, when typhoid bacilli are carried by flies from some infected feces to a pitcher of milk, the transmission is merely a mechanical transfer of the bacilli on the fly's legs and proboscis. It does not matter what species of fly is concerned; in fact, it need not be a fly at all, but some other insect. The transmission of plague from infected rats to man is probably of this kind, and, as far as our present knowledge goes, so is the transmission of typhus fever by lice.

Quite different are the circumstances governing the specific transmission. Common examples of these are malaria, yellow fever, and sleeping sickness. When malaria is carried from one person to another by the mosquito it is found that this is always a mosquito of the species Anopheles. The ordinary Culex mosquito is unable to effect the transmission. In malaria, as we have already seen, the tiny parasite sucked up in the patient's blood by the biting mosquito undergoes certain characteristic changes, and it is only after these changes have been completed that the mosquito is able to infect another person. But for some unknown reason these changes occur only in the stomach of Anopheles and not in other species of mosquitos. In yellow fever and sleeping-sickness conditions are entirely analogous, in the former a species of mosquito known as Stegomyia is required, and in the latter a species of biting fly known as "tsetse fly" effects the transmission. According to Rosenau poliomyelitis is transmitted in a specific non-mechanical manner by the bite of the common stable fly.

So far as the nurse is concerned, the above facts call for careful attention to flies, mosquitos, fleas, bed-bugs, lice, and other vermin about every case of infectious disease.

Recommended for Additional Reading

Chapin: The Sources and Modes of Infection, Wiley & Sons, New York.

Doty: The Prevention of Infectious Diseases, Appleton, New York.

CHAPTER X

IMMUNITY

It is well known that certain infectious diseases occur naturally only among some of the lower animals, and do not affect man; while, conversely, others appear to attack only man. Among the latter may be mentioned typhoid fever, syphilis, gonorrhea. In speaking of the resistance evidently possessed by certain individuals or certain species, we make use of the term *natural immunity*. Thus, chickens and frogs possess a natural immunity against tetanus (lock-jaw); dogs, a natural immunity against anthrax; goats, a natural immunity against tuberculosis, and man, a natural immunity against certain diseases of cattle. This natural immunity, however, is not absolute. Chickens, for example, can be infected with tetanus if the body is chilled, and frogs can be made susceptible to tetanus by keeping them unduly warm.

Another form of immunity is that observed in individuals who have had one attack of a particular infection; thereafter they are practically safe from a second attack. These individuals are said to possess an *acquired immunity*. This form of immunity is well illustrated in scarlet fever, measles, small-pox, yellow fever. Often this immunity lasts throughout the lifetime of the individual, though there are exceptions.

In studying this acquired immunity, Pasteur, a French scientist who lived 1822 to 1895, conceived the idea of artificially producing an attack of a given infection in order to protect the individual against another attack. He realized that it was necessary, however, to so control matters that the original attack should run a very mild course and not endanger the life of the individual. After considerable experimental labor, Pasteur found that this could be accomplished by artificially weakening the bacteria with which the original attack of the disease was produced. Subsequently Salmon and Smith, in this country, showed that it was not necessary to produce even a mild attack of the disease by the injection of living bacteria, but that the injection of dead bacteria would produce an immunity against that particular infection.

Acquired immunity, whether caused by a previous natural attack of the disease, or artificially by the inoculation of bacteria, is always *strictly specfic*, that is, the protection extends only to the particular disease which has previously occurred or whose germs have previously been injected. An attack of scarlet fever protects only against scarlet fever, but not against measles. Inoculating an individual with typhoid bacilli protects him only against typhoid fever, but not against dysentery, plague, cholera, etc. This acquired immunity is often transmitted from mother to offspring, transmission being effected mainly, according to Famulener, through the colostrum. This shows the importance of placing baby to the mother's breast soon after birth.

Before examining into the nature of this very specific form of immunity, it will be well to call attention to certain important means by which the body defends itself against bacterial invasion in general. Many of these are so commonplace that their significance is often overlooked:

(1) The protection afforded to the body by the unbroken skin is undoubtedly one of the most important means of defence. It is well to remember this, and especially to bear in mind that we say "unbroken" skin. In the sterilization of the skin prior to a surgical operation a great deal of harm is sometimes done by too vigorous scrubbing or the application of too concentrated disinfectants.

(2) A similar protection, though less powerful, is afforded by intact and healthy mucous membranes. Any condition injuriously affecting these renders the body more liable to bacterial invasion. This is well illustrated by the frequency with which an attack of measles (which affects the mucous membranes to a marked degree) is the starting-point of other and more serious infections.

(3) The acid gastric juice undoubtedly destroys large numbers of bacteria which are swallowed. Disorders of digestion may, therefore, constitute the deciding factor in determining a bacterial invasion, especially of the intestinal tract.

(4) It has been found that fresh blood-serum is able to kill a considerable number of bacteria, and this, therefore, constitutes another mode of defence against bacterial invasion.

(5) The white blood-cells, or leukocytes, as they are called, appear to be designed especially to destroy in-

vading bacteria. These cells take hold of, or rather engulf, the bacteria and digest them.[1]

(6) Still another mode of defence is seen in what takes place in abscesses. When these are examined, it is found that the body has built a wall around the infected area, thus shutting off the bacteria and their poisonous products from the rest of the body.

Returning now to the mechanism of the specific acquired immunity discussed above, we find that, in response to the invasion by pathogenic bacteria, the body manufactures certain specific substances designed to destroy the invaders or to neutralize their poisonous products.

These antagonistic substances are spoken of as antibodies. The important antibodies thus far known are as follows:

(1) Antitoxins.
(2) Bacteriolysins, hemolysins (cytolysins).
(3) Agglutinins.
(4) Opsonins.
(5) Precipitins.
(6) Antiferments.

Antitoxins.—When an animal is injected with gradually increasing doses of toxin—*e. g.*, with diphtheria toxin—it will be found that after a time the animal withstands doses of the poison which would suffice to kill hundreds of animals not so treated. This was done in 1890 by von Behring, who found that the blood of the treated animals contained something which neutralized

[1] Certain substances, such as alcohol, also exposure to cold, make the leukocytes sluggish, so that drunkeness on the part of an individual or exposure to cold often lead to bacterial invasion.

the diphtheria poison and rendered it harmless. It was natural to see whether this blood-serum could be used to treat other animals which had previously been injected with diphtheria poison, and on doing this von Behring found that the serum thus used was able to save the animals from death. The action of the substance in the serum which counteracted the effect of the poison was found to be exactly like that of an alkali on an acid, *i. e.*, it neutralized the poison. It was, therefore, called an *antitoxin*, meaning *against toxin*. The antitoxic serum from an animal treated with toxin does not differ in appearance from that of a normal untreated animal. And even when tested chemically, but little difference can be discovered between the two. In order, therefore, to recognize the presence of this antitoxin in the serum, and especially in order to measure its amount, we must test it in animals, and see how small a quantity of antitoxic serum will save an animal after injection with a certain amount of diphtheria toxin. When guinea-pigs are used for the test, it may be found that $\frac{1}{1000}$ cm. of the antitoxic serum will often be sufficient to save the animal from death, even after it has been injected with ten fatal doses of the diphtheria toxin! Sometimes, in fact, as little as $\frac{1}{5000}$ cm. suffices. The strength of the antitoxic serum is, therefore, expressed in units. In the examples just cited the serum would be said to have a strength of 100 or of 500 units respectively.

Bacteriolysins.—Just as when an animal injected with gradually increasing doses of toxin produces an antitoxin in its blood, so also, when injected with bacteria, it produces substances which kill and dissolve the injected micro-organisms. We have already said that fresh blood-serum is able to kill a considerable number of bacteria; when injected with gradually increasing amounts of bacteria, however, this destructive power increases enormously, but only for the particular kind of bacterium used for injection. Thus, if an animal is injected with typhoid bacilli the serum will, after a time, kill enormous numbers of typhoid bacilli, even in very small doses; tested against cholera bacilli, or any other bacteria, its destructive effect is merely that of normal serum from an untreated animal. When the action of the serum on the bacteria is studied under the microscope it is seen that the bacteria are actually dissolved. Hence, such a serum is spoken of as a "bacteriolysin," which means bacteria dissolving. Since the bacteria are killed by this action, we also speak of the serum as being "bactericidal," which means bacteria killing.

It has been found that this action of the serum may be developed against other cells than bacteria. When red blood-cells are used the serum acquires dissolving properties for these; and here, again, the action is strictly specific, so that when blood-cells from a chicken are injected into an animal the serum of the injected animal acquires increased solvent powers only for chicken blood-cells, but not for blood-cells of other animals. Instead of using the word bacteriolysin, we speak of such a serum as a hemolysin, meaning blood dissolving.

The term "cytolysin" is used to embrace all these dissolving sera, "cyto" signifying cell; hence, cell dissolving.

Investigation showed that the mode of action of these dissolving sera was somewhat complex and required the joint action of two different constituents. One of these constituents decomposes very easily, so that a serum which has stood several days may be found to have almost entirely lost its solvent power. Curiously, however, the addition of a little fresh serum, even from a normal animal, immediately restores its power. This very unstable constituent, which is present in all serum, even in serum from normal animals, is spoken of as complement, because it completes or complements the action of the other constituent. The stable constituent is called the amboceptor or the immune body.

When the animal is repeatedly injected with gradually increasing doses of bacteria (or other cells), it responds by manufacturing large quantities of this amboceptor or immune body, directed specifically against the injected bacteria. This substance lays hold of the invading bacteria, and, with the aid of the complement, effects their destruction. The complement alone would be unable to destroy the bacteria; the amboceptor is needed to prepare the bacteria in some way as yet unknown.

Agglutinins.—When the serum of an animal which has been repeatedly injected with gradually increasing doses of bacteria is brought into contact with some of these bacteria, careful observation under a microscope reveals a very interesting series of changes. Thus, if typhoid bacilli are mixed with a specific antityphoid serum (obtained, say, from a rabbit previously injected with typhoid bacilli), one notices first that the motility of the bacilli becomes markedly diminished. This is followed by the gradual collection of the bacilli into clumps. At the end of an hour or two, in place of countless bacteria moving quickly through the field, one sees merely several groups of absolutely immobile bacilli. If the reaction is feeble, the clumps are small, and one finds comparatively many isolated and perhaps also moving bacteria. This phenomenon is spoken of as agglutination, and the substance in the serum which brings it about as agglutinin. The clumping thus brought about does not kill the bacteria; moreover, it makes no difference whether the serum is freshly drawn or has been kept for some time, it will agglutinate equally well, and does not require the addition of fresh serum as do the bacteriolysins.

Like the antitoxins and the bacteriolysin, the agglutinins are strictly specific, *i. e.*, a serum from an animal injected previously with typhoid bacilli will agglutinate only typhoid bacilli; one from an animal injected with cholera bacilli will agglutinate only cholera bacilli, etc.

Since the agglutinins do not kill the bacteria, it may be asked what their function is. Up to the present time we do not know. Through the studies of Gruber and of Widal, however, the agglutinins have come to play a prominent part in the diagnosis of bacterial infections, and, in what is called the Widal reaction, afford an important aid in diagnosing typhoid fever. The Widal test in typhoid fever may be performed with blood-serum from the patient or, still simpler, with a drop of blood collected on a glass slide and allowed to dry. If the latter method is employed, the drop is soaked off with sufficient distilled water to make approximately a dilution containing 1 part of blood in 20 of the mixture. Next, a loopful of this mixture is mixed with a loopful of a broth culture of typhoid bacilli, and this mixture of diluted blood and typhoid culture then examined by

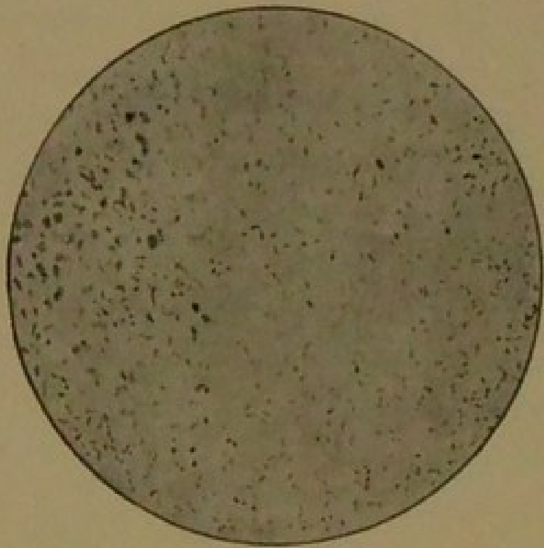


Fig. 23.—Typhoid bacilli unagglutinated (Jordan).

means of the hanging-drop method under the microscope. If complete agglutination takes place within

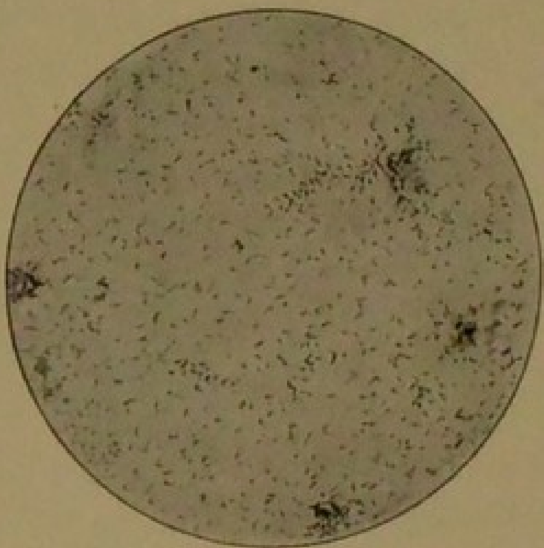


Fig. 24.—Typhoid bacilli partially agglutinated (Jordan).

twenty to thirty minutes, one speaks of having obtained a positive Widal reaction. This means that the patient is suffering from typhoid fever or has recently had the disease, for the serum continues to show the reaction for some time after convalescence.

Agglutination reactions may also be employed in a reverse manner for identifying bacteria. In that case, one employs an agglutinating serum made against a certain bacterium and tests the bacterium one is studying. If it agglutinates with this serum, one argues that it is identical with, or at least very closely related to, the bacterium used for making the serum.

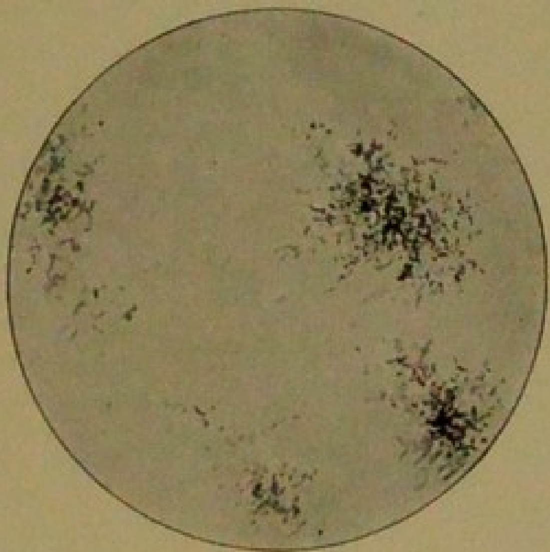


Fig. 25.—Typhoid bacilli, showing typic clumping by typhoid serum (Jordan).

Opsonins.—We have already said that the white blood-corpuscles—*i. e.*, the leukocytes—take up bacteria and destroy them. Sir Almroth Wright, a distinguished English physician, discovered that certain substances present in blood-serum had the power of increasing the appetite, as it were, of the leukocytes, and, furthermore, that the amount of these substances could be increased by properly administered injections of the appropriate bacteria. These substances he called opsonins. They are specific, just as are the antitoxins, the bacteriolysins, and the agglutinins; that is to say, when the body is injected with typhoid bacilli, only the opsonic power for typhoid bacilli is affected; when staphylococcus pyogenes is employed, only the opsonic power for this germ is affected; when pneumococci are injected, only the opsonic power for pneumococci is affected. Wright devised a special technic for measuring the amount of opsonin present in a serum, and expressed this in what he calls the opsonic index. This is merely the opsonic power of the patient's serum, as compared with the opsonic power of several known normal sera, using the same leukocytes and the same bacteria in the one test. Although Wright believes that this opsonic index is essential in the bacterial vaccine treatment of infections, most other observers have failed to find the index of any real help.

Precipitins and Other Antibodies.—We have seen above that the injection into the animal body of bacteria or other cells is followed by the production of a number of different antibodies. If, instead of injecting bacteria, we inject solutions of albuminous material, for example, inject a rabbit with chicken egg-albumin (white of egg), we shall find that the rabbit's serum acquires the power to produce a precipitate when mixed with chicken egg-albumin. This action is highly specific, so that if the serum is tested against albumin from any other animal—*e. g.*, from a duck—no precipitate will be produced. If a rabbit is injected with human blood (which, of course, is really an albuminous solution) the rabbit serum will produce a precipitate when mixed with human blood, but not when mixed with any other blood.

The antibodies concerned in this reaction are called precipitins. The precipitin test is now made use of in criminal cases where it is necessary to determine whether certain blood-stains are from human blood or otherwise. This reaction may also be used to determine whether sausage contains any horse meat. In addition to the foregoing, still other antibodies are known. When ferments are injected into an animal, the latter responds by producing antiferments. When certain antibodies are injected, anti-antibodies are produced. The entire subject is extremely complex, and further discussion in such a work as this is out of place.

Anaphylaxis.—When albuminous substances are taken into the body through the mouth, that is, into the stomach and intestines, they are acted on by certain ferments, digested, and serve as body nourishment. When, however, they are introduced through other channels—*e. g.*, by means of hypodermic, intramuscular, or intravenous injection—they cause the production of antibodies as was described above. Some of these antibodies appear to have digesting properties; at least they split up the injected material, evidently so that the body may get rid of it. Recent studies have shown that this non-intestinal splitting up of albuminous substances may give rise to serious symptoms, and that the rashes sometimes following the injection of diphtheria antitoxin are due to this cause. It has been found that such rashes are more likely to follow second injections. In experimenting with guinea-pigs it is possible to so arrange matters that the second injection will prove fatal. This phenomenon is spoken of as anaphylaxis.

Serum and Vaccine Therapy

The principles underlying the production of diphtheria antitoxin have already been described. Injected into a patient suffering from diphtheria, the antitoxin at once lays hold of the toxin which the diphtheria bacilli are producing and quickly restores the patient to health. The great convenience in the use of diphtheria antitoxin lies in the fact that we can get a horse to produce it for us, and then by bleeding the animal, collecting the serum, and injecting this serum into man, can confer immunity against diphtheria on the person so injected. We speak of this kind of immunity as *passive* immunity, because the man's body has taken no active part in the production of the protective substance, the antitoxin. It is, of course, plain that the antitoxin can merely ward off from the cells of the body the toxin which is threatening them; the toxin which has already begun to act on the cells cannot be neutralized by the antitoxin. In every case of diphtheria, therefore, it is most important to give the full dose of antitoxin as early as possible, and to give a small dose also to all who have been or expect to be in direct contact with the patient.

In the case of tetanus antitoxin the clinical results have not been nearly so striking as with diphtheria antitoxin. Within a limited field, however—namely, the use of preventive injections in cases likely to develop tetanus—tetanus antitoxin has a distinct field of usefulness, and its more extensive employment in recent years has undoubtedly been the means of saving life. The reason why tetanus antitoxin often fails in the treatment of developed cases of tetanus is because the diagnosis cannot possibly be made until after the toxin has had abundant time to combine with the body-cells. In the treatment of epidemic cerebrospinal meningitis spinal injections of specific antimeningococcus serum have reduced the mortality to about one-half that of cases not so treated.

So far as the bacteriolysins are concerned the clinical results have not been very satisfactory. Investigation has disclosed many difficulties which must still be overcome. In speaking of these sera it is better to use the term "antibacterial," because, after all, when we immunize an animal against a certain bacterium we do not produce merely a bacteriolysin, but a serum which contains also agglutinins, precipitins, opsonins, and, perhaps, still other antibodies.

Because of the non-success attending the use of the antibacterial sera, attention has been turned to treatment of bacterial infections by means of *active immunization.* This consists usually in injecting the patient with small doses of dead bacteria, thus causing the production, on his part, of the various antibodies already described, and thus bringing about a condition of immunity. The bacteria are usually grown on agar, in the ordinary way, and, after being washed off into a test-tube containing a little salt solution, are heated for about half an hour to 60° C. in order to kill all the bacteria. Sterility is insured by suitable tests. The suspension is then diluted, so that each cubic centimeter will contain exactly a certain number of million bacteria, after which it is ready for injection. Such a suspension is spoken of as a "bacterial vaccine." The doses of the different vaccines vary. In the case of staphylococcus vaccine the ordinary dose is from 250,000,000 to 500,000,000. Gonococci are usually given in much smaller doses, namely, from 15,000,000 to 50,000,000. The dose of typhoid vaccine is from 500,000,000 to 1,000,000,000. The vaccines are usually given in several doses, injections being made from five days to a week apart.

SPECIAL BACTERIOLOGY

CHAPTER XI

TYPHOID FEVER

THE typhoid bacillus was discovered in 1880 by Eberth. It is a motile bacillus about $\frac{1}{10,000}$ inch long and $\frac{1}{40,000}$ inch thick. It decolorizes when stained according to Gram's method, and does not produce spores. Typhoid bacilli grow readily on the ordinary laboratory media, even at room temperature. They do not ferment lactose (milk-sugar), so that when grown in litmus milk or on lactose litmus agar they do not change the color of the medium.

In typhoid fever the bacilli are found chiefly in certain parts of the wall of the small intestine and in the intestinal contents. In early stages of the disease they are also found in the blood. In the wall of the intestine they cause ulceration, and this frequently involves the blood-vessels, giving rise to severe hemorrhages. Sometimes the ulceration passes entirely through the intestinal wall, and this is called a perforation. With the escape of fecal matter into the peritoneal cavity comes the development of peritonitis. In many cases the typhoid bacilli are found not only in the feces, but also in the urine. This is important to remember in guarding against infection of others.

In the country, where privies and cesspools are common, it often happens that typhoid stools insufficiently disinfected find their way into a well, spring, or stream, and so lead to the infection of others. In summer, when flies abound, it sometimes happens that flies carry infected material from such a privy directly into the kitchen, and deposit typhoid bacilli on the food standing about. If a pitcher of milk thus becomes infected, the bacilli at once thrive and multiply so that in a very short time the milk contains enormous numbers of typhoid bacilli. Some infections have been traced to the washing of dairy utensils—cans, etc.—in typhoid-infected water. Other cases have been caused by unrecognized mild cases, especially when the latter had something to do with the handling of food. In the city a large number of cases are undoubtedly due to quite direct infection from a previous case. When a patient recovers from typhoid fever the bacilli usually disappear from the feces, but in about 5 per cent. of the cases the patients continue to harbor typhoid bacilli in their feces although they themselves are perfectly well. Such persons are spoken of as "bacillus carriers," and constitute a very difficult feature of the typhoid problem. The author has traced a number of epidemics of typhoid fever to dairymen who were such bacillus carriers.

From what has been said it follows that great care must be taken to properly disinfect the discharges, both urine and feces, of all persons having typhoid fever. Moreover, this should include all those cases of fever in which the presence of a typhoid infection is possible, even though the diagnosis is not yet positively established. Many a case of obscure fever, running a mild course, and therefore dismissed as of no consequence, has subsequently been found to have been typhoid fever, and resulted in the infection of others because no typhoid precautions were taken. Chlorid of lime is one of the most efficient disinfectants for the stools, but, like all disinfectants, it should be used freely, and in such a way that the disinfectant will really remain in contact with the feces for a sufficient time. If the masses of feces are hard, a constipated stool, it is important to break them up with a stick and mix them thoroughly with the disinfectant. Ordinarily it is well to keep the disinfectant in contact with the stool in the vessel for about an hour before emptying the vessel. In the city the stool can then be poured into the closet; in the country, where there is merely a shallow earth closet, it is advisable to bury the stools. The underclothing, night clothes, handkerchiefs, towels, etc., of the patient, as well as the bed-linen, must be carefully disinfected before it is given out to be laundered. Disinfection of these articles is accomplished by soaking them for some hours in carbolic acid solution of from 2 to 5 per cent. Bichlorid of mercury solution, 1:5000, can also be similarly used. Very useful in deodorizing and disinfecting stools is the solution of chlorids put up by many druggists. For the purposes of at once disinfecting the hands after handling the patient, the nurse should have standing near the bed a basin containing either 5 per cent. carbolic acid solution, or 1:1000 bichlorid of mercury, or some other convenient hand disinfectant of similar strength. In this more than in any other infectious disease it is important to keep flies out of the sick room.

When typhoid bacilli are examined under the microscope in a drop of sterile water they will be found to be uniformly scattered throughout the drop and in active motion. When to such a drop a little blood from a typhoid patient is added the bacilli at once begin to gather together in clumps and cease their movements. Blood from a normal person has no such effect. This reaction is very valuable for diagnosis, and is known as the "Widal test" for typhoid fever. It has been found that blood from a typhoid patient can be diluted from twenty to forty times or more, and still produce this peculiar clumping effect; in some cases, in fact, diluting the blood several thousand times still permits the reaction to take place. The collection of the blood for the test is a very simple matter, as a couple of drops of blood dried on a glass slide suffice. It is important, however, to let the blood dry spontaneously, and not attempt to hasten the drying by heat.

CHAPTER XII

DYSENTERY—CHOLERA

Dysentery

The dysentery bacillus was discovered by Shiga in Japan, and by Flexner in the Philippines. It is a Gram-negative, non-motile bacillus, somewhat smaller than the typhoid bacillus. Two main varieties are encountered, those which ferment mannite (a kind of sugar) and those which do not.

Acute dysentery, in this climate, is usually due to the dysentery bacillus or some closely related variety. In tropical countries a form of chronic dysentery is due to organisms called amebæ, and it is, therefore, customary to speak of "bacillary dysentery" and "amebic dysentery." The usual summer diarrheas, however, are not due to dysentery bacilli.

Bacillary dysentery affects especially the mucous membrane of the large intestine. In mild cases only the superficial portion is involved, but in severe cases deep ulceration may occur. The stools are at first fecal, but soon become nothing but masses of bloody mucus and serum. When the disease is at its height there are from twenty to fifty stools in the twenty-four hours. At this time dysentery bacilli are very abundant in the stools and the superficial layers of the affected mucous membrane. With the return of the fecal stools the bacilli disappear.

The path of infection in dysentery is the same as it is in typhoid fever, *i. e.*, by means of infected water, milk, or other food contaminated from the stools of dysentery patients. The means of guarding against infection are, therefore, the same as in typhoid fever. All the stools should be carefully disinfected, one of the best disinfectants for this purpose being chlorid of lime. Careful attention should be paid to soiled cloth-

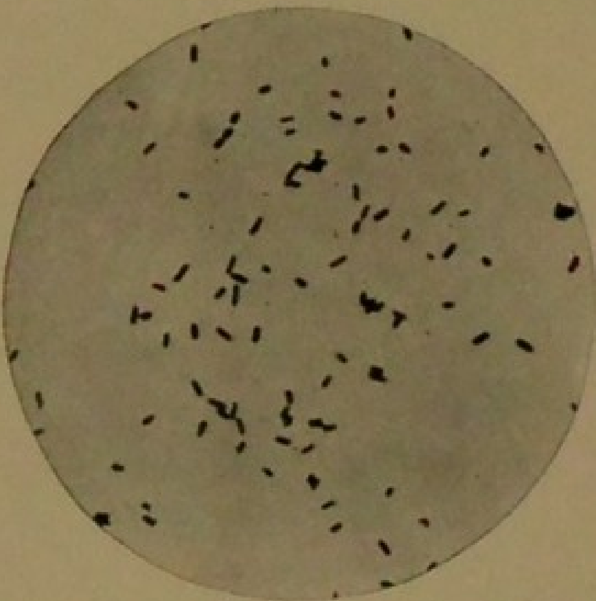


Fig. 26.—Bacillus of dysentery from agar culture. Fuchsin stain (Kolle and Wassermann).

ing and bedding, and, when rectal irrigations have been employed, the irrigation-tube should be disinfected by boiling.

Cholera

The spirillum of cholera was discovered by Koch in 1884, and from its form is often called the "comma bacillus." It grows well on ordinary culture-media, even at room temperature, and when grown on gelatin causes liquefaction of the medium. The cholera spirillum can multiply in water. It is motile, does not produce spores, and is decolorized when stained according to Gram's method.

Cholera is constantly present in India and other parts of Asia, hence the name "Asiatic cholera." From time to time enormous epidemics of the disease invade Europe, causing thousands of deaths. The symptoms

Fig. 27.—Spirillum of Asiatic cholera, from a bouillon culture three weeks old, showing long spirals; × 1000 (Fränkel and Pfeiffer).

begin with diarrhea and colicky pain in the abdomen. In a short time the diarrhea becomes intense and profuse and is accompanied by vomiting. Many of the patients die at this period in a state of collapse. The stools are at first yellowish, but soon become grayish white, and are then termed "rice-water stools." These discharges often contain the cholera spirilla in practically pure culture. When recovery takes place the stools gradually resume their normal color and the cholera spirilla disappear.

The disease is spread chiefly by contaminated water used for drinking, cooking, and washing. Vegetables washed in infected water, particularly lettuce, cress, and the like, may convey the disease. Wash-women and others who are brought into very close contact with the linen of cholera patients or their stools are prone to contract the disease. Like in typhoid fever, it has recently been found that some healthy persons may carry cholera germs in their stools. These are spoken of as "bacilli carriers," and have already been spoken of in connection with typhoid fever.

So far as the prevention of further infection is concerned, the same precautions must be taken as have already been described under Typhoid Fever and under Dysentery.

CHAPTER XIII

TUBERCULOSIS

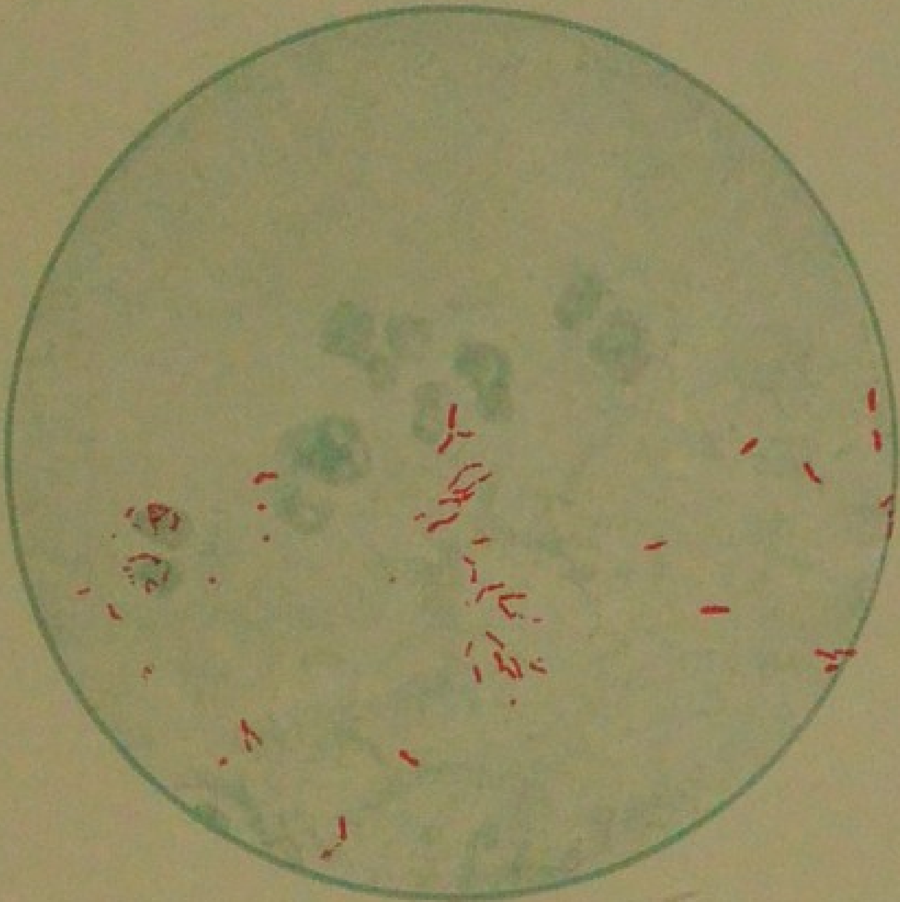
The bacillus of tuberculosis, also called the tubercle bacillus, was discovered by Koch in 1882. It is the cause not only of "consumption" (tuberculosis of the lungs), but also of all other forms of tuberculosis, such as tuberculosis of bone (Pott's disease, hip-disease, white swelling, cold abscess), tuberculosis of the intestines, of the peritoneum, of the kidney, of the meninges, of glands (scrofula), etc. The tubercle bacillus is a slender rod, $\frac{1}{10,000}$ inch long and $\frac{1}{75,000}$ inch thick. It is strictly aërobic, grows only on special media, and then but slowly, is not motile, and does not produce spores. It stains with difficulty, but, once stained, resists decolorization with acids. It is, therefore, spoken of as an "acid-fast" bacillus. (See Plate I.)

Tuberculosis is an extremely common disease in man, and causes about one-eighth of all deaths. The disease is also very prevalent among cows, and hence tubercle bacilli are often found in cows' milk. The tubercle bacilli from this source differ somewhat from those found in human pulmonary tuberculosis, and until recently there was considerable controversy regarding the rôle of bovine tuberculosis in the spread of tuberculosis in man. It is now established that while pulmonary tuberculosis is practically always caused by bacilli of human origin, certain other tuberculous infections, especially in children, are due to milk from infected cows, and that the danger should be guarded against.

In man the most common form of tuberculous infection is that of the lung. In this situation the bacilli set up destructive inflammatory changes, and as a result of these a considerable quantity of sputum is usually coughed up. This sputum is loaded with tubercle bacilli, and is, therefore, highly infectious. During the act of coughing and sneezing tiny particles of infected sputum are scattered into the air and may be inhaled by other persons in the vicinity. Or these infected particles may lodge on the furniture, hangings, floor, etc., in the form of dust, and so again constitute a grave menace to others. In tuberculosis of the intestine (tuberculous enteritis) tubercle bacilli are found in large quantities in the feces, and this source of infection must be guarded against. For that matter, even in ordinary pulmonary tuberculosis tubercle bacilli are usually found in the feces, owing to the fact that the patients swallow some of their sputum.

In seeking to prevent the infection of others, therefore, it is important that the consumptive be carefully instructed to always spit into a vessel containing some disinfectant, or into a paper sputum cup which can be burned each day. In coughing, the scattering about of droplets of sputum should be prevented by holding a paper handkerchief in front of the mouth. The consumptive's room should contain no unnecessary furniture, bric-a-brac, hangings, or other objects likely to catch dust. Remembering that drying and sunlight are potent in the destruction of bacteria, it follows

PLATE I



Bacillus tuberculosis in sputum, stained with carbolic fuchsin and aqueous methylene-blue. × 1000 (Ohlmacher).

that the maximum of air and sunshine should be provided. Dry sweeping should not be permitted, dust should always be wiped up with a rag dampened with crude oil. From what has been said concerning the bacteriology of tuberculosis, other precautions will suggest themselves.

When tubercle bacilli are grown for a time in glycerin beef-broth, they gradually cause the broth to become loaded with poisons. When such a broth culture is evaporated and filtered, so as to be entirely free from tubercle bacilli, we have what is known as tuberculin. A curious thing about this tuberculin is that when minute quantities are injected into an individual infected with tuberculosis, a characteristic reaction takes place, marked by fever, prostration, some pains, increased cough, etc. In a normal, uninfected individual no such reaction is produced. This tuberculin reaction is thus of diagnostic value. It can also be applied by scarifying the skin with a needle and rubbing a drop of tuberculin into the scarifications. A positive reaction is denoted by distinct inflammatory changes at the site of the inoculation. This method of making the test is often spoken of as the von Pirquet test. If a dilute solution of tuberculin is dropped into the eyes, it may give rise to a reaction in the form of a marked congestion of the conjunctiva. This is spoken of as the conjunctival or Calmette reaction. Rubbed into the skin in the form of an ointment, tuberculin may also give rise to a reaction. This is Moro's test.

Tuberculin is also used in the treatment of tuberculosis. For this purpose very minute quantities are injected and the amounts gradually increased.

CHAPTER XIV

DIPHTHERIA

The diphtheria bacillus was discovered by Klebs, and first isolated in pure culture by Löffler. It is, therefore, usually spoken of as the Klebs-Löffler bacillus. It is rather long and thin, frequently somewhat clubbed at the ends, and possesses peculiar staining properties. It is a non-motile, Gram-positive, strictly aërobic

Fig. 28.—Bacillus of diphtheria, fifteen-hour serum culture. Löffler's methylene-blue; × 2000 (Denny, Journal of Medical Research).

organism, and produces a powerful poison, diphtheria toxin, when grown in broth cultures.

The regions most frequently invaded by the diphtheria bacillus are the tonsils and palate, the nasal passages, and the larynx. The characteristic feature of the inflammation produced by this bacillus is the formation of a peculiar dirty gray membrane on the surface of the part. This membrane consists of fibrin, pus cells, and granular débris, and contains numerous diphtheria bacilli. Somewhat similar membranes, however, are produced by other bacteria, especially by streptococci, and, while an experienced clinician can often tell by the appearance of the membrane whether the infection is due to the diphtheria bacillus or not, most physicians prefer to have the diagnosis established by bacteriologic examination. This should be done by spreading some of the membrane on a slide, fixing, and staining with Löffler's alkaline methylene-blue, and then examining under the microscope. In addition, where the facilities are at hand, by means of a sterile swab rubbed first over the membrane, and then over the surface of a tube of sterile Löffler's serum, a culture is made, incubated for from twelve to eighteen hours, and the growth examined under the microscope. In cases of true diphtheria such a culture will usually show enormous numbers of diphtheria bacilli. Both methods should be employed in order to insure a correct diagnosis, for certain germs, for example, those of Vincent's angina, will not grow on the culture-medium.

Knowing the location of the diphtheria bacilli, it is not difficult to devise measures to prevent the infection of others. All the mouth and nasal discharges must be carefully disinfected, carbolic acid being very useful for this purpose. Disinfection should, of course, extend to spoons, glasses, and other things coming in contact with the mouth. When examining the throat it is well to interpose a pane of glass between the patient and examiner, in order to safeguard the latter when the patient coughs. Quarantine is usually kept up until bacteriologic examination shows the absence of diphtheria bacilli.

In 1893 Behring, a German scientist, found that animals could be accustomed to injections of diphtheria poison, and that after a time the blood of these animals had acquired the power to cure other animals injected with many times a fatal dose of diphtheria poison.

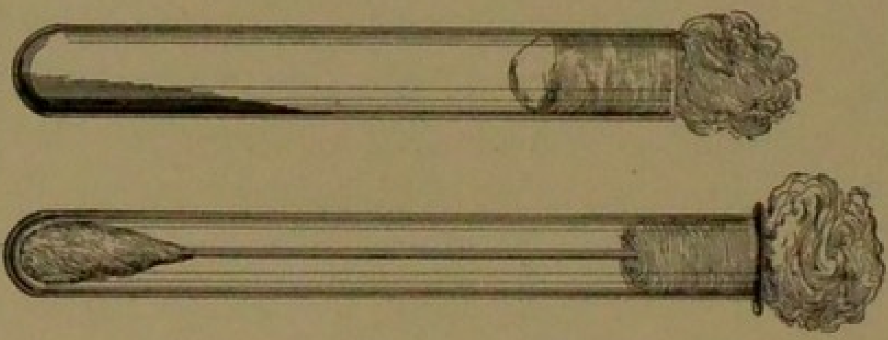


Fig. 29.—1, A tube of blood-serum; 2, a sterilized cotton swab in test-tube. Rub the swab gently but freely against the visible exudate, and without laying it down, after withdrawing the cotton plug from the culture-tube, insert it into the latter, and rub that portion which has touched the exudate gently but thoroughly over the surface of the blood-serum without breaking its surface. Now replace the swab in its own tube, plug both tubes, and place them in the box provided by the health officials. This is to be sent to the bacteriologic expert. In laryngeal diphtheria the swab is to be passed far back and rubbed freely against the mucous membrane of the pharynx and tonsils (Anders).

We have already said that the diphtheria bacillus when grown in broth produces a strong poison. This poison is spoken of as diphtheria *toxin*. The something in the blood of the treated animals which was able to overcome or neutralize the effects of the diphtheria toxin is, therefore, called diphtheria *antitoxin*. At the present time this diphtheria antitoxin is made by injecting horses with gradually increasing doses of diphtheria toxin over a period of several months, until at last the horse will stand, at one injection, as much diphtheria toxin as

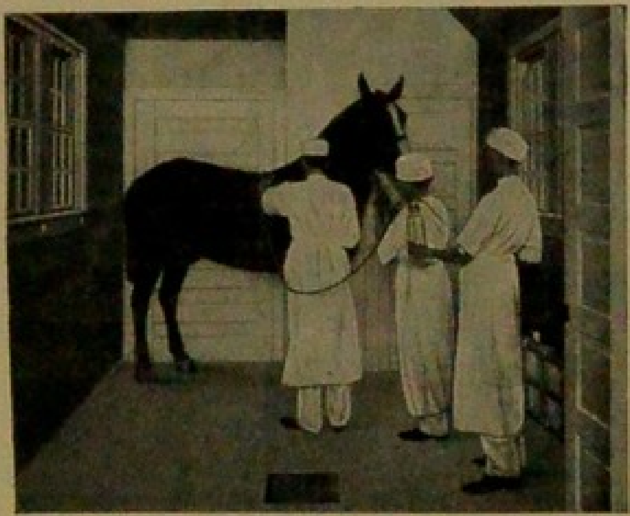


Fig. 30.—Injecting horse with toxin. (Courtesy of H. K. Mulford Company, Phila.)

would ordinarily suffice to kill several hundred horses. Then the animal is bled, as much as ten quarts of blood

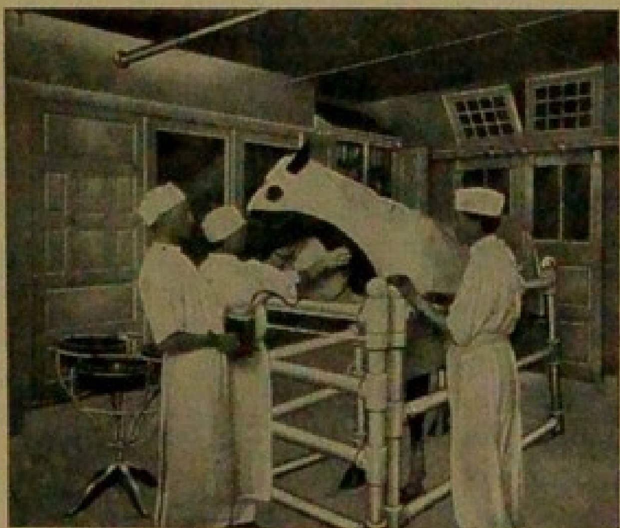


Fig. 31.—Bleeding horse in operating-room. Every precaution is taken to insure asepsis. (Courtesy of H. K. Mulford Company, Phila.)

being sometimes collected at one bleeding. When this blood is allowed to stand in a sterile vessel, in a cool place, it clots, and a clear, light-yellow fluid separates. This fluid is the blood-serum, and constitutes the diphtheria antitoxic serum used in the treatment of the disease. It is necessary to carefully test this antitoxic serum for purity and also for its strength. The latter is indicated by finding out against how many fatal doses of toxin a certain quantity of the serum will protect an animal. This is expressed by saying the serum contains so many units per cubic centimeter.[1] The ordinary sera now on the market contain from 500 to 1500 units per cubic centimeter.

In the treatment of diphtheria the antitoxic serum should be given early and in full doses (from 3000 to 10,000 units, depending on the severity of the disease). Ordinarily the serum is given by means of hypodermic injections, but in severe cases, especially when seen late, it is well to make the injections directly into a vein. When there are several children in the family affected, injections may also be given to the well children, in order to prevent their contracting the disease. Such injections are spoken of as "immunizing injections"; the dose for this purpose is usually 1000 units.

[1] As a matter of fact, one unit is that amount of antitoxin which will just protect a guinea-pig against 100 fatal doses of diphtheria toxin.

CHAPTER XV

TETANUS

TETANUS is caused by a bacillus which was first obtained in pure culture by Kitasato in 1889, five years after Nicolaier had succeeded in producing tetanus in laboratory animals by inoculating them with garden earth. In spite of the relatively frequent occurrence of the bacillus of tetanus in street dust, garden earth, manure, etc., tetanus is a rather rare disease. This is due to the fact that certain conditions must be present before the germ can do its deadly work. Thus, inoculation with a pure culture rarely produces the disease, but if other bacteria and dirt are introduced into the wound at the same time the bacillus can elaborate its toxin. An open wound is not nearly so favorable for its development as a small deep puncture or laceration; the type of wound which most frequently leads to tetanus is that made by a Fourth-of-July toy pistol. The bacillus of tetanus does not grow in the presence of oxygen, *i. e.*, it is an anaërobe, and is usually cultivated in the laboratory in an atmosphere of hydrogen gas, or in air from which oxygen has been abstracted. If this condition is fulfilled, it grows quite well on the ordinary culture-media, producing gas and a very disagreeable odor.

Grown under favorable conditions, the bacillus is a slender rod, of medium length, which is not decolorized by Gram's stain, *i. e.*, it is "Gram-positive." It is able to travel across the microscopic field, owing to the presence of flagella, which are arranged around its entire body. It shows greater resistance than most other bacteria to drying, to heat, and to chemic disinfectants, because it has the power to produce spores under adverse conditions. The spore is located at one end of the bacillus, and, being larger in diameter than the bacillus itself, gives to the latter somewhat the appearance of a nail. Heating to 105° C. for ten minutes is sufficient to

Fig. 32.—Bacillus of tetanus, showing spores. Pure culture on agar. Fuchsin stain (Kolle and Wassermann).

kill tetanus spores, yet they have remained alive on splinters of wood and have caused the disease after eleven years.

When tetanus bacilli are introduced into the body they multiply very slightly; local symptoms are only slightly marked or entirely absent. But the bacilli produce a powerful toxin which is the cause of the general symptoms. The toxin can be separated from cultures by filtration through a Berkefeld filter, and causes typic tetanus when introduced into animsls. Its action is weakened by exposure to light and entirely destroyed by heating to 55° C. and over. Like diphtheria toxin, tetanus toxin, when injected in small and gradually increasing doses into horses, produces in the serum of these animals an antitoxin. In fact, the toxin-antitoxin reactions, which have become so important in diphtheria, were first studied in connection with the bacillus of tetanus. The serum of immunized horses protects laboratory animals against experimental tetanus, and it was thought that the same might be used in the treatment of tetanus in man. But, unfortunately, tetanus symptoms develop late, anywhere from four to fourteen days after inoculation, while, to be of service, the antitoxin must be given before the toxin has spread through the system. To obtain a quick action of antitoxin it is best injected into a vein; 10,000 units (U. S. standardization) should be given and repeated every eight to twelve hours.

(Tetanus antitoxin is prepared like diphtheria antitoxin, but its standardization is not uniform, each country having its own standard unit.)

In New York City during the last few years apparently good results have been obtained with immunizing doses; 1500 (U. S.) units have been injected in cases where any suspicion of infection existed, mainly in Fourth-of-July wounds, and no cases of tetanus have developed where this method was pursued.

CHAPTER XVI

THE PNEUMOCOCCUS

THE pneumococcus, also called the diplococcus lanceolatus, was discovered by Fränkel. As its name implies, the organism occurs usually in lance-shaped twos. It is not decolorized when stained according to

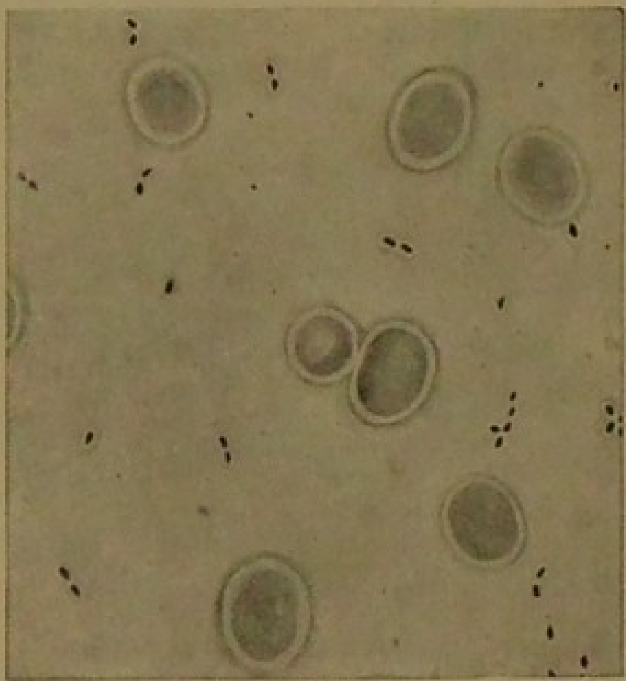


Fig. 33.—Capsulated pneumococci in blood from the heart of a rabbit; carbol-fuchsin, partly decolorized; ×1000 (McFarland).

Gram's method, and when occurring in sputum or blood is usually surrounded by a thick gelatinous capsule. The pneumococcus is non-motile and does not produce spores. It grows on ordinary media, but prefers those to which a little blood or blood-serum has been added.

The pneumococcus is closely allied to the streptococcus, from which it is sometimes hard to distinguish.

This is the germ which is responsible for most of the cases of lobar pneumonia and for more than half of the other forms of pneumonia. Other infections in which the pneumococcus is frequently the causative agent are pleurisy, otitis media, with its complicating mastoiditis, meningitis, endocarditis (inflammation of the valves of the heart), rhinitis (inflammation of the nasal passages), tonsillitis, arthritis (inflammation of joints), and conjunctivitis and keratitis (inflammation of the outer covering of the eyeball).

In pneumonia the pneumococci are found in enormous numbers in the sputum; in otitis media, in the pus discharged from the ear; in rhinitis it is in the nasal secretion; in tonsillitis, in the exudate covering the tonsils; in conjunctivitis and keratitis, in the mucopurulent secretion of the eye. Moreover, it has been found that the pneumococcus is also present in the mucus of the mouth and throat of very many healthy persons.

We see, therefore, that a great many different sources of infection must be guarded against. So far as the care of pneumonia patients is concerned, all the sputum should be carefully disinfected, and care should be taken that, in coughing, particles of sputum are not sprayed into the air. In crowded rooms the inhalation of such moist spray particles by others is undoubtedly a common source of infection. Patients suffering from pneumonia are often too ill to prevent their soiling their lips, face, and hands with sputum, and the nurse should, therefore, be on her guard to prevent further infection from this source. The enumeration of the main sources of infection as given above should suffice to guide the nurse in guarding others against pneumococcus infection. It is encouraging to know that the pneumococcus is very sensitive to germicidal agents. Exposed to direct sunlight pneumonic sputum loses its infectivity after a few hours. The fine spray expelled in coughing that remains suspended in the air soon dries so completely that no pneumococci survive after two hours.

CHAPTER XVII

STREPTOCOCCUS INFECTIONS

THE Streptococcus pyogenes[1] was observed by Koch and, independently, also by Ogston in 1882, but was first isolated by Fehleisen in 1883. The cocci are spheric or

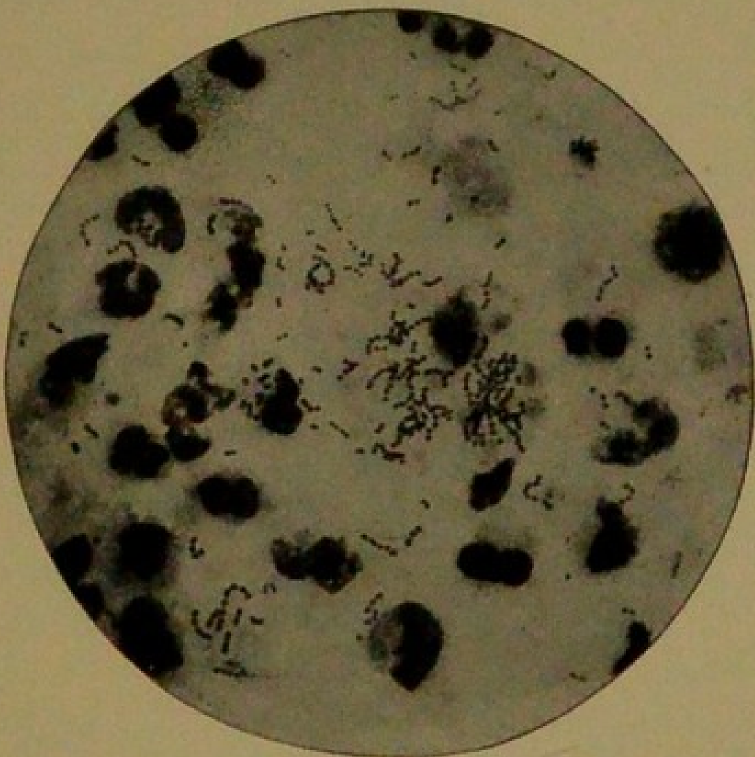


Fig. 34.—Streptococcus pyogenes, from the pus taken from an abscess; ×1000 (Fränkel and Pfeiffer).

oval, and occur in chains of eight, ten, twenty, or more individuals, though often merely in pairs. They stain readily with the ordinary stains, and retain the color

[1] Pyogenes means "pus producer."

when treated according to Gram's method. They grow readily on various media, but prefer media containing blood or blood-serum. Many varieties of streptococci have a peculiar dissolving effect on blood, so that, when grown on solid media containing blood, each colony is seen to be surrounded by a clear zone. We speak of such varieties as "hemolyzing" (blood-dissolving) streptococci.

Streptococcus pyogenes is the cause of a great variety of infections in man. Among these may be mentioned erysipelas, cellulitis, sepsis, puerperal infection, acute peritonitis, tonsillitis, bronchopneumonia, otitis media, and its complicating mastoiditis, meningitis, enteritis, endocarditis, synovitis, and arthritis. It must not be understood, however, that these infections are always due to streptococcus pyogenes, for we have already learned that other bacteria may be the cause. A number of observers hold that scarlet fever is a streptococcus infection, but the general opinion is that this organism is merely a secondary invader, probably through the tonsils.

The Streptococcus pyogenes, fortunately, is not difficult to kill. Thus, an exposure to a temperature of 130° F. for from ten to twenty minutes ordinarily suffices. Bichlorid of mercury, 1:5000, carbolic acid, 1 per cent., lysol, ½ per cent., kill the germ in a few minutes.

It should be unnecessary to enumerate all the precautions which a nurse should take in preventing the spread of streptococcus infection to others. They will differ, of course, with the kind of infection one is dealing with. It is well to remember, however, that transmission is probably always direct, and that infection through the air is very unlikely. For this reason, it is unreasonable to insist on isolating cases of erysipelas while keeping cases of puerperal sepsis in the ward. In fact, so long as the skin remains unbroken in the former condition, there is not much likelihood of transmission to others. The most virulent streptococci are those coming immediately from septic infections. Owing to the extreme susceptibility of women directly after childbirth to infection by way of the inner raw surface of the uterus, it is imperative that no nurse who has just before been in contact with streptococcus infections, or even with pus of any kind, be allowed to care for obstetric cases.

An antistreptococcus serum, obtained by injecting horses repeatedly with various cultures of Streptococcus pyogenes, has been used in the treatment of streptococcus infections. The results, as reported by different observers, are variable, but in certain cases appear to be good. The dose of the serum is large, from 50 to 100 c.c. or more intravenously, is usually recommended. Moser, of Vienna, uses the serum extensively in the treatment of severe cases of scarlet fever, and claims good results. The treatment of streptococcus infections by means of bacterial vaccines has yielded rather favorable results in the hands of some observers.

Years ago it was noted that malignant tumors sometimes tended to disappear or at least improve in persons who had recovered from accidental erysipelas. This led to the artificial production of erysipelas in such cases by the inoculation of pure cultures of streptococcus. Later on, only their toxic products were employed.

Coley, of New York, has obtained some striking results in the treatment of inoperable sarcoma by injections of the mixed toxins of the streptococcus and the Bacillus prodigiosus. The injected fluid is usually spoken of as "Coley's mixed toxins." This treatment is advised in inoperable cases.

CHAPTER XVIII

STAPHYLOCOCCUS INFECTIONS

THE staphylococcus was first observed by Pasteur in 1880, and first carefully studied in pure culture by Rosenbach in 1884. As seen in colonies, the organism appears orange, white, or lemon yellow, and is, therefore, divided into varieties termed respectively Staphylococcus aureus, Staphylococcus albus, and Staphylococcus citreus. The individual organisms are small spheric bodies, which usually group themselves in irregular masses. They stain well with the ordinary stains, and do not decolorize when treated according to Gram's method. They grow well even at room temperature, and do not demand any special media. When grown on gelatin they cause liquefaction of the medium.

The staphylococcus is much more resistant than other non-spore-bearing bacteria. Cultures may sometimes be heated for an hour to 140° F. without killing all the organisms. Dried pus contains living staphylococci for weeks and even months, and they can be found alive in the dust of air almost everywhere. To kill the organism in pus with bichlorid of mercury, 1:1000, requires an exposure of several hours.

The most common bacterial excitants of acute abscesses in man are the Staphylococcus and the Streptococcus pyogenes, though, of course, other bacteria may also produce abscesses. The Staphylococcus albus appears to be an almost constant inhabitant of the skin, and to be the common cause of "stitch abscess." In contrast to most other pathogenic bacteria, the staphylococcus appears to be able to infect through the unbroken skin. The organism has also been found in various pustular affections of the skin and mucous membranes, in acute abscess in the lymph-glands, in empyema, endocarditis, septicemia, and pyemia. Boils and carbuncles are very frequently due to this organism.

Fig. 35.—Staphylococcus pyogenes aureus (Günther).

So far as a source of infection of others is concerned, we really need not worry much about the occurrence of the staphylococcus in the dust in air. Lister, it will be remembered, kept a spray of carbolic acid solution playing about the operating-room during surgical operations in order to kill the germs which might be present in the air. Experience, however, soon showed that this was unnecessary. The presence of the staphylococcus on the skin is of more importance, but this, too, presents no great obstacle in controlling infection. The main point to bear in mind, in guarding against the spread of these infections, is the high resistance of the organism, especially in pus, and this indicates careful attention on the nurse's part, chiefly to the sterilization of instruments, hypodermic needles, and the like.

In recent years considerable success has attended the treatment of abscesses, boils, and other localized staphylococcus infections by means of bacterial vaccines. The doses ordinarily employed are from 300,000,000 to 500,000,000 dead staphylococci suspended in salt solution. The injections are given at intervals of about five or six days.

CHAPTER XIX

THE MENINGOCOCCUS

The meningococcus, also called the Diplococcus intracellularis meningitidis, was discovered by Weichselbaum in 1887. It is a somewhat flattened organism, occurring mostly in twos (diplococcus), and occasionally in small chains of fours. When stained according to Gram's method it decolorizes; that is, it is Gram-negative. It does not grow well except on media to which blood-serum or ascitic fluid has been added. The organism is not very resistant, and dies readily on drying or on exposure to direct sunlight.

The meningococcus is the cause of epidemic cerebrospinal meningitis. Other forms of meningitis are caused by the tubercle bacillus, by the pneumococcus and streptococcus, and occasionally also by other bacteria. In epidemic cerebrospinal meningitis the meningococcus is found in the purulent exudate covering the meninges and in the cerebrospinal fluid drawn by means of lumbar puncture. In fact, it is only by means of lumbar puncture that the variety of meningitis present can be determined.

It has also been found that the meningococcus is present in the nasal secretions of patients suffering from epidemic cerebrospinal meningitis, and in the nasal secretions of about 10 per cent. of the persons in intimate contact with such patients. The exact mode of infection is not known, but is probably through infected nasal secretions. This, of course, indicates the measures which should be taken in order to prevent the spread of the disease to others.

Epidemic cerebrospinal meningitis has been treated with specific antimeningococcus serum, obtained by injecting horses with cultures of the meningococcus.

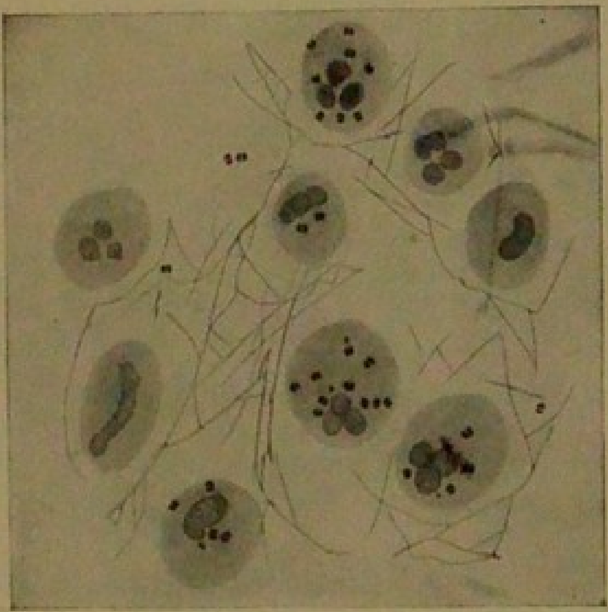


Fig. 36.—Meningococcus in pus cells: Pus cells containing diplococci from the meninges. A few diplococci are in the exudate outside of the pus cells. Between the pus cells there are delicate fibrillæ of fibrin. The illustration is an accurate representation of a group of cells in the field of the microscope (Councilman).

The serum is injected, by means of lumbar puncture, into the spinal canal, and the results thus obtained have been very encouraging, the death-rate being but one-half that of cases not so treated. As in all treatment with a specific sera, it is useless to employ antimeningococcus serum in cases of meningitis produced by germs other than the meningococcus. It is important, therefore, before employing the serum to make sure that the case is really one of meningococcus meningitis. This, as already stated, is done by means of lumbar puncture. The fluid thus obtained is centrifuged, the sediment spread on a slide, dried, fixed, and then stained according to Gram's method. In case of meningococcus meningitis Gram-negative diplococci will be found mostly in the interior of pus cells. (See Fig. 36, page 99.) If the organisms are Gram-positive the case is not one of meningococcus meningitis.

CHAPTER XX

THE GONOCOCCUS

The micrococcus of gonorrhea was discovered by Neisser in 1879. It is a small coccus, occurring in pairs (diplococcus). The two organisms which form the pair are flattened on their adjacent sides, which gives to the organism somewhat the appearance of a coffee bean. When stained by Gram's method the gonococcus is

Fig. 37.—Gonococci in urethral pus (McFarland).

decolorized, *i. e.*, it is "Gram-negative." It can only with difficulty be grown on artificial media, but thrives fairly well on glucose agar to which either blood or ascitic fluid has been added. Quick drying destroys it, and it cannot resist a temperature of 45° F. more than a few minutes. But in thick smears, on linen, etc., it has been found alive after a lapse of seven weeks.

The gonococcus is the cause of various severe purulent inflammations, among which the most important are gonorrheal urethritis and vaginitis and gonorrheal ophthalmia, as well as chronic joint affections and chronic endocarditis. In adults ophthalmia is usually due to an indirect infection, through soiled towels, etc., but in newborn babies it is caused by direct inoculation with gonococci found in the vaginal discharge of the mother. As a prophylactic measure the use of a 2 per cent. solution of silver nitrate in the eyes of every newborn baby has become a routine practice in obstetrics, with the result that the number of cases of blindness due to gonorrheal ophthalmia neonatorum has materially diminished.

In smears of fresh pus many of the gonococci will be found within the pus cells, and this peculiarity, together with their behavior toward Gram's stain, are aids in the diagnosis. (The meningococcus in pus from meningitis gives a similar picture, but it is smaller than the gonococcus, and does not, as a rule, occur under the same conditions.)

The gonococcus may remain dormant in the vagina and urethra for years, and at any time set up a fresh acute process. A vaccine, prepared by suspending the killed gonococcus in an indifferent fluid (physiologic salt solution), has apparently given good results in some joint lesions. The dose varies from 20,000,000 to 1,000,000,000, repeated at intervals of three to seven days. Attempts have been made to produce a curative serum by inoculating horses with increasing doses of vaccine, but so far the results of its use have not been specially satisfactory.

CHAPTER XXI

SYPHILIS

It was not until 1904 that the causative microorganism of syphilis was discovered, and not until 1911 was it successfully cultivated on artificial media. The organism belongs to the class known as Treponema, and in shape resembles a cork-screw. The organism stains with difficulty. For rapid examinations the so-called "ultramicroscope," or microscope with dark-field illumination, is usually employed. The picture thus produced is shown in Fig. 38.

Acquired syphilis begins with a characteristic sore known as a chancre or hard chancre. If the disease has been acquired through sexual intercourse the sore appears on the genitals. The stage of chancre is also spoken of as the primary stage. It lasts about six to eight weeks, and is followed by the secondary stage. The symptoms of the secondary stage include a rash, sore throat, pains in the joints, falling out of the hair, etc. The duration of this stage is variable, and no hard-and-fast line can be drawn between it and the tertiary stage. During the latter the disease shows a tendency to produce certain skin eruptions, gummatous growths in the viscera, and degenerations.

The ulcerations, especially the primary sore (chancre), and the so-called "mucous patches" in the mouth and throat, are exceedingly infectious. Examined with the dark-field microscope, scrapings from these ulcerations are seen to swarm with the *Treponema pallidum*. A syphilitic having mucous patches may infect a drinking-cup or a spoon and cause infection of others. The infection then makes its appearance on the lip or tongue of the victim. Infection may also be carried through kissing.

Fig. 38.—Treponema pallidum appearing as bright refractive body on a dark field, as shown by India ink or ultramicroscope (Park and Williams).

When syphilis is transmitted from parent to offspring, the disease often shows itself in the baby by what are called "snuffles." The secretion from the nose of such babies is highly infectious. A syphilitic baby should not be given to a healthy wet-nurse to suckle. If the mother cannot nurse it, the baby should be brought up on the bottle.

A great aid in the diagnosis of syphilitic infections is that devised by Wassermann, of Berlin. This test can be performed either on the blood or the cerebrospinal fluid of patients. While a positive result indicates a syphilitic infection, a negative result does not indicate the absence of such infection.

CHAPTER XXII

EXANTHEMATA[1]

UNDER this head are included measles, German measles, scarlet fever, small-pox, chicken-pox, and typhus fever. They are alike, in that no specific organism has yet been demonstrated and definitely proved to be the cause of the infection. The causative agent is spoken of as a "virus," and typic clinical symptoms can be produced in healthy animals or humans by inoculation with skin or blood from patients ill with one of the exanthematous diseases.

Scarlet Fever.—In 1904 Mallory described tiny glistening corpuscles in tissue cells which he regarded as the protozoan causes of scarlet fever. Other observers were unable to demonstrate them in living tissues, but found them also in measles, blisters, and in some antitoxin rashes. They are now generally regarded as degenerated leukocytes. The streptococci which cause the severe sore throats in scarlet fever are by most bacteriologists considered as a constant but secondary infection, and not as the cause of the general symptoms and of the rash of scarlatina.

Measles and German Measles.—Bodies similar to Mallory's scarlet fever bodies have been described, and an influenza-like bacillus has been held responsible for

[1] Exanthemata, the plural of exanthem = a breaking out, an eruption.

the coryza which accompanies measles, but nothing definite has been proved about the bacteriology of these two diseases.

The virus of measles, whatever its nature, exists in the blood of the patient during the fever. This has been demonstrated by several investigators, who have succeeded in producing the disease in monkeys by inoculating these animals with the blood of measles patients. After the fever abated the blood was no longer infectious. In monkeys the disease runs a milder course than in human subjects, and a monkey that has passed through one attack is thereby made immune.

The virus passes through a Berkefeld filter, that is, the filtered material remains infectious. It is destroyed by heating to 55° C. for fifteen minutes, but resists drying for twenty-four hours. No development takes place on any of the usual culture-media.

Bacteriologists have found cocci and bacilli which for a time were considered the causes of the disease. We know now that these were accidental contaminations. Weigert also described "bodies" included in epithelial cells, which have since been variously interpreted as degenerative forms of tissue cells, or as protozoa causing the disease.

Cow-pox is presumably identical with **small-pox,** being modified because it develops in a different host. When calves are inoculated with small-pox virus they develop lesions very similar to cow-pox. In monkeys inoculation with cow-pox virus protects against small-pox, and vice versa, and the same protective action holds in man. This has been proved for more than a century, *i. e.*, since Jenner, in 1796, introduced vaccination. In every country where vaccination has been made compulsory there has been a sudden and constant

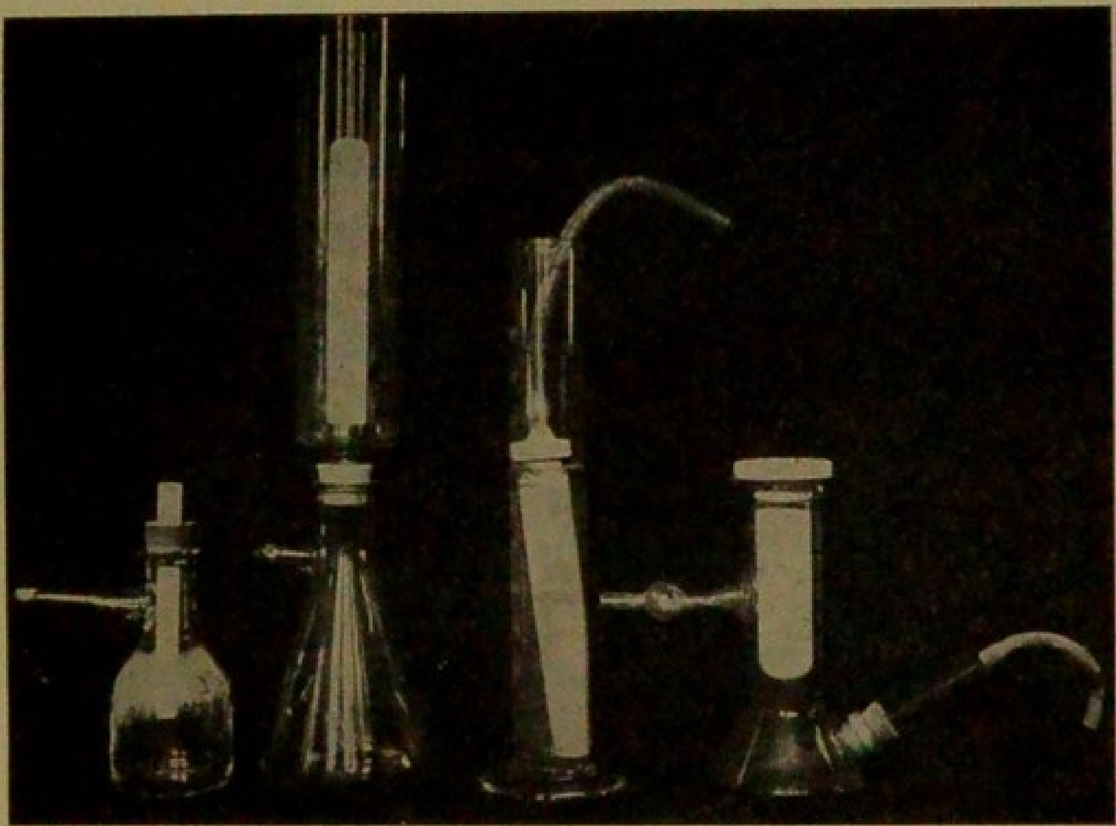
Fig. 39.—Operating-room. Collecting vaccine from a calf. The calves which are used in the preparation of the virus are first washed, the long hair is clipped, and the skin is cleaned with bichlorid solution, then in an alkaline bath, and finally all traces of the antiseptics are removed by thorough rinsing in sterile water, after which the surface to be operated upon is shaved. The animals are then conveyed to the operating-room, where they are vaccinated with tested virus under conditions similar to those existing in the operating-rooms of modern hospitals, after which they are transferred to the propagating stable and kept as clean as is possible. In about six days the virus is removed and prepared for use under rigid aseptic precautions. (Courtesy of H. K. Mulford Company, Phila.)

lowering of the number of small-pox cases, and those which do occur are of a milder nature than formerly.

CHAPTER XXIII

FILTERABLE VIRUSES

In describing bacteria it was stated that they varied in size from $\frac{1}{50,000}$ to $\frac{1}{1000}$ inch; the average pathogenic bacterium is about $\frac{1}{10,000}$ inch long. It is obvious that



a *b* *c* *d*

Fig. 40.—Different types of bacteriologic filters: *a*, Kitasato; *b*, Berkefeld; *c*, Chamberland; *d*, Reichel (McFarland).

such tiny organisms readily pass through ordinary paper filters and through absorbent cotton filters. It is possible, however, to construct filters which entirely hold back even such tiny particles as bacteria. Such filters are usually made of an unglazed, burnt clay. A number of different makes are on the market—Berkefeld, Pasteur, Chamberland, Pukall, etc. In all of these it is necessary to either draw the fluid through by suction or force it through by pressure. Figure 40 shows the construction of this type of filter.

Experiments conducted with filters of this type led to the astonishing discovery that the virus of certain infectious diseases was able to pass through. It was impossible to see any living particles in these filtrates even with the highest powers of the microscope, and yet the virus was present, as could be shown by appropriate animal experiments. Very little is known about the nature of these filterable viruses, but we have felt it well to mention the fact that they exist. Some of the diseases known to be caused by a filterable virus are:

Measles.
Hydrophobia (rabies).
Poliomyelitis.
Yellow fever.
Dengue.
Foot-and-mouth disease of cattle.
Rinderpest of cattle.
Hog cholera.

So far as hydrophobia is concerned, it appears that some of the finer grained porcelain filters hold back the virus. Certain characteristic bodies found in the brain cells of rabid animals are diagnostic of the disease. They are spoken of as "Negri bodies," and are held by some observers to be the causative organisms, *i. e.*, the virus.

CHAPTER XXIV

MALARIA

MALARIA is an infectious disease, the cause of which is not a bacterium, but an animal micro-organism, a *protozoön* (plural *protozoa*). Its old name, "plasmodium malariæ," has been replaced by the term "hemameba malariæ." This parasite was discovered in 1880 by Laveran, a French army surgeon, and in the course of work with the malarial parasite which followed upon Laveran's discovery, Manson, Ross, Grassi, and others found that the hemameba has two distinct life-cycles, a sexual one, which takes place in mosquitos, and a non-sexual cycle, occurring in the blood of human patients. The young forms of hemameba, both male and female, live in the *Anopheles*, a species of mosquito which breeds and lives largely in stagnant pools and marshes. In the stomach wall of this mosquito fertilization occurs, and the development of the young forms proceeds until, at the end of ten to fourteen days, they are set free into the digestive tract of the mosquito and pass, through the bite of the insect, into the blood-stream of a human being. Here they penetrate the red corpuscles, where they remain until they are fully matured, and divide into a number of round or oval segments, which are shed into the blood-stream. The same cycle can be repeated indefinitely in man, the stage of fever marking the setting free of amebulæ.

Although it is possible, experimentally, to produce malaria by inoculating a person with blood from a patient suffering from the disease, yet, in practice, malaria can never be transmitted without the aid of the particular mosquitos mentioned. In other words, without mosquitos there can be no spread of malaria.

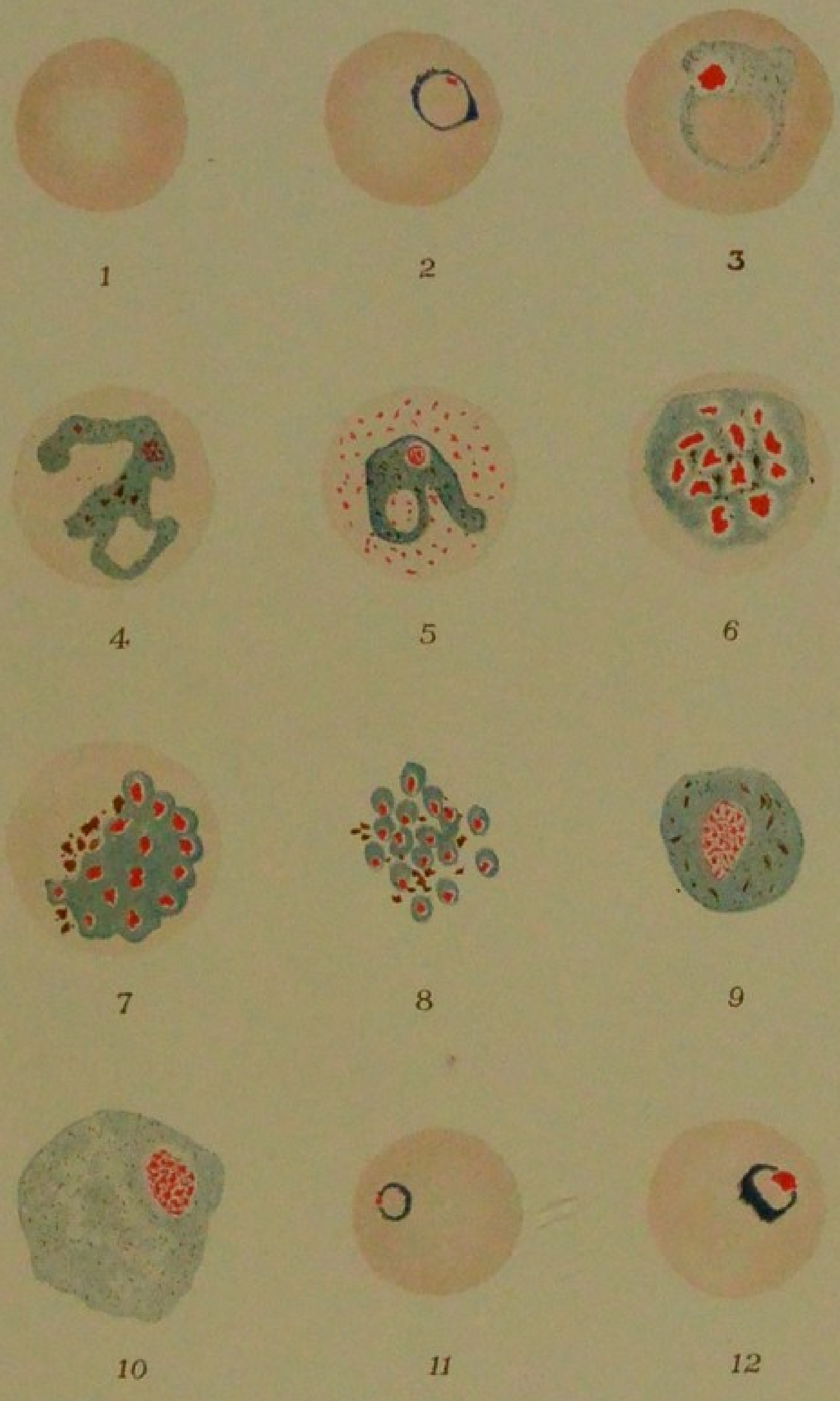
There are three recognized types of the hemameba—the quartan, the tertian, and the estivo-autumnal parasite. The two former cause a relatively benign infection, while the estivo-autumnal parasite causes malignant malaria. (Plate II.)

The organism of the quartan malaria develops in the blood in seventy-two hours; hence, there is a febrile stage every third day. Under the microscope, in a fresh smear, the organism is a tiny refractive body, slightly motile, and contains coarse, blackish-brown pigment. It segments into six to twelve round amebulæ.

The tertian parasite is less glistening, but more actively motile than the quartan; its cycle in the human host is completed in forty-eight hours, and it then divides into fifteen to twenty oval bodies. The pigment of the tertian parasite is yellowish brown and quite fine.

Estivo-autumnal parasites are small and show more active ameboid motion than the other two; they contain very little pigment, which is dark and quite fine. The red blood-corpuscles which contain the parasite are apt to shrink and assume a brassy color. This type completes its cycle chiefly in the blood of the internal organs (*e. g.*, the spleen), and it may be difficult to locate it at all in the circulation. Its sexual forms are crescentic in shape. All three types are best stained with methylene-blue. The Romanowsky method uses a compound ob-

PLATE II



MALARIAL PARASITES: 1 TO 10 INCLUSIVE, TERTIAN PARASITES; 11 AND 12, QUARTAN PARASITES. (Deaderick, "Study of Malaria.")

1. Normal red blood cell. 2. Young tertian ring. 3. Large tertian ring. 4. Half-grown tertian parasite. 5. Infected cell showing Schüffner's dots. 6. Adult tertian parasite. 7. Beginning sporulation. 8. Sporulation completed. 9. Tertian microgametocyte. 10. Tertian macrogamete. 11. Young quartan ring. 12. Older quartan ring.

tained by bringing together methylene-blue and water-soluble eosin; the resulting powder is soluble only in alcohol; it stains the parasites blue, red blood-cells a deep pink, and white blood-cells pale pink with blue nucleus.

Apparently there exists a slight natural immunity to malaria; occasionally a few residents in malarial districts escape infection. Also a partial immunity is acquired by some individuals who have passed through one or more infections. Thus the negroes on the west coast of Africa are less severely attacked than Europeans who go to live there, and Koch has attributed this to their having acquired a partial immunity during childhood.

The malarial parasites are actively destroyed by quinin, arsenic, and certain other substances. In the campaign in this climate against malaria it is well to direct attention also to suppressing the mosquito nuisance, and, hand in hand with that, to kill the malarial parasites in their human hosts by means of quinin.

TRYPANOSOMIASIS

In connection with malaria, a word may be said about trypanosomiasis, or "sleeping sickness." This dreaded African scourge is caused by a protozoön somewhat similar to that of malaria, and transmitted not by the mosquito, but by a species of biting-fly, known as the "tsetse fly." The characteristic symptoms are produced by the trypanosomes entering and growing in the cerebrospinal fluid. The disease appears to be almost invariably fatal.

CHAPTER XXV

BACTERIOLOGY OF MILK

MILK, one of the most important articles of human diet, is at the same time an excellent medium for the growth and development of bacteria; hence, great importance attaches to methods pursued at the dairy. The bacteria generally found in milk have two sources—they may be derived from the cow's udder, or they may fall into the milk while it is being drawn, or later at any stage of handling. It is practically impossible, even under the very best conditions at the farm and with the most approved methods of distribution, to obtain a milk absolutely free from bacteria. But, fortunately, the varieties generally found in market milk are not pathogenic, and are not to be considered dangerous to the consumer unless they are allowed to multiply abundantly, when they cause souring and curdling or putrefaction, and may thus render the milk unfit for use.

Broadly speaking, we may divide market milk into three groups:

(*a*) Best quality, showing not over 10,000 bacteria to the cubic centimeter.

(*b*) Good quality, not over 500,000 bacteria per cubic centimeter.

(*c*) Poor quality, 5,000,000 to 50,000,000 and more bacteria per cubic centimeter.

In summer these normal milk bacteria multiply with astonishing rapidity, and soon render the milk unfit for food. In addition to the curdling and the souring, there are produced by some of these bacteria toxic substances which are especially badly borne by infants, and, as it is chiefly as an infant foot that milk must be considered, it becomes necessary to devise means of keeping the milk sweet.

Much can be done at the dairy, by keeping stables and animals very clean, and by using due precautions when milking to keep out dust and dirt. Then, the warm milk must be rapidly cooled to about 40° to 50° F., bottled, and shipped in ice to the consumer. But such conditions prevail at comparatively few dairies, and naturally increase the cost of production considerably, bringing such milk beyond the reach of the great masses. When, therefore, for any reason the bacterial count of milk is high, it is best to resort to sterilizing by heat. This may mean boiling for five to ten minutes. The objections to this are: First, the coagulation of some of the proteins, which may render them less digestible, and, second, a peculiar and rather unpleasant taste and odor which are imparted to the milk. Therefore, pasteurization has largely superseded boiling. This means heating to 140°–160° F. for fifteen minutes or more. When done on a large scale, the milk to be pasteurized is allowed to run in a thin stream over a metal surface, which is heated by steam to the required temperature, or it may run through a coil of tubes, which are kept in hot water, bringing the temperature of all the milk up to the required degree. It is important that all the milk be thus heated, since otherwise bacteria remain alive in some of the milk, and will develop rapidly throughout the whole lot of milk. Commercial pasteurization has certain disadvantages as well as advantages. If properly done, with fresh milk which is then cooled rapidly, the pathogenic bacteria, such as typhoid and tubercle bacillus, are killed, as are also the lactic acid bacilli, which cause the souring of milk. What remains alive are the spore-bearing varieties. Among them are the putrefactive organisms, but these are present in small numbers only and are unable to develop at low temperature. But it is impossible to tell whether pasteurized milk was really fresh when heated, *i. e.*, it may have been in a tainted condition before pasteurization. Normally, the lactic acid bacilli, by altering the reaction of the milk, keep down the growth of putrefactive organisms, but in heated milk the growth of these latter is unchecked, and, unless carefully treated, well cooled, and kept cool, pasteurized milk may have a higher bacterial count than a good quality raw milk. For this reason the pasteurization of milk supplied by the dealers should be carefully supervised by the public health authorities.

There is no doubt that home-pasteurization of milk has been found of considerable advantage, especially for infants, and several pasteurizers have been put upon the market, the best known among them being those of Arnold and of Freeman.

A simple milk pasteurizer for home use consists of a tin pail, having a perforated cover and containing a wire basket, into which are fitted eight nursing bottles. The water in the pail is heated to boiling, the wire crate is then lowered until the bottles nearly touch the water. The milk is steamed in the open bottles for ten minutes, then the bottles are corked and steaming is continued another fifteen minutes. After that the milk is kept on ice until used.

Freeman's pasteurizer consists of a pail with a tight-fitting cover and a removable rack, holding a number of

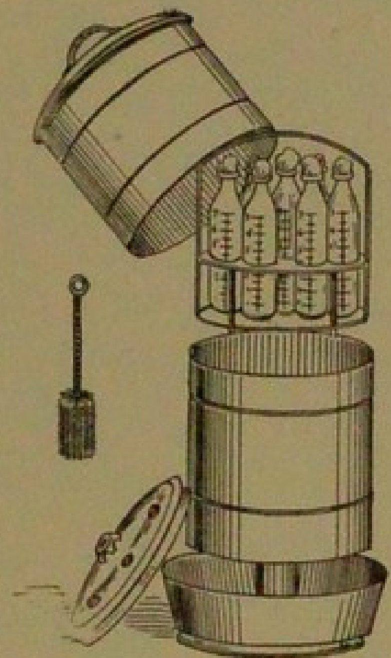


Fig. 41.—Arnold's apparatus for sterilizing milk (Ashton).

cylindric metal cups, which receive the milk bottles. The pail is filled with water to a groove about halfway

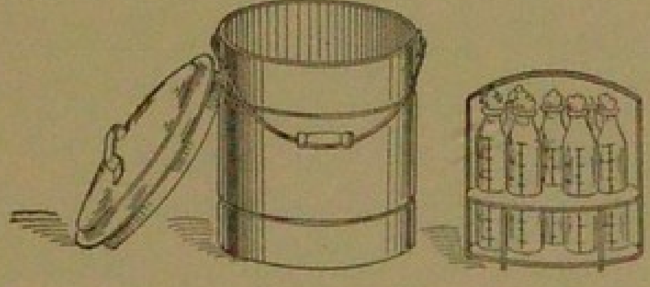


Fig. 42.—Apparatus for pasteurizing milk (Ashton).

from the top and the water is brought to the boiling-point. The milk bottles are then placed into the metal cups and are in these surrounded by water, which serves as a conductor of heat. The filled rack is immersed into the boiling water in the pail, the pail is removed from the stove, and the cover replaced. Within ten minutes the temperature of both water and milk reaches 160° F. and remains at that level for about twenty minutes. Then the bottles are removed and rapidly cooled in the water-bath, or, better, the hot water in the pasteurizer is replaced by cold, which is run in by means of a rubber tube attached to the kitchen faucet. The milk is then stored on ice.

Besides the above bacteria, which are inevitable inhabitants of all market milk, and which vary in the different grades of milk in number only, other and much more serious contaminations may occasionally be found. Of those derived from the cow the most frequent are streptococci from a suppurative mastitis, and the tubercle bacilli, from udder tuberculosis or tuberculous lesions elsewhere. It has been demonstrated that while the tubercle bacillus found in cows is not of the same variety as that which produces pulmonary tuberculosis in adults, it is nevertheless able to set up even fatal tuberculous processes in small children and infants.

Typhoid fever is not infrequently spread by means of milk; the bacillus is introduced into the milk directly, through uncleanly habits of the milkers, among whom there may be a so-called "carrier," that is, an apparently perfectly healthy individual who harbors in his intestines virulent typhoid bacilli, or, indirectly, by contaminated water which has been used to wash utensils, etc.

Asiatic cholera, dysentery, and similar diseases may be spread in the same manner, but are probably only infrequently disseminated in this way. Epidemics of scarlet fever and diphtheria, however, have been directly traced to contaminated milk.

It is important to keep flies from milk. A fly can readily infect milk through the filth which it carries on its legs.

Fig. 42*a*.—Colonies of bacteria transplanted by a fly's feet (Magruder).

When properly supervised by the health authorities, pasteurization of the milk offers the best protection against all these various infections.

CHAPTER XXVI

FERMENTED MILKS

According to Metschnikoff, many of the degenerative changes associated with old age are due to poisons generated in the intestines by putrefactive bacteria. Moreover, his investigations lead him to believe that excessive intestinal putrefaction can be greatly lessened by introducing bacilli which produce lactic acid in the intestines. In fact, he ascribes the healthfulness and longevity of certain people of eastern Europe to their extensive use of sour milk as an article of diet.

For many years the people of eastern Europe and western Asia have looked upon sour milk as an essential part of their daily diet. The term sour milk covers all milks or parts of milk in which lactic acid fermentation is pronounced. Ordinary buttermilk sours because of the growth of lactic acid bacteria in the raw milk. Sour milk from the dealers is more usually heated milk to which some special culture of bacteria ("starter") has been added. A starter, now extensively used, is one supplied by Metschnikoff.

Many different species of bacteria are able to provoke the lactic acid fermentation, but ordinarily only a few species are responsible for the natural souring of milk. Chief among the latter are the common lactic acid bacilli and an organism spoken of as the milk streptococcus. Inoculation of sterilized milk with pure cultures of these two organisms and with mixtures reproduces very closely the process of natural souring.

In addition to this lactic acid fermentation, milk is sometimes caused to undergo an alcoholic fermentation. This is done by fermenting the milk with yeast or with a mixture of lactic acid bacteria and yeast. A well-

Fig. 43.—Bacillus bulgaricus of the bacillary milk; × 1000 (Fairchild).

known drink, called koumiss (or kumyss), is made by the Tartars from mares' milk, a small quantity of old koumiss often being added to fresh milk as a starter. In this country koumiss is made commercially by fermenting milk with yeast and lactic acid bacilli. Such a preparation contains not only lactic acid, but also carbonic acid gas and about 1 per cent. of alcohol.

Matzoon, yoghurt, zoolak, fermilac, etc., are made from sterilized milk by fermentation with lactic acid bacteria. These preparations contain neither alcohol nor carbonic acid gas.

Detailed directions for the preparation of various kinds of fermented milks will be found in nurses' cook books, and in the circulars supplied with the various lactic acid bacillus cultures on the market.

CHAPTER XXVII

BACTERIAL FOOD POISONS

ALTHOUGH poisoning occasionally results from mineral poisons accidentally present in food, and poisoning may also be caused by fungi, by far the largest proportion of cases of food poisoning are due to bacteria which develop on animal or vegetable foods. Among these are certain types which produce powerful toxins analogous to diphtheria or tetanus toxins. All dead organic matter offers an excellent culture-medium for the growth of bacteria, and only careful storing and thorough cooking will prevent their development and the mischief they cause.

The *Bacillus enteritidis* was found by Gärtner to be the cause of a severe epidemic of food poisoning, and was traced to meat from a diseased cow. This organism is apparently closely related to the common colon bacillus, a normal inhabitant of the intestinal tract, which may, however, under certain conditions become pathogenic. Like the colon bacillus, it forms a toxin which resists heating, so that ordinary boiling does not render the tainted food harmless. There is nothing in the odor or appearance of the meat to excite suspicion.

One of the most frequent and most thoroughly studied causes of epidemic outbreaks of food poisoning is the *Bacillus botulinus*. This was first studied by Van Ermengem in some 30 cases, all of which were due to the eating of badly cured ham. The bacillus is a spore-bearing anaërobe of slight motility, producing a powerful toxin which acts on the nerve-cells, but which is, fortunately, easily destroyed by heat. The appearance of the food gives no warning, although there may be a slight rancid odor.

Another organism which may cause trouble is the *Bacillus proteus vulgaris.* This also does not alter the appearance of the food; boiling renders its toxin harmless. This explains why botulinus and proteus infections are almost entirely caused by the eating of sausages and ham, which in Northern Europe are smoked, but not cooked.

Anthrax has been known to be conveyed to man through the meat of calves or cattle suffering from the disease, as well as through gelatin made from calves' feet. As anthrax spores are very resistant to heat, ordinary boiling may not suffice to kill them.

Fish, as well as meat, can be the carrier of infection. This may be due to sewage contamination of the water (*e. g.*, oysters spreading typhoid fever), or it may be due to the development of poisonous bacteria in smoked or canned fish.

Milk, as stated before, is an excellent culture-medium for bacteria, and may, consequently, be responsible for certain epidemics of poisoning. Apart from such diseases as typhoid, there are on record certain epidemics of "milk poisoning," notably one in Christiania in 1888, which numbered 6000 cases in three weeks. A colon-like bacillus has been isolated from some of these epidemics. What applies to milk is true also of the milk products, notably, cheese and ice-cream; poisoning by these is due to the presence of bacteria which belong to the colon group.

From the foregoing it becomes evident that careful inspection of all food stuffs is necessary, together with such storing and preparation as will keep them in wholesome condition. Where proper storage facilities exist (*i. e.*, large cold-storage plants), in which edibles are kept at a constantly low temperature, meat, fish, eggs, fruit, etc., can be kept in good condition for months. In the absence of such facilities, perishable foods must be freshly consumed. In warm weather it is not safe to keep fish for more than twenty-four hours. In the home foods must be kept in the refrigerator. While bacterial growth at refrigerator temperature is very slow, it is not entirely inhibited, and for this reason the ice-chest must be kept very clean. It is especially important that food spilled on the shelves be immediately removed; the ice-box should be washed from time to time with a solution of soda in hot water and quickly cooled again; at all times it should be kept well filled with ice. The fluctuations of temperature due to insufficient ice supply are especially harmful.

From what has been said elsewhere of the habits of the house-fly, it follows that no food must be allowed to stand around in uncovered vessels. Food which is at all suspicious as to color or odor should be discarded, and all foods which are not perfectly fresh—including canned fruits and vegetables—should be thoroughly cooked before eating.

When bacterial decomposition has taken place in canned food the tops of the cans may present a convex surface, making what is known as a "blown" can. The contents of a "blown" can should, therefore, never be used for food.

CHAPTER XXVIII

BACTERIOLOGY OF WATER

All waters probably contain a greater or lesser number of bacteria, although those of the pathogenic variety are found only when there is direct contamination from human sources. The naked-eye appearance of any sample of water is rarely indicative of its safety; some very clear and sparkling water may be contaminated with typhoid bacilli and constitute a serious menace, while a turbid water may owe its lack of clearness and a possible disagreeable taste and odor to the presence of minute water plants and algæ that are absolutely harmless.

Rural communities depend almost entirely on springs and wells for their water supply, and great care is necessary to so locate cesspools, privies, drains, stable sinks, etc., that their discharge or overflow may not contaminate the drinking-water. Shallow wells, which are nearer the surface and receive the local wash after a rainstorm, are naturally richer in bacteria than deep wells, and in farming regions, in pasture lands, may contain large numbers of intestinal bacteria.

For cities the supply of safe and pure water has become a very important and serious problem. Where mountain springs are abundant, within reasonable distance, the water may be allowed to collect in reservoirs and be conducted to the city, often a distance of many miles. Such water is apt to be excellent, provided proper care is taken to prevent pollution at the reservoirs, but for most large towns and cities such a supply is unavailable, and they must often take their supply from lakes or rivers. In these cases the danger from pollution is very great, especially if the country around the body of water is thickly settled, and town after town empties its sewers into the same. The water of some rivers is practically dilute sewage, and polluting material is added so fast that the natural means of purification are entirely unavailing. The most important of these natural agents are sedimentation, oxidation, and the disinfecting action of sunlight. By sedimentation the large foreign bodies suspended in the water carry with them to the bottom many bacteria, and other bacteria are killed through the life-activities of certain water plants. Sunlight does not act to any great depth, but probably kills many bacteria in the water at the surface. Freezing mechanically frees water from a certain percentage of impurities, including bacteria, by squeezing them out, but low temperatures do not kill all germs; hence the danger of using ice from polluted lakes and streams.

The two most important water-borne diseases are typhoid fever and Asiatic cholera, and the latter disease has furnished a classic example of sewage contamination of drinking-water and its consequences, as well as the most striking proof of the efficiency of filtration. The two towns of Hamburg and Altona are situated closely together, at the mouth of the river Elbe, and both draw upon that river for their water supply. When, in 1892, the river water became polluted with the discharges of a cholera patient, Altona, which used filtered water, had but a few cases, most of which could be traced to Hamburg; while the latter city, whose sand-filters were not yet completed, paid a toll of 8000 lives. Bacterial examination of the water at Albany, N. Y., has shown that the sand-filters in use there remove from 98 to 99 per cent. of all the bacteria in the water. In Albany, as in other cities, the introduction of filter plants has enormously reduced the number of deaths from typhoid fever.

Briefly, these filters are huge reservoirs which hold a layer of coarse, broken stone, upon this a layer of smaller stone and gravel, then a layer of coarse sand, and at the top one of fine sand. As the dirty water percolates through these different layers it gradually deposits its gross impurities at the top, and coats the individual sand grains with a slimy covering. This "dirt cover" forms the really efficient filter, but it finally becomes too tenaceous to allow any water to pass through, and must be scraped off about once a month, hence it is necessary always to have at least two filtering beds. The water must not flow through the filters faster than 4 to 4½ inches per hour, as otherwise infectious material may be carried through. Waters which are very dirty require sedimentation to rid them of the grossest impurities before filtering. When, at the same time, the color is muddy, it is often advisable to add a chemical, usually alum, which acts much as egg-white in clearing fluids, and then to remove the jelly-like aluminum hydrate, plus impurities, through a relatively thin sand-filter.

Household filtration ought to be only a temporary makeshift. There are some very good types of domestic filters, but they are costly, and require very intelligent and conscientious handling to give good results. Many of the cheap ones are worse than useless because they cannot be cleaned at all, and thus soon become veritable culture-media for bacteria. This is true of sand, charcoal, and sponge filters, which, after the first few days, are merely "strainers," keeping back gross impurities, but allowing bacteria to grow in them and pass out into the "filtered" water in greatly increased numbers. Good types of domestic filters are the Pasteur and the Berkefeld filters. Both consist of a cylinder of porous porcelain called a "candle," fitted within a larger metal cylinder. The metal cylinder is attached to the faucet, the water enters it and cannot leave it except through the porcelain candle, which retains all bacteria. But there is danger of the bacteria "growing through" the candle; hence it becomes necessary to boil and scrub the candle every few days, and then dry it in the oven to kill all germs. After that the filter is again efficient. There must be a tight connection between the two cylinders, as otherwise unfiltered water may mix with the filtered.

Another method of purifying water is to distil it, *i. e.*, to convert it into steam and condense the steam in a vessel kept cold. Freshly distilled water is absolutely pure, since not only all living organisms are destroyed, but any chemicals in solution are kept back. Such water is quite expensive and not particularly palatable. Its continued use as a drinking-water is thought by some to be harmful, owing to the absence of any salts and the likelihood to abstract salt from the tissues.

Probably the simplest, easiest, and, at the same time, a very safe process of household purification of water is to boil it for ten minutes. The objectionable "flat" taste can be removed, for drinking-water, by pouring from the vessel at a considerable height, or by shaking it in an open vessel to aërate it. Of course, water which has been boiled to sterilize it for surgical purposes must be kept in a properly cotton-plugged vessel to prevent air contamination.

Regular bacteriologic examinations of the water supply of a town are made in order to keep informed on the purity of the water and to enable one to locate contamination at once. If tap-water is to be tested, it is necessary to allow it to run for some time, so as to flush the pipes and taps. If an examination is desired of lake or river water, samples are taken in sterile vessels which are shipped to the laboratory in ice. A definite amount of water (1 c.c. or less) is then added to a tubeful of melted agar, at 40° C., the mixture is poured in a Petri dish and allowed to stand at 22° C. for forty-eight hours. Then the number of colonies is counted. Since the bacterial examination of water yields only approximate results, the American Public Health Association has set up certain standards that insure uniform methods and allow the results to be compared.

If there is any reason to suspect sewage contamination, special tests are made to isolate the Bacillus coli. The water is added to lactose broth in a fermentation tube and is incubated at 37° C. for three days. The production of gas in the closed arm of the tube points to the presence of Bacillus coli. When litmus is added to lactose-agar, and the suspected sample of water is plated out, the colon bacillus will produce acid which causes its colonies to be surrounded by a red halo, while the rest of the culture-medium is blue. A few colon bacilli may accidentally occur in water, which is safe, but their presence in large numbers spells danger. It is difficult to isolate the cholera vibrio and especially the typhoid bacillus from contaminated drinking-water, hence the presence of colon bacilli is taken as showing sewage contamination, and the number of these organisms as the index of danger.

CHAPTER XXIX

ANIMAL PARASITES

ALTHOUGH in no sense related to bacteria, we venture to include a few words concerning some of the commoner animal parasites of man, because, in most instances, the methods of guarding against such infections is similar to those employed in guarding against bacterial infection.

Tapeworms.—These have a double cycle of life, existing in man as the common tapeworm familiar to all, and in the flesh of cattle or hogs in the form of tiny "bladder worms." The common tapeworm of North America is found in the meat of cattle, and, while it is readily killed by cooking the meat, is liable to infect persons who eat raw meat.

Sometimes it happens that man accidentally takes into his stomach the ripe ova (eggs) of a tapeworm. When this happens he is liable to become the intermediate host, the part usually played by the pig or by cattle. A disease known as "echinococcus disease" is caused by man accidentally swallowing the ripe ova of a tapeworm ordinarily infecting dogs.

Trichina.—This is a parasite found in the flesh of hogs and transmissible to man. From the intestinal canal of man these tiny worms pass into the muscles, where they lodge and give rise to considerable pain and weakness. Trichiniasis, as the disease is called, is uncommon in this country, where but little pork is eaten raw. Infection is usually due to eating raw (merely smoked) ham.

Hookworm.—A disease common in Porto Rico and in the Southern States is due to infection with hookworm. This parasite appears to live only in man, and infection usually takes place through the skin, especially in those walking barefooted. The first symptoms are those due to the penetration of the skin by the young worm, and constitute what is known as "ground itch." Subsequently the parasites enter the intestines and give rise to very characteristic symptoms, chief among which are anemia and laziness. The worm is sometimes spoken of as the "lazy worm."

Filaria.—The disease known as "filariasis" and "elephantiasis" is due to infection with a tiny worm which invades the blood and lymph passages. This infection is transmitted by a species of mosquito.

So far as the nurse is concerned, the description of the mode of infection, as just presented, should suffice to indicate the mode of prevention.

CHAPTER XXX

THE PRACTICE OF DISINFECTION

Boiling Water.—The simplest method of disinfection, and one which can be used in the most primitive establishments as well as in the best equipped hospital, is boiling. No bacteria can withstand the action of boiling water if continued for a sufficient length of time. Most pathogenic bacteria are killed by boiling

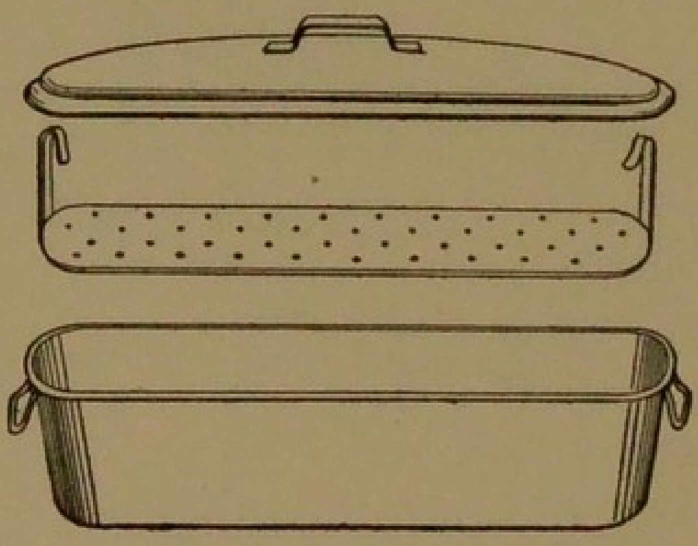


Fig. 44.—White enameled steel office sterilizer with handles and a perforated tray (Ashton).

at the end of ten minutes, while spore-bearers, like the anthrax bacillus, may require a half-hour or even longer. Any vessel which can be covered and placed over a fire answers for a sterilizer, though, of course, there are many types on the market constructed to suit various purposes. Usually they consist of a covered pan, fitted with a perforated tray or wire basket, supplied with handles, to enable one to lift the sterilized instruments, etc., out of the boiling water. The addition of 2 per cent. of ordinary washing soda to the water increases its disinfecting action, and at the same time prevents in a measure the rusting of metal instruments.

This method of sterilization is particularly well suited for soiled linens, for dishes, trays, pans, etc., that have come in contact with infectious material, for glass and metal instruments, such as catheters, irrigation tubes, forceps, etc. It is not so well suited for the sterilization of knives and scissors, since it spoils their keen cutting edge. For this reason some surgeons prefer to have these instruments kept in pure carbolic acid and transferred to sterile water before the operation. Catheters are to advantage boiled in water to which have been added 2 teaspoonfuls of liquid vaselin. This forms a thin, even coating of a sterile lubricant over the entire surface. Soiled linen should not at once be put into boiling water, since this fixes any stains; it may be put to soak for a few hours in cold water containing a pound of green soap in 25 gallons, and then may be heated in this to 70° or 80° C. These suds are then allowed to run off and are replaced by fresh, in which the linen is boiled fifteen to twenty minutes.

Steam.—A second method of using moist heat is in the form of live steam in a steam sterilizer, of which the Arnold sterilizer, already described, is a good example. This type of sterilizer is extensively used in bacteriologic laboratories for the sterilization of culture-media, and in hospitals for sterilizing dressings, rubber gloves, etc. Heating to 212° F. (100° C.) for an hour is enough to destroy all disease germs. Some culture-media, when heated to that degree for so long a time, undergo undesirable chemic changes; such media are subjected to what is known as fractional sterilization. They are heated in the Arnold sterilizer for twenty minutes on three consecutive days; the first heating destroys most,

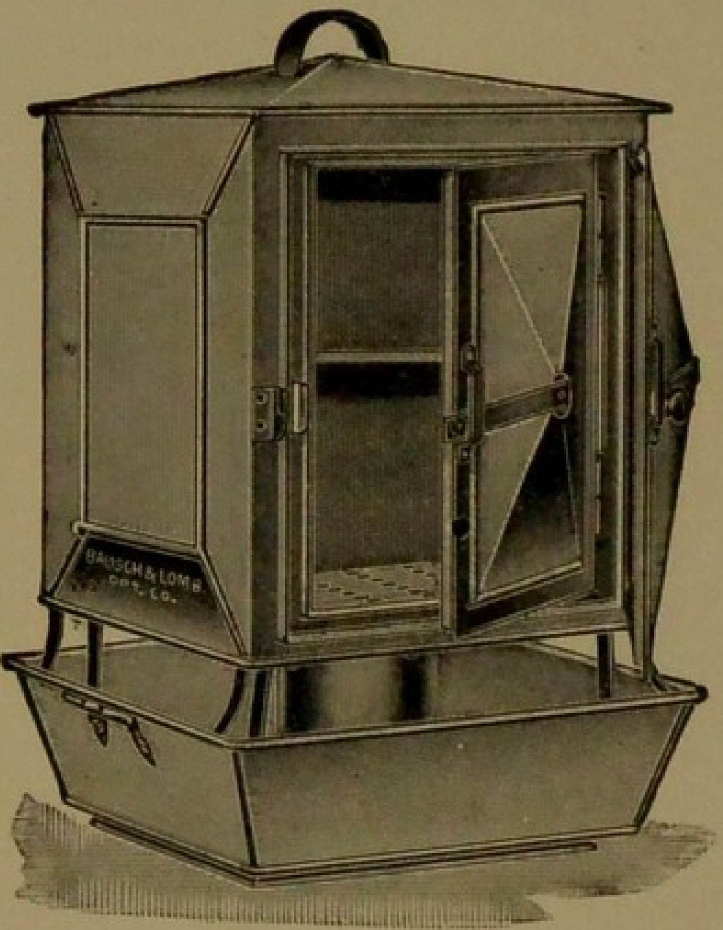


Fig. 45.—Arnold's steam sterilizer (Boston Board of Health form).

if not all, of the vegetating bacteria, and in the interval between the first and second heating the spores possibly present will develop into vegetative bacteria, in which state they are easily killed by the second heating. The process is repeated on the third day, in order to insure the death of all organisms which may have escaped the first two heatings.

Steam Under Pressure.—When water is heated in an open vessel or one loosely covered—that is, at atmospheric pressure—the temperature cannot go above

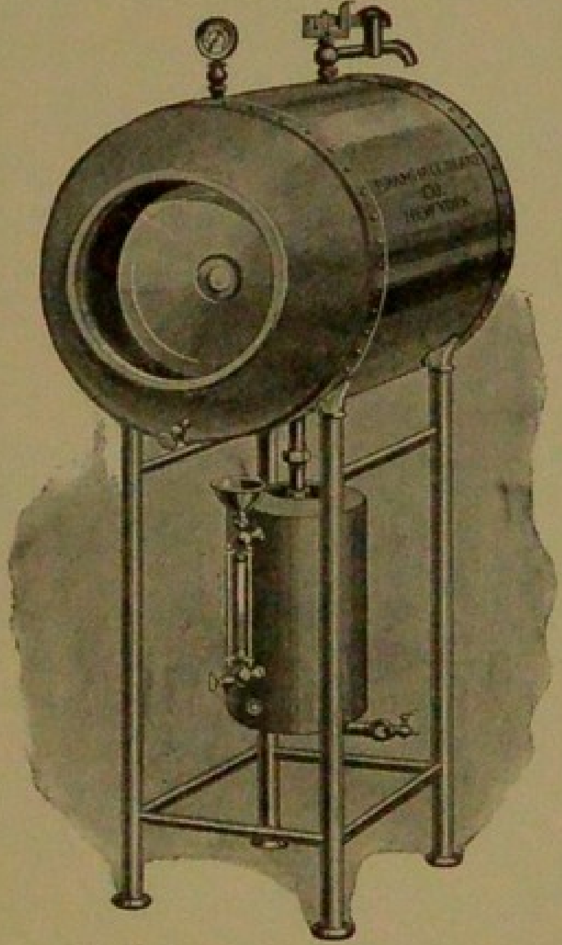


Fig. 46.—Autoclave sterilizer. Except in form, the autoclave differs but slightly from the full-jacketed sterilizer (Fig. 22, page 46). It is made of heavy copper with solid cast brass self-sealing door; the safety-valve is set to relieve at 15 pounds, and the jacket extends entirely around the chamber. The pressure, however, cannot be retained in the jacket while the door is open. Surgical dressings when withdrawn from the autoclave *are dry*. The latent heat of the steam at the high pressure will evaporate any moisture from the steam instantly upon exposure to the atmosphere.

212° F. (100° C.), but when heated in a tightly closed container both the temperature and pressure increase, so that a temperature of 130° C. and more, according to the amount of pressure employed, may be reached.

Under these conditions the steam generated not only kills bacteria more readily than steam generated at atmospheric pressure, but also has a much greater power to penetrate to the interior of bulky objects, such as mattresses, bundles of dressings, or clothing. Steam under pressure is, therefore, a more valuable disinfectant. A good example of high-pressure steam sterilizer is shown in Fig. 46.

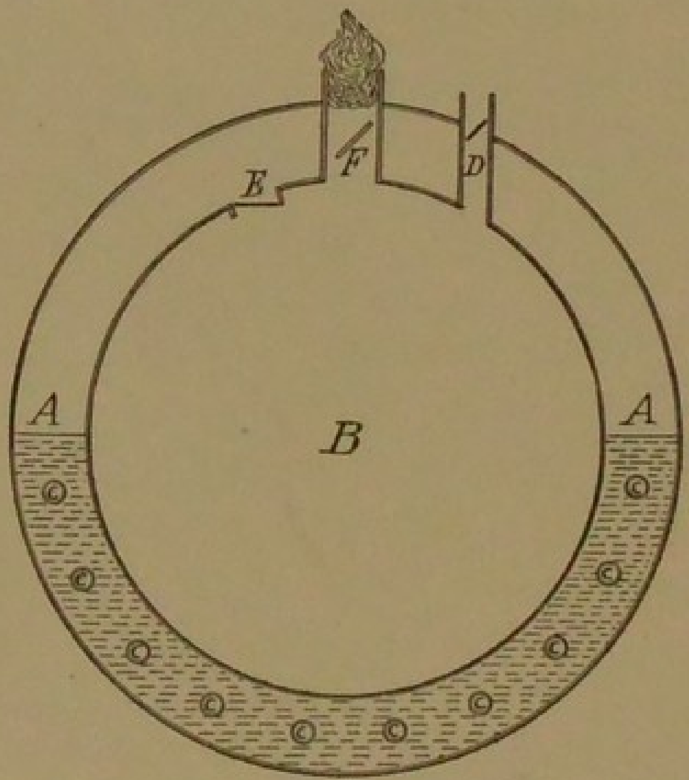


Fig. 47.—Diagram showing construction of a pressure steam sterilizer.

Another excellent type of pressure steam sterilizer consists of an outer and an inner jacket made of sheet metal. The space between these two, *A*, is half-filled with water, which is heated either from below by a gas burner or by means of steam circulating in coils (*C*) within. As the water grows hotter, the air in the disinfecting chamber, *B*, becomes rarefied, and may be further exhausted by means of an exhaust valve (*D*). When a partial vacuum has been created (5 inches, as registered by the gauge) the exhaust valve is shut off, and through another valve (*E*) steam from the steam chamber is admitted. As this steam finds a partial vacuum it eagerly penetrates any pervious material placed in the sterilizing chamber. Dressings and all material to be sterilized are put into the apparatus as soon as the heating is started, and are, therefore, gradually warmed; consequently, when steam is admitted, it does not condense and does not wet the dressings. When the dressings, etc., have been in contact with the steam (the temperature of which varies according to the pressure under which it is produced) for twenty to thirty minutes the exhaust valve is again operated, for the purpose of sucking the excess of steam out of the material and leaving it very nearly dry.

When the door of the apparatus is to be opened, the vacuum must first be destroyed by admitting air into the steam chamber through another valve (F), which is plugged with cotton.

The large municipal or private steam disinfecting plants act on the same principle, and differ only in size and details of construction.

This method of disinfection can be used for all ordinary cotton and woolen garments, bedding, rugs, mail from infected ports, etc., but it is not suited to rubber articles, furs, leather, delicate silks, or articles manufactured with glue, such as books. Experiments conducted at the New York Quarantine Disinfecting Station with self-registering thermometers have shown that when a temperature of 110° F. is maintained in the disinfecting chamber for fifteen minutes, the same, or but a slightly lower temperature, is reached in the center of large bundles of clothes and bedding.

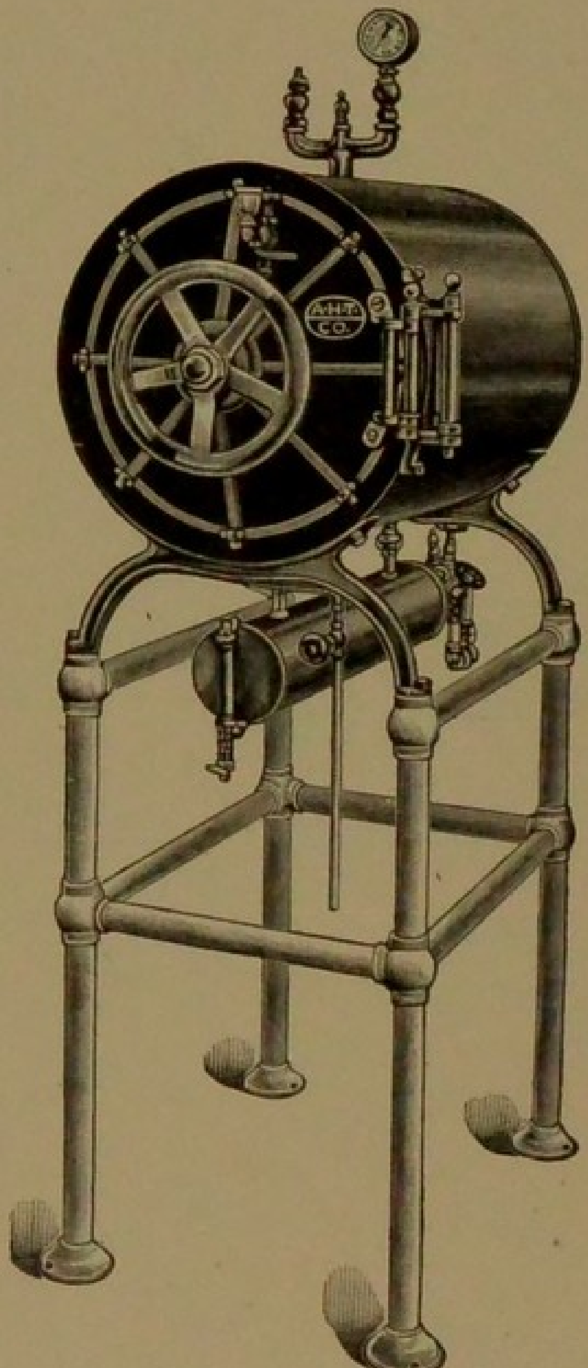


Fig. 48.—Autoclave (horizontal form).

Dry Heat.—When the rapid sterilization of small instruments, such as hypodermic needles, glass rods, etc., is required, these articles may be passed through the flame. This is the regular method of sterilizing the platinum wire used to transfer bacteria. But, except in an emergency, this method should not be used for surgical instruments, as it destroys the temper of steel and ruins the cutting edge of knives.

Glassware, such as catheters, pipets, test-tubes, etc., is sterilized in a hot-air oven. This is a box made of sheet metal with double walls, between which the hot air circulates. It is heated by gas burners from below, and a temperature of 150° C. for one hour is required to properly sterilize the glass- or metal-ware, for which alone it should be used. The oven of an ordinary kitchen range answers very well for a substitute. (See Fig. 19, p. 43.)

Chemicals.—There are a few objects which cannot be sterilized by any of the foregoing methods. Mention has already been made of the fact that boiling dulls the edge of knives, which are, therefore, kept in pure carbolic. Clinical thermometers are also kept in a carbolic solution. One of the most difficult materials to render and to keep sterile is catgut, and several ways have been devised for its sterilization. Catgut may be sterilized by dry heat, being first heated to 70° C. for two hours, to drive off the moisture. When this has been accomplished the catgut may be exposed to a temperature of 150° C. without becoming brittle. To keep it sterile it is stored in tubes plugged with cotton. When there is any doubt about its sterility it may be placed for eight days in a 3 per cent. solution of iodin in acetone, then into acetone for four days, to remove the excess of iodin, and, finally, into a mixture of acetone

85 parts, columbia spirits 10 parts, glycerin 5 parts. In this mixture it is kept until used.

Preparation of Patient for Operation.—Until comparatively recently it was the practice to prepare the patient for an operation by a full bath on the preceding night, to shave the site of the operation, and carefully cleanse it with hot water and green soap. It was then rinsed with alcohol and ether and with a 1:1000 solution of bichlorid of mercury. Then a gauze compress was applied which had been soaked in a 25 per cent. solution of green soap in water; this was covered with rubber tissue, and left in place from three to twelve hours. The washing with alcohol, ether, and bichlorid was then repeated and the skin covered with a bichlorid bandage. Just before the operation it was again scrubbed with soap and washed with alcohol and ether and bichlorid. This method was fairly efficient to sterilize the patient's skin, but it was cumbersome and very uncomfortable to the patient. Moreover, it was found that an absolute disinfection of the living skin could not be hoped for by any amount of scrubbing, since the deep skin glands continued to harbor bacteria. Some surgeons then covered the skin with an aseptic, gum-like substance, with the intention of holding the inevitable skin bacteria in place. These substances were apt to crack or tear and were not extensively used. Alcohol has a hardening effect on the skin, and tends to "fix" the bacteria there; it is used either alone or as a strong tincture of green soap as the sole disinfectant by some operators. This action is transient, and may be increased by adding to the alcohol such substances as tannin, ether, or nitric acid. A method which has found much favor both here and abroad is the disinfection by iodin. The patient receives a full bath on the evening preceding the operation; any hairy portions of the skin are shaved, but no dressing whatever is used; just before anesthetizing the site of the operation is painted with a solution of iodin in 50 per cent. alcohol and is covered with sterile towels. The painting is repeated just before the operation. The action of the iodin is the same as that of alcohol, but is more pronounced and lasting. Its greatest disadvantage is the occasional development of an iodin dermatitis; this is most likely to occur when the solution used is too strong (it should not be more than 5 per cent.); second, when the solution is old and contains decomposition products of iodin; third, when the skin is unusually tender, as in children; or, fourth, when the skin has been previously washed with antiseptic solutions or even plain water. In emergency cases no previous washing is resorted to, but the skin is cleaned with a 1 per cent. solution of iodin in benzene two to five minutes before the iodin is applied.

Disinfection of the hands is closely allied with the preparation of the patient, and, to a certain extent, the same methods can be used for both. A ten minutes' scrubbing with a bristle brush, using hot water and a tincture of green soap, and giving special attention to the skin folds at the base of the nails and the space under the nails, is followed by rinsing in alcohol, ether, and bichlorid solution. Hands may thus be superficially sterilized, but when they are immersed in hot solutions, which induces sweating, countless bacteria will be driven from the sweat and sebaceous glands to the sterilized surface. This has been repeatedly proved by experiments, and surgeons have had recourse to a mild process of tanning; that is, immersing the hands in a hardening solution, such as 60 per cent. alcohol or tincture of iodin. Both of these substances, when continuously used, are injurious to the skin, and the great majority of operators prefer to wear gloves during operations and require the same of the assistants. When rubber gloves are worn the soaking of the hands in bichlorid solution before putting on the gloves may cause a severe dermatitis. Rubber gloves are more frequently used than those of lisle, their chief advantages being that they are not porous, do not appreciably impair the tactile sense, and in certain cases, as in exploring a cavity, their slippery condition is a material aid. Against these are to be weighed their greater initial cost and their slight durability. Rubber gloves can be sterilized in the same sterilizer in which instruments are boiled, but they should be wrapped in gauze to prevent their coming into contact with metal; or, they may be kept for an hour in the Arnold steam sterilizer.

Disinfection to Prevent the Spread of Contagious Diseases.—It is usually far more important to prevent the spread of contagion during the patient's illness than it is to fumigate the apartment and its contents after convalescence. The sick room should be kept free of all unnecessary furniture, and particularly of rugs and hangings. In place of sweeping and dusting, the furniture, as well as the floor and any woodwork, should be wiped with an oiled rag or with a cloth moistened with 1:2000 bichlorid solution. No steaming, spraying, or fumigation of any efficiency can be carried out in an apartment which is occupied.[1] Hence, during the illness, aside from thorough ventilation, and the precautions already described, the important thing is to destroy or render harmless any discharges or dressings, etc., from the patient. Anything of no value, as dressings, should be burnt immediately; likewise nasal discharges or sputum collected in rags or paper receptacles.

Stools of patients suffering from typhoid fever, cholera, or other intestinal diseases must be received in covered vessels, and at once mixed with a disinfectant fluid; neither carbolic nor bichlorid is well suited to the purpose, since both are relatively inert in the presence of much albuminous matter. When chlorid of lime or milk of lime are used, a good mixture must be effected by thorough stirring. At least 1 quart of the standard solution of chlorid of lime (4 ounces to 1 gallon of water) should be used for each dejection. At the recent International Congress of Hygiene and Demography, Prausnitz advocated Kaiser's method of disinfecting stools by means of the heat generated by pouring water over quicklime which had previously been mixed with the stool.

Linen and cotton clothing is best boiled, and a method has already been indicated for its disinfection by this process. It may also be soaked in a 1:1000 solution of bichlorid of mercury or a 1:50 solution of carbolic acid; woolen clothing, which would be injured by boiling, may be similarly disinfected, or by means of formaldehyd. All bundles of infected clothing removed from

[1] In very chronic infectious diseases, like pulmonary tuberculosis, it is, however, advisable to thoroughly clean and disinfect the patient's apartment from time to time.

the sick room must be wrapped in a sheet, either sterilized or wrung from an antiseptic solution, to prevent spreading contagion on the way.

The patient's eating utensils must not be used by anyone else unless they have first been thoroughly boiled. This is especially true in cases of diphtheria or tuberculosis, but ought to be applied in all infectious diseases. All left-over food is to be burned.

After convalescence is established the patient should receive at least one full bath and have a complete change of clothing before he is allowed to mingle with others. Bichlorid of mercury may or may not be added to the bath.

Among the various agents used to fumigate apartments after an infectious disease sulphur dioxid has been extensively used in the past, but its action is not dependable, and it has been almost entirely superseded by formaldehyd. Sulphur fumigation is, however, still most useful in killing vermin, such as rats and mice, fleas, lice, etc. Before fumigation the apartment may be cleaned, all gross infectious material—*e. g.*, dried sputum, etc.—is soaked in 5 per cent. solution of bichlorid of mercury, scraped off, and burnt. All dust is soaked with the same solution, the floors and all the wood work are carefully washed with it; also the walls, if this is practicable. Then soap and hot water are liberally applied, and the apartment is thoroughly ventilated. If this process is carefully and faithfully carried out it may be possible to dispense with formalin disinfection; the latter is, however, an additional safeguard. Before starting fumigation, all cracks and crevices, keyholes, and other small openings are tightly sealed with gummed paper.

There are various methods of generating formaldehyd gas, and a number of lamps have been constructed for the purpose. Of late good results have been reported by mixing the solid commercial formalin or paraform with potassium permanganate, using 6 ounces of each for 1000 cubic feet of air space.

A special apparatus has been constructed for this, but it is possible to carry it out by using a deep enameled pail. The formalin or paraform must be thoroughly broken up before the permanganate and water are added, otherwise much will remain unaltered and will not be converted into gas. The fumes are kept in the room for twelve hours, and when the process of disinfection is completed they may be displaced by ammonia. Formaldehyd does not injure wool or silk, gilt, copper, or leather.

Formaldehyd is a very efficient surface disinfectant, but under ordinary circumstances it does not penetrate to any depths. The "Japanese method" secures much greater penetration. In this the formaldehyd gas is diffused, by means of a rather complex apparatus, throughout steel chambers which have previously been heated to 65° C. Clothing, rugs, etc., are exposed to these formaldehyd vapors for fifteen minutes with satisfactory results—*i. e.*, bacteria in the interior of the bundles were destroyed.

CHAPTER XXXI

COLLECTION OF MATERIAL FOR BACTERIOLOGIC EXAMINATION

Oftentimes the material sent to the laboratory for bacteriologic examination has been so improperly collected or handled that its examination is entirely useless. Much of the trouble can be avoided by a little attention to details.

In most cases bacteriologic specimens should be collected in sterile containers. An exception may be made in the case of sputum to be examined microscopically for tubercle bacilli. When cultures are to be made the specimens should be hurried to the laboratory without delay. All specimens should be accompanied by a memorandum showing the character and source of the material, the name of the patient, date and hour of collection, and a definite statement as to what information is wanted from the bacteriologist. It is important not to add disinfectants to specimens from which cultures are desired.

Sputum.—Care should be taken that the specimen of sputum has actually been coughed up. Some patients will hawk up mucus coming from the nose, others will spit out saliva, still others will be at a loss what to do. Sputum should never be sent to the laboratory merely in a gauze handkerchief or on a piece of paper, but only in a small, wide-mouthed bottle securely corked, or in specially prepared water-proofed wood boxes. In infants and children sputum can be obtained by means of a small piece of gauze, held with a stick or thumb forceps in the child's throat. This induces a reflex cough, with the expulsion of some of the desired sputum on the gauze.

Throat Smears.—When the throat is covered with membrane the physician often desires cultures to determine the nature of the infection. These are made as follows: Prepare a small sterile cotton swab, place the patient in a good light, and then gently wipe off some of the exudate. Make sure that no antiseptic has been applied to the throat within the previous two hours. If culture-tubes are available, wipe the swab holding the exudate over the surface of the culture, being careful not to break the surface. For accurate diagnosis it is advisable also to spread some of the exudate on the swab on a glass slide and send this along with the culture.

Water.—Water for bacteriologic examination should be collected in sterile 1-ounce bottles, and kept cool during transportation to the laboratory. In collecting water from a faucet care should be taken to secure a typic specimen by allowing the water to run for some time before collecting. In the case of springs, wells, reservoirs, etc., one should not dip water from the surface, for such a specimen would probably contain an undue proportion of bacteria from the dust of the air.

Milk.—When milk is to be examined, one must be sure to secure a representative sample by thoroughly mixing milk and cream. The latter always contains a very large number of bacteria.

Autopsies.—Specimens of organs are secured free from outside contamination by first searing the surface of the organ with a hot iron, and then cutting a piece of tissue from beneath the seared surface. Similarly, in securing specimens of heart's blood the surface of the heart is first seared with a hot iron, and then, with a sterile hollow needle, blood is drawn from within the heart cavity by thrusting the needle through the seared surface. The piece of tissue or blood should be placed in a sterile bottle or test-tube plugged with cotton and at once carried to the laboratory.

CHAPTER XXXII

OTHER IMPORTANT PATHOGENIC MICRO-ORGANISMS

In addition to the micro-organisms already described, the following are important ones pathogenic for man:

Colon Bacillus.—A rather plump, Gram-negative bacillus, normally occupying the intestines of man and animals, and capable of producing infection in man.

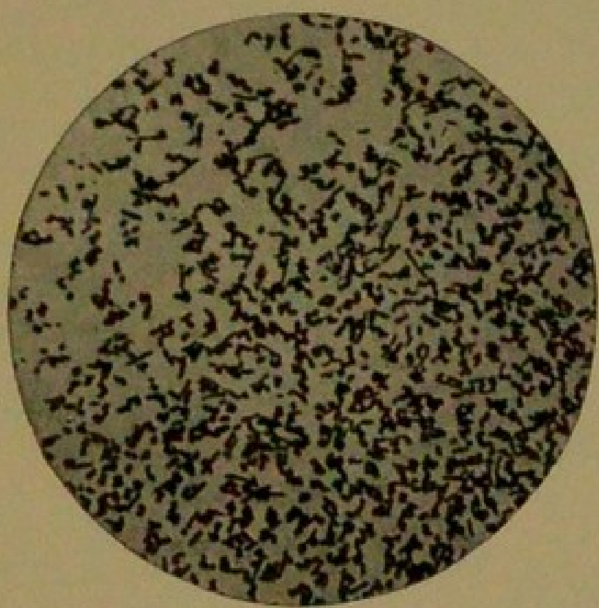


Fig. 49.—Colon bacillus; twenty-four-hour agar culture; × 650 (Heim).

The presence of colon bacilli is used in sanitary water examinations as an indication of fecal pollution. Prophylaxis is similar to that discussed under Typhoid Bacillus.

Pneumobacillus of Friedländer.—A short bacillus, often occurring in pairs or chains of four, capsulated, and Gram-negative. Found in certain cases of pneumonia and pleurisy. Prophylaxis is similar to that discussed under the Pneumococcus.

Paratyphoid Bacilli.—Similar to typhoid bacilli and colon bacilli, and producing infections in man resembling typhoid fever or, at times, symptoms of epidemic meat-poisoning. Prophylaxis is discussed under Typhoid Bacillus and under Bacterial Food Poisoning.

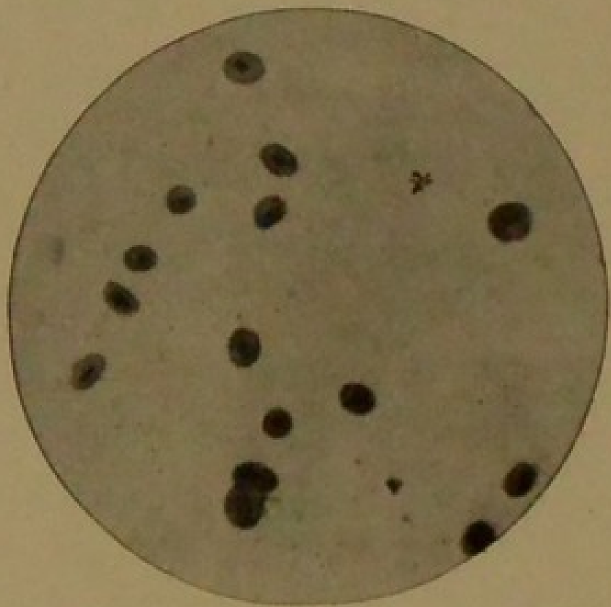


Fig. 50.—Friedländer's pneumobacillus. Welch's capsule stain; × 1100 (Jordan).

Influenza Bacillus.—A very small, moderately thick bacillus, growing only on media containing blood (hence spoken of as a "hemophilic" bacillus) and occurring chiefly in inflammations of the respiratory passages. A similar bacillus appears to be associated with whooping-cough. Prophylaxis is similar to that discussed under Pneumococcus.

Micrococcus of Malta Fever.—A very small, rounded or slightly oval micro-organism, Gram-negative, and growing rather feebly on artificial media. The organism appears to be present in the feces of goats in Malta, and probably contaminates the milk. In man a typhoid-

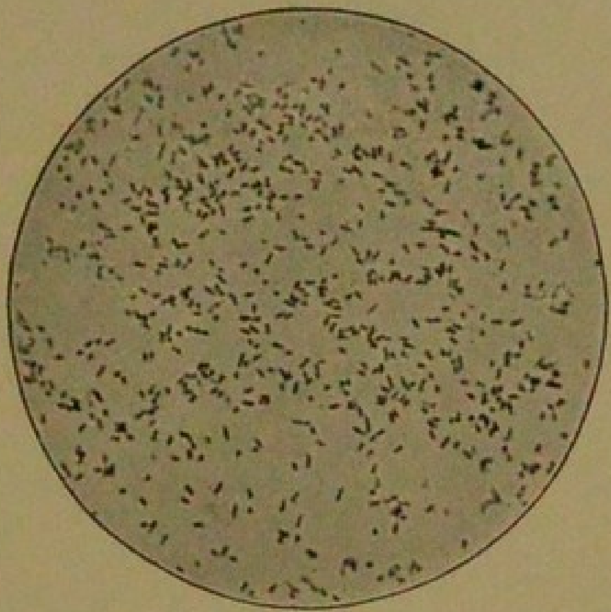


Fig. 51.—Bacillus of influenza; × 1000 (Král).

Fig. 52.—Micrococcus of Malta fever. Carbol fuchsin; × 1200 (Jordan).

like fever is produced. Prophylaxis is similar to that discussed under Typhoid Bacillus.

Bacillus Pyocyaneus.—A slender, aërobic, motile

Fig. 53.—Bacillus pyocyaneus. Pure culture on agar. Fuchsin stain (Kolle and Wassermann).

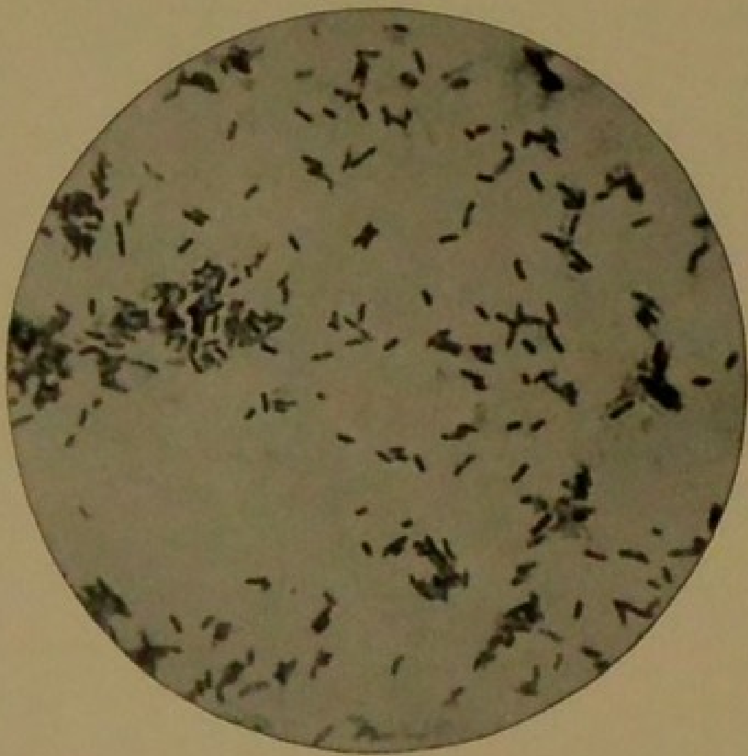


Fig. 54.—Bacillus mallei (glanders). Pure culture from glucose-agar. Carbol fuchsin; $\times$ 1200 (Jordan).

bacillus, widely distributed in nature and occasionally producing infections in man. These are characterized by the production of a blue or blue-green pus, whence the name, *pyocyaneus,* signifying blue pus. Prophylaxis is similar to that described under Streptococcus and Staphylococcus.

Glanders Bacillus.—A small bacillus with rounded ends, Gram-negative, non-motile. Common in horses, where it produces the disease known as glanders or farcy, and easily communicated to man, where it produces an in-

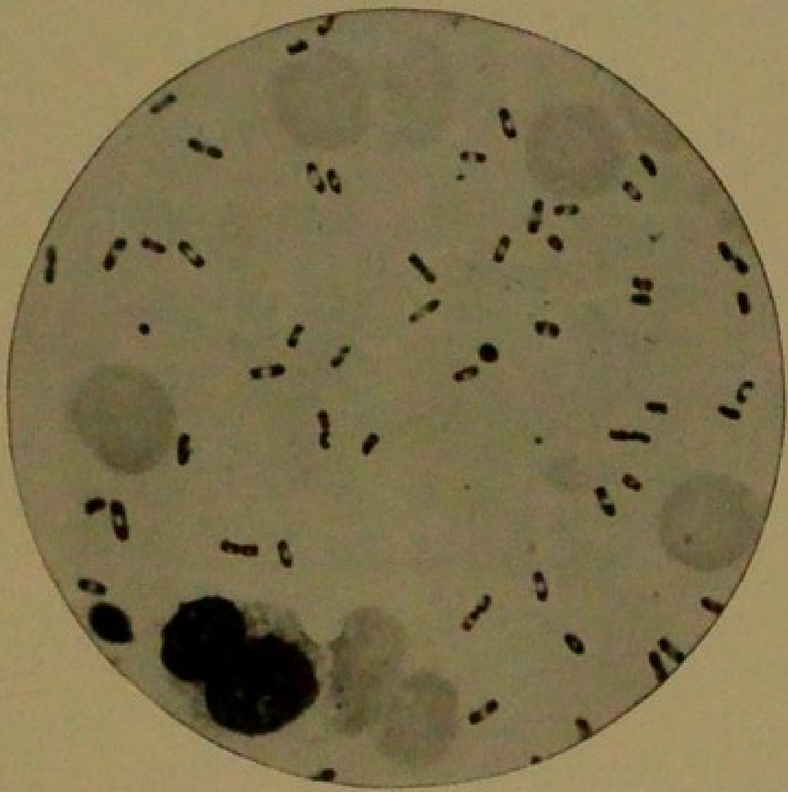


Fig. 55.—Bacillus pestis (bubonic plague) in smear from rat's liver, showing bipolar staining; × 720 (Wherry).

fection which is fatal in 60 per cent. of the cases. The infective material exists in the secretions of the horses' nose, in the pus of glanders nodules, and frequently in the blood. Prophylaxis is indicated by what has just been said. Glandered horses should be promptly destroyed.

Bubonic Plague Bacillus.—Short, thick rods with rounded ends, Gram-negative, aërobic, and non-motile.

In man the infection occurs in two forms: the bubonic, involving the lymph-glands; the pneumonic, involving the lungs. The disease is spread directly from man to man, especially in the pneumonic form, and also from rats and other rodents to man. In the latter case infection is usually intermediate through fleas infesting these rodents. Prophylaxis: Discovery and destruction of all infected rats, and in the pneumonic form extreme

Fig. 56.—Bacillus of anthrax in spleen pulp. Fuchsin stain; × 2000; C. Fränkel prep. (Kolle and Wassermann).

care to guard against infection through coughing, sneezing, etc., and infection from the sputum.

Anthrax Bacillus.—Mostly in the form of slender, non-motile rods, Gram-positive, and forming spores possessing great resistance to destructive agents. Anthrax is primarily a disease of cattle and sheep, but man is occasionally infected, usually in the form of "malignant pustule." Among wool-sorters a pulmonic type of infection is observed. Prophylaxis: The disease in cattle and sheep is combated by means of immunizing injections of anthrax vaccine. Care should be taken to properly dispose of the carcass of any animal dead of anthrax.

Malignant Edema Bacillus.—A fairly long, thick rod with square ends, Gram-negative, and forming spores. It is a strict anaërobe. The infections in man are usually the result of infecting wounds with garden earth. Pro-

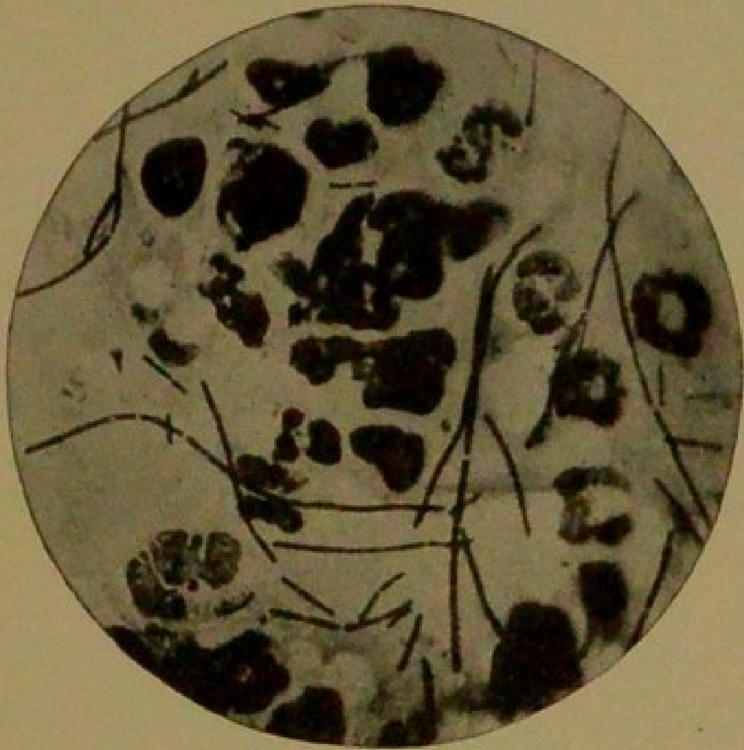


Fig. 57.—Bacillus of malignant edema. Tissue juice of guinea-pig after injection with a broth culture. Smear preparation, stained with fuchsin. × 1000 (Fränkel and Pfeiffer).

phylaxis: The careful cleansing of all wounds, especially those thought to be infected with earth.

Typhus Fever.—The causative organism has not yet been isolated, though it is known to be a "filterable virus." Infection is carried from man to man through the bite of infected body lice, and perhaps also other vermin.

Leprosy Bacillus.—Small, acid-fast rods, resembling tubercle bacilli, found in large numbers, especially in the

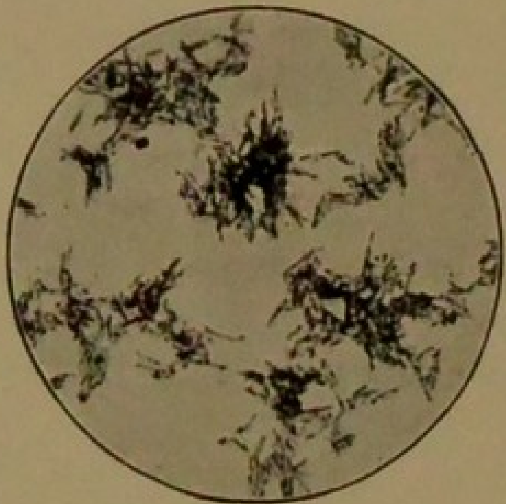


Fig. 58.—Pure culture of bacillus of leprosy, showing the characteristic morphology and arrangement of the bacilli (Duval).

Fig. 59.—Microsporon furfur, fungus of pityriasis versicolor; × 700 (Kaposi).

cutaneous lesions. It is not yet established just how the disease is communicated.

Microsporon Furfur.—This is a mold producing in man

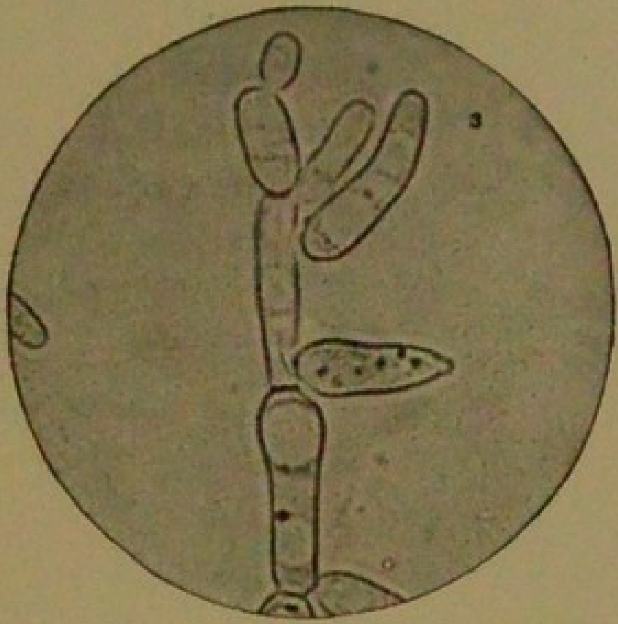


Fig. 60.—Oïdium (Kolle and Wassermann).

Fig. 61.—Achorion schönleinii, section showing the hyphæ (Fränkel and Pfeiffer).

the skin disease known as "pityriasis." It is observed chiefly in persons living under conditions of uncleanliness or among those who combine these conditions with a tendency to profuse perspiration.

Oïdium Albicans.—This is a mold producing in children the disease of the mouth known as "soor" or "thrush."

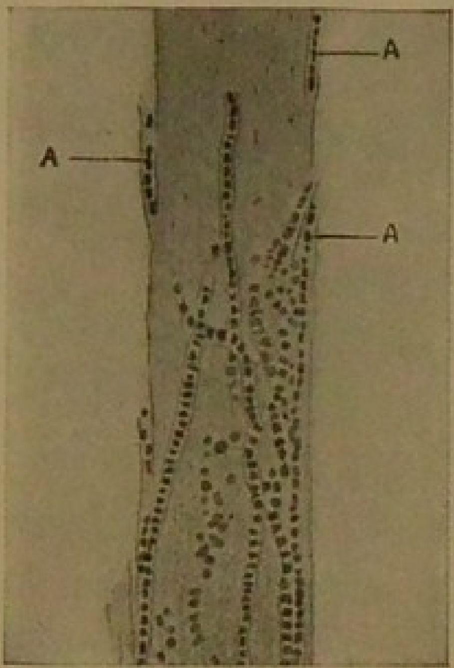


Fig. 62.—Invasion of a human hair by trichophyton: A, Points at which the parasitic fungi coming from the epidermis are elevating the cuticle of the hair and entering into its substance; × 200 (Sabouraud).

Achorion Schönleinii.—This is a mold producing the disease known as "favus," is an affection of the scalp, which runs an extremely chronic course.

Trichophyton Tonsurans.—This is a mold producing the disease in man known as "ring-worm."

Poliomyelitis.—The infecting microörganism of this disease has not yet been isolated, but is known to exist in the nasal secretion and blood of infected individuals. It must be very small, for it passes through the pores of a Berkefeld filter. The disease can be transmitted through the bite of stable flies, and probably also through infected nasal discharges.

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