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Modern Surgery - Chapter 1. Bacteriology

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MODERN SURGERY.

I. BACTERIOLOGY.

BACTERIOLOGY is the science of micro-organisms. Though a science in the youth of its years, bacteriology has not only profoundly altered, but it has also revolutionized, pathology, and our views of surgery would be incomplete, misleading, and erroneous without its aid.

Micro-organisms, or microbes, are minute non-nucleated vegetable cells closely connected with fungi and algæ, many of them being visible only by means of a highly powerful microscope and after they have been brightly stained. The contents of these cells are protoplasm and nuclear chromatin enclosed by a structure containing cellulose.

Even in the most remote times some have believed that "the mysterious cause of contagious and epidemic diseases must be sought in living entities" (Monti on "Modern Pathology"). Bacteria were discovered by Leeuwenhoek in 1675, but definite knowledge of these minute bodies and of their actions dates from the study of fermentation by the celebrated Frenchman Pasteur, who in 1858 asserted that every fermentation has invariably its specific ferment; that this ferment consists of living cells; that these cells produce fermentation by absorbing the oxygen of the substance acted upon; that putrefaction is caused by an organized ferment; that all organized ferments are carried about in the air; and that entirely to exclude air prevents putrefaction or fermentation.

In 1860 Pasteur published the observation that sterile liquids will not be contaminated by air if the air gains entry only through a long curved tube, the reason being that dust and growths fall from the entering air by gravity ("Comptes rendus," 1860).

In 1863 Pasteur published his experiments which proved that beer cannot ferment without yeasts and that wine received in sterile vessels and kept from external contamination will not undergo ammoniacal change.

The views of Pasteur, which were radical departures from accepted belief, inaugurated a bitter controversy, and in that controversy were born the microbic theory of disease, the doctrine of preventive inoculation, antiseptic surgery, and serum-therapy.

The word *microbe*, which signifies a small living being, was introduced in 1878 by the late Professor Sédillot, of Paris. At that time the nature of these bodies was in doubt; some thought them animal, and called them *microzoaria;* others thought them vegetable, and called them *microphyta;* the designation "microbe" does not commit us to either view. We now know them to be vegetable, but the term "microbe" has remained in use.

The micro-organisms connected with disease in man are divided into:

1. Yeasts, Saccharomyces, or Blastomycetes;

2. Moulds, or Hyphomycetes;
3. Bacteria, or Schizomycetes.

Yeasts or **budding fungi** include most of those fungi which can cause alcoholic fermentation in saccharine matter. They consist of small cells which can live without free oxygen, and which multiply by *gemmation or budding*. When a cell multiplies a small bud of protoplasm projects from or near the end of the cell. This bud increases progressively in size and a constriction appears between the bud and the parent-cell. The constriction deepens as the projection enlarges, until the bud attains the size of the parent. Thus a chain or series of rounded yeast-cells is formed. These cells contain spores when nourishment is insufficient. Under certain conditions yeast fungi can form mycelial threads.

Moulds or **filamentous fungi** consist of filaments, each filament being composed of a single row of cells arranged end to end, and all filaments springing from a germinal tube which grows from a germinating spore. The yeast fungi are the common but not the only cause of fermentation. Mould fungi are connected with processes of decomposition. Putrefaction is due to bacteria and retards the growth of yeasts and moulds.

Most yeasts and moulds grow best upon dead organic matter, some attack plants, a few the lower animals, and a very few grow upon or in the tissues of the human body.

The *oidium albicans* is a yeast fungus which by growing in the mucous membrane produces the disease known as *thrush*. This disease attacks especially the mucous membrane of the mouth and pharynx, but occasionally the growth takes place upon the esophagus, the vocal cords, the stomach, the vagina, the respiratory tract, and the areola of the breast of a nursing woman. The proliferating fungus presents the appearance of milky white spots which by thickening and coalescence form curd-like masses, the superficial layer of epithelium being raised and cast off.

Blastomycetes dermatitis is an inflammation of the skin due to yeast fungi and bearing a resemblance to tuberculosis or syphilis. Sanfelice and others maintain that yeasts are responsible for the growth of *malignant tumors*. It is certain that yeasts may exist in a carcinoma and can be cultivated, but proof is entirely lacking that they are anything but a contamination. Many skin diseases are due to fungi; among them should be mentioned: *Favus*, pityriasis versicolor, herpes tonsurans, parasitic sycosis, and eczema marginatum.

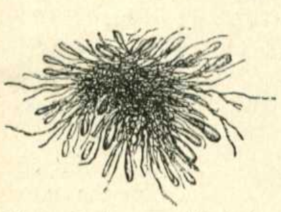


Fig. 1.—Actinomyces (Ziegler).

Actinomycosis is due to the ray fungus (see page 221). It is uncertain in which group the ray fungi should be placed; it is quite certain that more than one variety exists, and they seem to occupy a place between moulds and bacteria. *Madura-foot*, or *mycetoma*, is due to the *streptothrix Maduræ*.

Schizomycetes or **bacteria** chiefly claim our attention. It is important to remember that the term "bacteria," though applied to the class *schizomycetes*, has also a more restricted application—that is, to a division of the class; it may mean either *schizomycetes* in general, or rod-shaped *schizomycetes*, whose length is not more than twice their breadth. In this work it is employed to designate *schizomycetes* as a class.

Bacteria are minute, unbranched, non-nucleated, vegetable cells, free from chlorophyl, varying in shape and occasionally presenting locomotive flagella. The cell consists of a cell membrane, a layer of protoplasm, and some central fluid. No true nucleus has yet been demonstrated, but granules are found within the cells which some call *metachromatic bodies* (Babes) and others *nuclei* (Ernst). The cell membrane varies greatly in thickness, and when it is very thick the cell is said to have a *capsule*. The round cells have a smooth outer surface, but some of the rod-shaped cells show many *flagella* or at the end a single flagellum. Flagella enable some bacteria to move (*motile bacteria*), but all organisms which contain them are not motile, and under certain conditions bacteria without flagella may develop them, or organisms which possess flagella may lose the power to develop them.

Some of the *schizomycetes* induce certain fermentations; others grow upon dead organic matter, but are not able to invade living tissues, and are called *saprophytes* or *non-pathogenic* bacteria; still others, known as the *pathogenic*, invade living tissue and cause various diseases. *Parasitic* bacteria can grow on or in the tissues of the body. *Obligate* parasites are those which have not been cultivated outside of the body (as the bacilli of leprosy). *Facultative* parasites usually live outside the body, but may enter into the body and produce disease. The schizomycetes vary much in shape, size, color, arrangement, mode of growth, and action upon the body. One form cannot be transformed into another, but each maintains its specific identity. Every organism comes from a pre-existing organism, this being true of all forms. Pasteur proved that spontaneous generation is impossible. The protoplasm of these cells can be stained with anilin colors, and the cell wall is more readily detected after treating it with water, which causes it to swell.

Many bacteria are colored; others are colorless. Some move (*motile bacteria*); others do not move (*amotile bacteria*). The bacilli of anthrax and tuberculosis and all cocci are amotile. Most bacteria can change from motile to amotile, or from amotile to motile, when subjected to certain changes of soil and environment. The oscillations of cocci are physical in nature, not vital; they are Brunonian or Brownian movements, movements due to alterations in equilibrium because of currents or changes of level in the fluid in which the micro-organisms are contained. Bacteria seem to possess the power of attracting elements necessary for their nutrition (*positive chemiotaxis* or *chemotaxis*) and of repelling harmful elements (*negative chemiotaxis* or *chemotaxis*).

Fig. 2.—Micrococcus.

Fig. 3.—Bacillus.

Fig. 4.—Spirillum.

Forms of Bacteria.—The three chief forms of bacteria are—

1. The *Coccus* or *Micrococcus*—berry-shaped, oval, or round bacterium (Fig. 2);

2. The *Bacillus*—rod-shaped bacterium (Fig. 3);

3. The *Spirillum* or *Vibrio*—corkscrew-shaped or spiral bacterium (Fig. 4). A short spiral organism is called a comma bacillus.

De Bary compares these forms, respectively, to the billiard-ball, the lead-pencil, and the corkscrew.

Cocci and Bacilli.—We have to do only with *cocci* and *bacilli*. Cocci may be designated according to their arrangement with one another; namely, when existing singly they are called *monococci;* in pairs they are called *diplococci* (Fig. 5, A); arranged end to end in a chain they are called *streptococci* (Fig. 5, C); in a group side by side clustered like a bunch of grapes they are called *staphylococci* (Fig. 5, B); in groups of four they are called plate cocci, *tetracocci;* in cubical groups they are called *sarcinæ* or *wool-sack* cocci. Irregular masses, resembling frog-spawn, constitute *zoöglea masses* (Fig. 6). The gelatinous matter in such a mass is formed by a transformation in the walls of the bacteria. The term *ascococci* is applied to a group of cocci enclosed in a capsule (G. S. Woodhead).

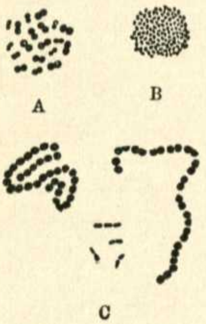


Fig. 5.—Forms of cocci.

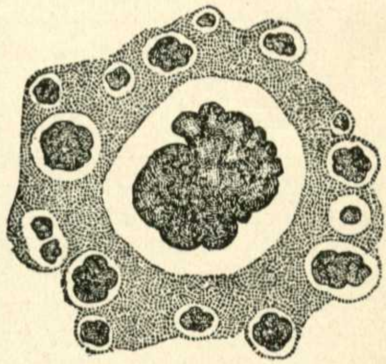


Fig. 6.—Zoöglea (Ball).

The cocci are often named according to their function, as, for example, "pyogenic," or pus-forming. Cocci may be named according to the color of the culture. The name may embody the form, arrangement, color, and function; for instance, *Staphylococcus pyogenes aureus* signifies a round, golden-yellow micro-organism, which arranges itself with its fellows in the form of a bunch of grapes, and which produces pus.

The *bacilli* are long, staff-shaped organisms. Long, delicate, jointed bacilli having wavy outlines are known as *leptothrix* forms. Chain-like bacilli are called *streptobacilli*. Bacilli give origin to many surgical diseases.

Multiplication of Bacteria.—Bacteria multiply with great rapidity when placed under suitable conditions. They can multiply by fission or by spore-formation. Some bacteria multiply by both methods. In fission, or segmentation, a bacillus undergoes an increase in size: a coccus does not increase in size but elongates. In either case about the middle of the cell a transverse constriction begins, which deepens until the cell has divided into two parts, each of which soon grows as large as its parent (Figs. 7, 8). As a rule, the micro-organisms separate after division of the cell; but they may not do so; and if they do not separate, the special grouping receives a particular name (diplococci, streptococci, etc.). If the division is invariably in the same direction, and if the new cells remain in contact, streptococci or streptobacilli are formed. Tetracocci and sarcinæ are formed when a number of cocci "divide in two or three successively vertical directions" ("Clinical Bacteriology," by Levy and Klemperer), forming four quadrants (*tetracocci*) or eight octants (*sarcinæ*). All cocci

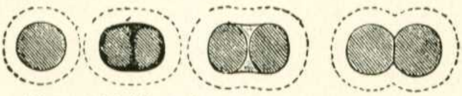


Fig. 7.—Divisions of a micrococcus (after Macé).

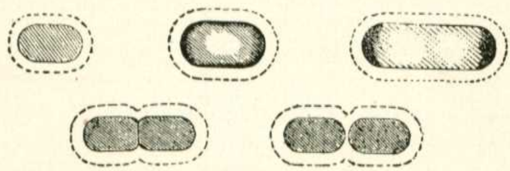


Fig. 8.—Divisions of a bacillus (after Macé).

and some bacilli multiply by fission. If segmentation of a single cell and the growth to maturity of its products require one hour (it really takes place in less time, the cholera bacillus requiring but twenty minutes to divide), a single cell in a single day, if the conditions for increase were ideally favorable, would have sixteen million descendants, and in three days the mass of new cells would weigh 7500 tons (Cohn). In order, however, for such enormous multiplication to occur conditions would have to be absolutely favorable to the cells, and conditions are never absolutely favorable. Were it otherwise, all other forms of life would be destroyed.

Spores.—A *spore* is a germ, and corresponds with the seed of a plant. Some bacilli, a few spirilla, and it may be sarcinæ, multiply by spore-formation. Cocci do not undergo spore-formation after the manner of bacilli, though some observers maintain that cocci occasionally undergo an alteration that makes them very resistant to any destructive influences (*arthrospores*). When spore-formation is about to occur in a bacillus, a point of cloudiness or an area of bright refraction appears in the protoplasm and the cell generally elongates. When a row of cells sporulate, the segments, each of which contains a lustrous area or a region of cloudiness, look like parts of a necklace of beads (Fig. 9). The spore enlarges, the spore membrane bursts, and the young bacillus emerges through the opening. A cell usually contains but one spore, which may be situated at the end of the cell (*endspore*) or in the middle of the cell (*endospore*). Sometimes a single cell contains several

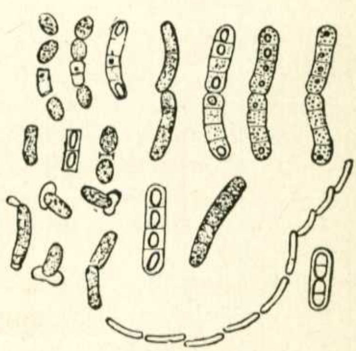


Fig. 9.—Sporulation (after De Bary).

spores. If an endspore exists, the end of the cell containing the spore is swollen or club-shaped (*drumstick bacterium*). If an endospore exists, the cell becomes spindle-shaped (*clostridium*). When multiplication is by a single endospore, the bacillus does not elongate. When multiplication takes place by a process of combined spore-formation and fission, the mother-cell divides into a number of daughter-cells, which are called *arthrospores*. Organisms which when active multiply by fission take on spore-formation when subjected to certain conditions.

Spore-formation tends to occur when bacilli are about to die for want of nourishment or when there is an excess of oxygen present. The spore has a dense envelope or covering which is very resistant to destructive agents. So resistant is the covering that twice the amount of heat is necessary to kill a spore as to kill an active adult cell. Spores when placed under conditions unfavorable for development may remain inactive for an indefinite period, just as seeds remain inactive when unplanted. When spores encounter favorable conditions, they at once develop into adult cells, just as seeds develop when planted. It seems probable that spores occasionally remain dormant in the human body for long periods, and finally awaken into activity because of injury or disease of the tissue in which they lie.

Life-conditions of Bacteria.—In order to grow and to multiply, bacteria require a suitable soil and the favoring influences of heat and moisture. The soil demanded consists of highly organized compounds rather than crude substances, and slight modifications in it may prove fatal to some forms of bacterial life, but highly advantageous to others. Some organisms require albuminous matter, others need carbohydrates; they all require water, carbon, nitrogen, oxygen, hydrogen, and certain inorganic materials, especially lime and potassium (Woodhead). All organisms require water. If dried, no micro-organisms will multiply, and many forms will die. The fluid and tissues of the individual may or may not afford a favorable soil for the germs of a disease, or, in the same person, may afford it at one time and not at another. Some individuals seem to possess indestructible immunity from, and others are especially prone to, certain contagious diseases. Impairment of health, by altering some subtle condition of the soil, may make a person liable who previously was exempt.

The presence of oxygen influences microbic growth. Most organisms thrive best when exposed to the oxygen of the air, and they are known as *aërobic*. The term *anaërobic* is employed to designate organisms that can grow and multiply and produce particular products only when air is absent, free oxygen being fatal to them. Tetanus bacilli and the bacilli of malignant edema are anaërobic. An organism which can grow indifferently where oxygen is abundant or where free oxygen is absent is called a *facultative-aërobic bacterium*. It may need oxygen; but if it does, it is able to obtain it from the tissues when air is excluded. A sensitive organism which dies when the amount of oxygen is even slightly diminished is called an *obligate-aërobic bacterium*. Most microbic diseases in man are due to facultative-aërobic bacteria.

Effect of Motion, Sunlight, the X-rays, Cold, and Heat.—The majority of *fungi* grow best when at rest; violent agitation retards the growth of some. Sunlight antagonizes the growth of certain bacteria, especially tubercle bacilli and the bacilli of typhoid fever. It is claimed by some that the *x*-rays retard bacterial growth. Temperature influences bacterial growth. Some organisms will grow only within narrow temperature-limits, while others can sustain sweeping alterations, but most grow best between the limits of from 86° to 104° F. Freezing renders bacteria motionless and incapable of multiplication, but it does not kill them: they again become active when the temperature is raised. The absurdity of employing cold as a germicide is evident when the fact is known that a temperature of 200° F. below zero is not fatal to germ-life, cell-activities by such a temperature only being rendered dormant. Bacteria have been placed in hermetically sealed tubes and the tubes immersed in liquid air for seven days. The germs were thus subjected to a temperature of −190° C., but there was no change produced in their virulence (A. MacFayden and S. Roland in "Lancet," March 24, 1900). High temperatures are fatal to bacteria; moist heat is more destructive than dry heat, and adult cells are more easily killed than spores. A temperature less than 212° F. will kill many organisms, and boiling will kill every pathogenic organism that does not form spores. Some spores are not destroyed after prolonged boiling, and some will withstand a temperature of 120° C. As a practical fact, however, boiling water kills in a few minutes all cocci, most bacilli, and all pathogenic spores; though the spores of anthrax, tetanus, and malignant edema are harder to kill than are the spores of other bacteria.

Effect of Bacteria upon Bacteria.—Some bacteria are antagonistic to others, some are synergistic to others. The streptococcus of erysipelas is antagonistic to the bacillus of anthrax and also to syphilis, tuberculosis, and sarcoma. The growth of some microbes in culture-media makes a soil favorable or unfavorable for other microbes, and the same process may occur in the human body. We are not yet able to cure a microbic disease by inoculating the sufferer with antagonistic microbes, on the principle of sending a thief to catch a thief.

Mixed Infection.—A fact of practical importance to the surgeon is that an area infected by one form of micro-organism may be invaded by another form. This is known as a *mixed* infection, and consists in a *primary* infection with one variety of organism, and a *secondary* infection with another, or in an infection at the same time with different micro-organisms. Koch found both bacilli and micrococci in the same lesion of tuberculosis. A soil filled with pneumococci favors the growth of pus cocci and tubercle bacilli. Tuberculous or syphilitic lesions may be attacked by erysipelas. Chancre and chancroid can exist together. A syphilitic ulcer is a good culture-soil for tubercle bacilli (Schnitzler). Suppuration in lesions of tuberculosis is due to secondary infection with pus organisms. Occasionally in empyema and other conditions pus organisms may have lost much of their virulence, but a mixed infection with some germ usually harmless may break down surrounding barriers and intensify the virulence of bacteria.

Placental Transmission.—The direct transmission of bacteria from parent to fetus is a problem still in course of solution. Certain it is that some diseases (as syphilis) are due to the direct carrying of the microbes by sperm-cell to germ-cell, or to the transmission of the micro-organism through the septum of separation between the circulations of the mother and child.

In many other diseases the microbe is not directly transmitted (as in phthisis), but a patient born with weakened tissue-cells is prone to fall a prey to the latter malady.

Chemical Antiseptics and Germicides.—It is necessary to make a distinction between deodorizers, antiseptics, and germicides.

A deodorizer is an agent which destroys an offensive odor. It is true that an offensive odor may be due to microbic growth. It is also true that nasty odors may prove injurious to those who inhale them. But, nevertheless, the odor is the result of microbic action, and destroying an odor does not render harmless the bacteria which caused it. Charcoal is a well-known deodorizer.

An antiseptic is an agent which retards or prevents putrefaction. It acts by weakening or killing saprophytic organisms, but is not fatal to spores.

A germicide or disinfectant is an agent which is fatal to adult bacteria and spores. The destruction of the germs of the disease in clothing, in excreta, in a wound, etc., is known as disinfection. Disinfection of a wound, dressings, or instruments is called also sterilization.

Antiseptics and germicides should not be used in clean wounds. Repair will occur more quickly if they are not used. Tillmanns has pointed out that when antiseptics are used cell-division is late in beginning and is slow in progress. Neither should they be used in fatty tissue, as bacteria surrounded with oil cannot be reached by the drug, and the chemical is irritant and apt to cause fat necrosis (Haenel, in "Deutsch. med. Woch.," 1895, No. 8).

Corrosive Sublimate.—Many chemical agents will kill bacteria, one of the most certain of them all being *corrosive sublimate.* Koch showed that corrosive sublimate is an efficient test-tube germicide when present in the proportion of only 1 part to 50,000. It is used in surgery in strengths of 1 part of the salt to 1000, 2000, 3000, or more parts of water. Badly infected wounds are occasionally irrigated with solutions of a strength of 1 to 500. Contact with albumin precipitates from a solution of corrosive sublimate an insoluble albuminate of mercury which forms a white layer upon the surface of the wound, is not a germicide, and prevents deep diffusion of the mercurial fluid. In surgical operations by the antiseptic method the mercurial salt should be combined with tartaric acid in the proportion of 1 to 5, which combination prevents the formation of the insoluble albuminate of mercury.

But though corrosive sublimate under certain conditions is extremely powerful, it is not always absolutely reliable. Many spores are very resistant to its action. Even a 1 per cent. solution of bichlorid of mercury is not certainly destructive of the spores of anthrax. Geppert tells us that anthrax-spores may be active after a twenty-five-hour immersion in a 1 : 100 solution of sublimate (Schimmelbusch). In the presence of hydrogen sulphid corrosive sublimate is useless, inert and insoluble sulphid of mercury being precipitated; hence corrosive sublimate is without value as a rectal antiseptic; in fact, Gerloczy has proved that a concentrated aqueous solution of sublimate will not disinfect an equal quantity of feces. Corrosive sublimate contained in dressings after a time undergoes decomposition and ceases to be a germicide. It is not germicidal in fatty tissues because it is unable to attack bacteria which are coated with oil. Corrosive sublimate is very irritating to the tissues and causes copious exudation. Hence, after tissues have been irrigated with this agent drainage must be employed. In some cases the irritated tissues lose to a great extent their power of resistance, and infection may be actually facilitated by irrigation with sublimate. In rare instances corrosive sublimate is absorbed and produces poisoning. In spite of these shortcomings and drawbacks it is a valuable aid to the surgeon and must be frequently used, especially upon the skin of the patient and the hands of the operator and his assistants. It should be dissolved in distilled water, because ordinary water causes a precipitate to form (common salt prevents the formation of this precipitate).

Because of the fact that corrosive sublimate is poisonous and very irritant, it should not be used upon serous membranes. It is absorbed quickly from serous membranes and destroys the endothelial cells, and should not be introduced into the pleural sac, into joints, or into the peritoneal cavity. It should never be put within the dura, and should not be applied, in strong solution at least, to mucous membranes. It is better to make the solution when it is needed, so as to have it fresh, for in old solutions much of the soluble corrosive sublimate has been converted into insoluble oxychlorid, and the fluid has ceased to be germicidal. In order to make up fresh solutions use tablets, each of which contains about 7½ grains of the drug—one of these tablets added to a pint of water makes a solution of a strength of 1 to 1000. Tablets which also contain ammonium chlorid are more soluble than those which contain corrosive sublimate only. Hot solutions of the drug are more powerfully germicidal than cold solutions. As corrosive sublimate is irritant, leads to profuse exudation, and may produce tissue-necrosis, it should never be introduced into an aseptic wound. In such a wound it can do no good and may do much harm.

Griffin, in Foster's "Practical Therapeutics," sets forth the strengths of solutions applicable to different regions:

For disinfection of the surgeon's hands and the patient's skin, 1 : 1000; for irrigating trivial wounds, 1 : 2000; for irrigating larger wounds and cavities, 1 : 10,000 to 1 : 5000; for irrigating vagina, 1 : 10,000 to 1 : 5000; for irrigating urethra, 1 : 40,000 to 1 : 20,000; for irrigating conjunctiva, 1 : 5000; for gargling, 1 : 10,000 to 1 : 5000.

Instruments cannot be placed in corrosive sublimate without being dulled, stained, and corroded.

Corrosive Sublimate Poisoning.—Corrosive sublimate may be absorbed from a wound, a serous surface, or a mucous membrane, ptyalism and diarrhea resulting. The absorption of bichlorid of mercury may be followed by cramp in the limbs and belly, feeble pulse, cold skin, extreme restlessness, and even collapse and death. At the first sign of trouble withdraw the drug and treat the ptyalism (page 238).

Carbolic acid is a valuable germicide in the strength of from 1 : 40 to 1 : 20. It is certainly fatal to pus-organisms, but weak solutions fail to kill most bacteria and do not destroy spores. Unfortunately, this acid attacks the hands of the surgeon; consequently in the United States it is chiefly employed as an antiseptic medium in which to place the sterilized operating-instruments, or as a germicide to prepare the skin of the patient before the operation is performed.

Carbolic Acid Poisoning.—Carbolic acid is very irritant to tissues, and carbolized dressings may be responsible for sloughing of the wound or dry gangrene. Because of its irritant properties wounds which have been irrigated with it should be well drained. Carbolic acid, like corrosive sublimate, is inert in fatty tissues. Carbolic acid is readily absorbed, and may thus produce toxic symptoms. Absorption is not uncommon when the weaker solutions are used, but rarely occurs when a wound has been brushed over with pure acid, because the pure acid at once forms an extensive zone of coagulation, which acts as a barrier to absorption. One of the early indications of the absorption of carbolic acid is the assumption by the urine of a smoky, greenish, or blackish hue. This hue appears a little time after the urine has been voided, whereas the smoky hue of hematuria is noted in urine at once after it has been passed. The condition produced by carbolic acid is known as *carboluria*, and examination of such urine shows a great diminution or entire absence of sulphates when the acidulated urine is heated with chlorid of barium. The diminution of precipitable sulphates is explained by the fact that these salts are combined with carbolic acid, forming soluble sulphocarbolates (Griffin). Such urine is apt to contain albumin. If during the use of carbolized dressing or the employment of carbolic solutions the urine becomes smoky, the use of the drug in any form must be at once discontinued, otherwise dangerous symptoms will soon appear. These symptoms are subnormal temperature, feeble pulse and respiration, muscular weakness, and vertigo. If death occurs, it is due, as a rule, to respiratory failure. The treatment of slow poisoning by carbolic acid consists in at once withdrawing the drug, giving stimulants and nourishing food, administering sulphate of sodium several times a day and atropin in the morning and evening.

Pure carbolic acid is a reliable disinfectant for certain conditions. It is used to destroy chancroids, to purify infected wounds and abscess cavities, to disinfect the medullary cavity in osteomyelitis, to stimulate granulation after the open operation for hydrocele, or to purify sloughing burns or ulcerated areas. The pure acid rarely produces constitutional symptoms, but it occasionally causes sloughing. Its application causes pain for a moment only, and then analgesia ensues. Even dilute solutions of carbolic acid greatly relieve pain when applied to raw surfaces. The local action of carbolic acid can be at once antidoted by the application of *alcohol* (Seneca D. Powell). When carbolic acid is applied to a wound, the area about the wound should first be moistened with alcohol. After the application of pure carbolic acid to a joint, a wound, the medullary canal, or an infected area, wait about one minute and then apply alcohol.

Carbolic acid acts more slowly and less certainly than corrosive sublimate. It requires twenty-four hours for a 5 per cent. solution to kill anthrax-spores. Pus or blood (albuminous matter) greatly weakens the germicidal power of carbolic acid, and fatty tissue cannot be disinfected by it. It is not even the best of agents in which to place instruments, as it dulls them. After operation upon the mouth it is used as a wash or gargle, 1 to 2 per cent. being a suitable strength. It is used sometimes to irrigate the bladder and often to cleanse sinuses, but is not employed in the peritoneal cavity, the pleural sac, or the brain. It is occasionally injected into tuberculous joints. Never apply carbolic solutions to clean wounds.

Creolin, which is a preparation made from coal-tar, is a germicide without irritant or toxic effects. It is less powerful than carbolic acid, but acts similarly, and is used in emulsion of a strength of from 1 to 5 per cent., and does not irritate the skin like carbolic acid.

Peroxid of hydrogen is an excellent agent for cleansing a purulent or putrid area, but it is never applied upon an aseptic wound. It comes in a 10-volume solution, which should be diluted one-half or two-thirds. It probably destroys the albuminous element upon which bacteria live, and starves the fungi. When peroxid of hydrogen is applied to a purulent area ebullition occurs, liberated oxygen bubbling up through the fluid and the pus being oxidized. The peroxid of hydrogen is not fatal to tetanus bacilli; in fact, tetanus bacilli can be cultivated in a strong solution of it. Some surgeons use it to wash out appendicular abscesses (R. T. Morris). It must not be injected into a deep abscess in any region unless a large opening exists, as otherwise the evolved gas may tear apart structures and dissect up the cellular tissue. The use of peroxid should not be too long continued, for if used for a considerable period it makes the granulations edematous and retards healing. In fact, its continued use may actually prevent a sinus closing.

Iodoform is largely used; it is not truly a germicide, as bacteria will grow upon it, but it hinders the development of bacteria and directly antagonizes the action of the toxic products of germ-life. Iodoform stimulates the production of connective tissue. It is of the greatest value when applied to putrid foci, infected areas, and tuberculous processes. The laboratory workers who condemn it have in many cases used nutrient material in which it does not dissolve (P. F. Lomry, "Archiv für klin. Chir.," 1896). Its use in suppurating tissues retards the growth and attenuates the virulence of pus cocci and organisms of putrefaction. Clinically, no real substitute for it has yet been found. It can be rendered sterile by washing with a solution of corrosive sublimate. It need not be applied to clean wounds, but the powder is very useful when dusted into infected wounds. It prevents wound-discharges from decomposing and distinctly allays pain. Gauze impregnated with iodoform is used to keep abscesses open after evacuation, to drain the belly after certain operations, to pack aside the intestines and prevent their infection during some abdominal operations, and as packing to arrest intracranial hemorrhage. Iodoform gauze will drain serum well, but will not drain pus. In fact, it blocks up a pus-cavity, and if retained long leads to the collection of purulent matter behind and about the supposed drain. If used in an abscess, it must be removed in twenty-four or thirty-six hours. Tuberculous joints and cold abscesses are injected with iodoform emulsion, which is made by adding the drug to sterile glycerin or olive oil. The emulsion contains 10 per cent. of iodoform. A solution in ether of a strength of 10 per cent. may be used to inject the cavity of a cold abscess.

Iodoform-poisoning.—The drug must be used with some caution. Absorption from a wound sometimes happens, producing toxic symptoms. These symptoms are frequently misinterpreted, being usually attributed to infection. R. T. Morris has pointed out that in iodoform-poisoning the wound seems to be in excellent condition, whereas in sepsis the wound is unhealthy. The symptoms in some cases are acute and arise suddenly, and consist of hallucinatory delirium, nausea, fever, watery eyes, contracted pupils, metallic taste in mouth, yellowness of the skin and eyes, an odor of iodoform upon the breath, the presence of the drug in the urine, the outbreak of a skin eruption resembling measles or one which is erythematous, vesicular, bullous, or petechial (see Stelwagon on "Diseases of the Skin"). There is often nephritis and always excessive loss of flesh and strength. Patients with such acute symptoms usually pass into coma and die within a week. Such attacks are most apt to arise in those beyond middle life (see Gerster and Lilienthal, in Foster's "Practical Therapeutics"). Iodin can be recognized in urine by adding a few drops of commercial nitric acid and a little chloroform. When the mixture is shaken the chloroform will take up the free iodin and become purple, and on standing the purple layer will settle to the bottom of the tube. Another method is as follows: Put a little urine in a saucer, add a little calomel, and stir. If the urine contains iodoform a brown color will be noted (R. T. Morris). The finding of iodin in the urine, however, is not proof that the patient is poisoned. We may find it when no sign of poisoning exists. In chronic cases of iodoform-poisoning the first symptoms usually observed are moroseness, bewilderment, and irritability, followed by depression, with unsystematized persecutory delusions, delirium, coma, and even death.

In systemic poisoning by iodoform, discontinue the use of the drug, sustain the strength of the patient, and favor the elimination of the poison.

Iodoform sometimes produces greal local irritation of the cutaneous surface, the dermatitis being eczematous or else being manifested by crops of vesicles filled with turbid yellow serum or even bloody serum. These vesicles rupture and expose a raw oozing surface, looking not unlike a burn. The use of the drug must be at once abandoned, for to continue it will not only increase the dermatitis, but will produce constitutional symptoms. Wash the vesiculated area with ether to remove iodoform, open each vesicle, and dress the part for several days with gauze wet with normal salt solution. After acute inflammation ceases apply zinc ointment or cosmolin.

Aristol is an odorless iodin compound used by some as an antiseptic dusting-powder.

Loretin is an antiseptic powder which is odorless, germicidal, non-irritant, and which is said to be non-toxic.

Europhen is a powder containing iodin, and the iodin separates from it slowly when the powder is applied to wounds or burns. It does not produce toxic symptoms readily, if at all, and is a valuable substitute for iodoform. It is used especially in the treatment of ulcers and burns.

Nosophen is a pale yellow powder containing 60 per cent. of iodin. Its bismuth salt is known as **antinosin.** Nosophen is not toxic, is free from odor, and is the best of the substitutes for iodoform.

Acetanilid is frequently used as a substitute for iodoform. It is of value when applied to suppurating, ulcerating, or sloughing areas, but it does not benefit tuberculous conditions. Sometimes absorption takes place to a sufficient extent to cause cyanosis, sweating, and weakness of the pulse and respiration. If cyanosis arises, suspend the administration of the drug and administer stimulants by the stomach.

Airol is a substitute for pure iodoform, and is composed of gallic acid, bismuth, and iodoform. It is non-irritant and non-toxic.

Among other powders we may mention iodol, amyloform, subiodid of bismuth, and dermatol or subgallate of bismuth.

Silver is a valuable antiseptic. Halsted and Bolton have shown that metallic silver exerts an inhibitive action upon the growth of micro-organisms and does not irritate the tissues. Credé has also demonstrated the same facts. These statements indicate one great reason why silver wire is such a useful suture-material. Halsted is accustomed to place silver foil over wounds after they have been sutured, and Credé employs as a dressing a fabric in which metallic silver is intimately incorporated.

Credé considers silver lactate (**actol**) an admirable antiseptic. It does not form an insoluble albuminate when introduced into the tissues and is not an irritant. Silver citrate (**itrol**) is said to be even a better preparation than silver lactate, and it is a useful dusting-powder. A preparation of metallic silver is made which is soluble in water and in albuminous fluids; it remains as metallic silver when in solution, and is said to be powerfully germicidal. A 1 per cent. solution is used and can be injected. **Credé's ointment of silver** is used in septic diseases. In a child 15 grains of the ointment is rubbed in the skin at one time, in an adult 45 grains, and the rubbing should be kept up from ten to thirty minutes. There is said to be no risk of argyria. **Protargol** is a silver salt much used in gonorrhea. **Argyrol** is a new and valuable preparation of silver which I have used frequently with much satisfaction. It is known as silver vitelline, is not irritant, and contains 30 per cent. of metallic silver. In a strength of 5 per cent. it is a very useful injection for gonorrhea, as it has powerful gonococcidal properties. In some types of chronic cystitis several drams of a 3 per cent. solution may be injected into the bladder from time to time, and much stronger solutions can be used with safety. Inflamed mucous membranes may be painted with a solution of a strength of from 20 to 50 per cent. A sinus or a sluggish area of granulation may be stimulated by touching with a solution of a strength of from 25 to 50 per cent. I have found it of much service in sinuses.

Formaldehyd, or **formic aldehyd,** has valuable antiseptic properties. **Formalin** is a 40 per cent. solution of the gas in water. Solutions of this strength are very irritant to the tissues, but 2 per cent. solutions can be used to disinfect wounds. A solution of a strength of 0.5 per cent. is used to irrigate sinuses, tuberculous areas, abscess-cavities, and suppurating joints. A strong solution is used to asepticize chancroids and other ulcers. The vapor of formalin can be so applied as to disinfect wounds, and Wood suggests its employment in septic peritonitis as a means of disinfection after the abdomen has been opened. The vapor of formalin thoroughly disinfects catheters. A 2 per cent. solution disinfects instruments satisfactorily.

Formalin-gelatin has recently been introduced by Schleich as an antiseptic powder. When applied to a clean wound it gives off formalin and keeps the wound aseptic. When it is applied to a sloughing surface it will not give off formalin unless it is mixed with pepsin and hydrochloric acid. The commercial preparation is known as **glutol.** Formalin-gelatin has been used to replace bone-defects.

Lysol is a valuable germicidal agent. It is saponified phenol and is used in a solution of a strength of from 1 to 3 per cent.

Mustard is an excellent emergency germicide. Its value has been demonstrated by Roswell Park. A mixture of soap, cornmeal, and mustard flour is used to scrub the surgeon's hands or the patient's skin (Park). Mustard removes the odor of decay at once.

Commercial gasoline is used by Riordan and others to clean wounds and ulcers, and to prepare the field of operation. Its vapor is so inflammable that the material must not be used when an artificial light is necessary, and it is used only in the daytime and on free surfaces where evaporation is rapid. It is sterile, non-irritant, and on evaporation leaves a dry, clean surface.

Tincture of iodin may be applied to an infected wound in the same manner as is pure carbolic acid; its use is advocated by Carl Beck. In dilute solution it is used to irrigate sinuses. The proper dilution for irrigation is obtained when the fluid is the color of sherry wine.

Nucleins, especially protonuclein, possess germicidal powers. *Protonuclein* is of value in treating areas of infection, particularly when sloughing exists.

Among other antiseptics and germicides of more or less value we may mention trichlorid of iodin, chlorid of zinc, chlorid of iron, salol, oxycyanid of mercury, fluorid of sodium, argonin, sugar, lannaiol, bichlorid of palladium (in very dilute solution), thymol, potash soap, salicylic acid, boric acid, camphor, eucalyptol, cinnamon, bromin, chlorin (as gas or as chlorin-water), cinnamic acid, permanganate of potassium or of calcium, chlorate of potassium, alcohol, normal salt solution, and oxalic acid.

The best germicide is heat, and the best form in which to apply heat is by means of boiling water (even better than steam). One can use boiling water upon instruments and dressings, but rarely upon a patient. Jeannel, of Toulouse, uses boiling salt solution in abscess-cavities, and some other surgeons employ steam or boiling water to disinfect the medullary canal in osteomyelitis. Nevertheless, boiling water is rarely applied to the patient, and in many cases a chemical germicide must be used. The surgeon should always scrub his hands in a germicidal solution.

Distribution of Bacteria.—Microbes are very widely distributed in nature. They are found in all water except that which comes from very deep springs; in all soil to the depth of three feet; and in air, except that of the desert, that over the open sea, and that of lofty mountains.

Microbes may be useful. Some of them are scavengers, and clean the surface of the earth of its dead by the process known as "putrefaction," in which complex organic matter is reduced to harmless gases and to a mineral condition. The gases are taken up from the air by vegetables, and the mineral matter is dissolved in rain-water and passes into the soil from which it came, there again to be food for plants, which plants will become food for animals. Other organisms purify rivers; others cause bread to rise; still others give rise to fermentation in liquors. Microbes may be harmful. They may poison rivers and soils; they may be parasites on vegetable life; they cause diseases of the growing vine, and also of wine; they produce the mould on stale, damp bread; they occasionally form poisonous matter in sausages, in ice-cream, and in canned goods; and they produce many diseases among men and the lower animals.

With so universal a distribution of these *fungi*, man must constantly take them into his organism. They are upon the surface of his body, he inhales them with every breath, and he swallows them with his food and drink. Most of them, fortunately, are entirely harmless; others cannot act on the living tissues; but some are virulent, and these are generally, but not always, destroyed by the cells of the human body. The alimentary canal always contains bacteria of putrefaction, which act only upon the dead food, and not upon the living body; but when a man dies these organisms at once attack the tissues, and post-mortem putrefaction begins in the abdomen.

Koch's Circuit.—To prove that a microbe is the cause of a disease it must fulfil Koch's circuit. It must always be found associated with the disease; it must be capable of forming pure cultures outside the body; these cultures must be capable of reproducing the disease; and the microbe must again be found associated with the artificially produced morbid process.

Disease Production.—Disease-producing organisms which enter the body are usually rapidly destroyed. They cannot dwell there long without inducing disease, but spores can lie dormant in the system for years, only waking into activity when they come in contact with some damaged, weakened, or diseased part where the circulation is abnormal—a so-called point of least resistance (a *locus minoris resistentiæ*)—which affords a nest for them to develop and to multiply, the cellular activities of the weakened part being unable to cope with the activities of the germs. Even large numbers of pathogenic organisms may induce no trouble in a healthy man; but let them reach a damaged spot, and mischief is apt to arise. Kocher established subcutaneous bone-injuries in dogs, and these injuries pursued a healthy course until the animal was fed upon putrid meat, whereupon suppuration took place. This experiment proves that micro-organisms can reach a damaged area by means of the blood, and it enables us to understand how a knee-joint can suppurate when we merely break up adhesions, and how osteomyelitis can follow trauma when the skin is intact. A given number of organisms might produce no effect on a healthy man, whereas the same number might produce disease in an individual who was weak or ill nourished, suffering from depression or fear, or debilitated by the habitual use of alcohol. The personal equation plays a great part in disease-production. Some individuals seem to be immune to certain diseases; others seem especially liable to develop certain diseases; and these immunities and liabilities may be hereditary or acquired, temporary or permanent.

Enzymes.—Bacteria contain and excrete ferments, and these ferments are known as enzymes. Bacterial ferments resemble pepsin and trypsin, the digestive ferments. The digestive ferments convert albumin into peptone, starch into sugar, and break up fat. When microbic infection of the tissues occurs the enzymes of the bacteria act upon the tissues just as the digestive ferments act upon the food, and form microbic albumoses. The enzymes are the weapons of micro-organisms. By means of these ferments bacteria not only prepare substances for assimilation, but seek to destroy antagonists and cell enemies. It is probable that enzymes when absorbed are frequently productive of toxemia.

Toxins.—The action of pathogenic bacteria upon the tissues is of great importance. In the first place, they abstract from the blood, the lymph, and the cells certain elements necessary to the body,—as water, oxygen, albumins, carbohydrates, etc.,—and thus cause body-wasting and exhaustion from want of food. In the second place, bacteria produce a vast number of compounds, some harmless and others highly poisonous. The symptoms of a microbic disease are largely due to the absorption of poisonous materials from the area of infection. These poisons may be formed from the tissues by the action upon them of the bacteria (toxins and peptones) or may be liberated from the bodies of degenerating microbes (bacterial proteid). Bacteria contain and secrete ferments; and as albumoses are formed in the alimentary canal by the action of digestive ferments upon proteids, sugars, and starches, so microbic albumoses are formed by the action of microbic ferments upon tissues. Just as the albumoses formed in digestion are poisonous when injected, so the albumoses of microbic action are poisonous when absorbed. The albumoses of microbic action are called *toxalbumins*, and these albumoses often operate as virulent poisons to the body-cells.

A number of compounds formed by the microbic destruction of tissue are *alkaloidal* in nature. These poisonous alkaloids are readily diffusible and, many of them, very virulent. It is probable that every pathogenic organism has its own special toxin which produces its characteristic effects, although the effects are modified by the nature of the soil—that is to say, by the condition of the tissues. The absorption of toxins may be very rapid; for instance, the toxins of cholera may kill a man before the bacilli have migrated from the intestine. Brieger uses the term *toxin* to designate all of the poisonous products of bacterial action. He divides toxins into alkaloidal or crystallizable and amorphous, the latter being called toxalbumins.

Ptomaïns.—By many writers the term "ptomaïn" is used to designate these toxins, but in reality a ptomaïn is a form of toxin produced by the action of saprophytic bacteria. A ptomaïn is a putrefactive alkaloid, and a toxin is any poison of microbic origin. Among these putrefactive alkaloids may be mentioned tetanin, typhotoxin, sepsin, putrescin, tyrotoxicon, muscarin, and spasmotoxin. The poison which occasionally forms in cheese, ice-cream, sausage, and canned goods is composed of ptomaïns. Poisoning by any putrid food is called ptomaïn-poisoning.

Leucomaïns must not be confounded with the above-mentioned bodies. Leucomaïns are alkaloidal substances existing normally in the tissues, and arising from physiological fermentations or retrograde chemical changes. They are natural body-constituents, in contrast to toxins, which are morbid constituents. Leucomaïns are found in expired air, saliva, urine, feces, tissues, and the venom of serpents. If not excreted, these bodies may induce illness, and when injected may act as poisons. Ordinary colds and some fevers result from leucomaïns; they play a great part in uremia, and when excretion is deficient the retained leucomaïns make the system a hospitable host for pathogenic bacteria. Sickness due to the retention and absorption of leucomaïns is known as *autointoxication*. Among leucomaïns may be mentioned adenin, hypoxanthin, and xanthin, allied to uric acid, and other substances allied to creatin and creatinin. The surgeon should never forget the possibility of harm being done by retained leucomaïns, and should endeavor to prevent autointoxication in all cases by keeping the skin, the bowels, and the kidneys active.

Immunity.—If a person will not contract and cannot be infected with a certain disease, he is said to be immune. It has long been known that when a person recovers from certain diseases he has become immune to the disease from which he suffered. Immunity may be transitory, prolonged, or permanent. Immunity may be compared to fermentation. When fermentation ceases, the addition of more ferment is without result. When a person recovers from certain diseases, the addition to his blood of more of the causative bacteria is also void of result. Some persons seem naturally immune to certain diseases. Immunity to some diseases may be produced artificially.

Alexins and Antitoxins.—Immunity was long believed to arise from the exhaustion of some unknown constituent of tissue necessary to the life of the bacteria. This theory was advanced by Pasteur. It has been abandoned because of the demonstration that though an animal may be immune to certain bacteria, these bacteria will grow in its blood or tissue. A theory proposed by Chauveau is known as the "retention theory," and is the opposite of Pasteur's "exhaustion theory." According to Chauveau, bacteria growing within the body leave as a legacy excrementitious material, and the accumulation and retention of excrementitious products produce immunity.

At the present time there are two notable theories of immunity, and it is probable that each is at least partly true. The first theory is that of phagocytosis, which assumes that certain body-cells attack, consume, and destroy bacteria (see below). The other theory is founded on the discovery of Nuttal that normal blood-serum is germicidal. Vaughan and others have shown that the germicidal agent is probably a nuclein furnished chiefly by the white cells and held in solution by the alkaline serum. This germicidal agent Buchner called "alexin" or defensive proteid, and explained immunity by its presence. This theory is known as the "humoral theory." According to this theory, when an animal is naturally immune to a bacterial disease it is assumed that the blood-serum and body-fluids contain enough of this alexin to destroy the bacteria.

Since the above discoveries were made it has been found that when an animal recovers from a bacterial disease the blood-serum and body-fluids contain a new protective substance which is not an alexin, but which has the power of destroying the toxins of the bacteria. It is known as an antitoxin and is produced by the body-cells under the stimulation of bacterial toxins. It is thus seen that bacteria not only produce poisons, but also stimulate the body-cells to produce antidotes to these poisons. Alexins exist in normal blood and kill bacteria. Antitoxins exist in blood of animals rendered immune and do not kill bacteria, but simply neutralize their toxins. It was pointed out by Kitasato and Behring that animals can be rendered immune to tetanus by artificial means and that the blood-serum of immune animals will, if injected into other animals, render them immune, or will cure the disease if injected into animals suffering from tetanus. The same statements were soon after proved to be true of diphtheria. Now many experimenters are endeavoring to find the antitoxin of each microbic disease for the purpose of using it therapeutically and also as a preventive agent.

The real mechanism of antitoxin-formation is unknown, although it seems certain, as Roux maintains, that it is secreted by the body-cells.

Ehrlich's theory of the mechanism of immunity is at present attracting much interest. His theory may be explained in the words of D. H. Bergey ("American Medicine," Oct. 11, 1902).

"In the light of our later knowledge upon the subject, Ehrlich, in 1898, . . nulated his hypothesis of the mechanism of immunity which is receiving very general acceptance by scientists to-day. His theory of the mechanism of immunity is based upon Weigert's teaching of the process of tissue repair. It is a matter of universal observation that nature is prodigal in her attempts to repair an injury. This is shown in the healing process in an ordinary wound. A much larger amount of material is thrown out to bridge the chasm than is really utilized in the formation of new tissue. The presence of an excessive amount of new material is shown by the fact that the part is raised above the level of the surrounding sound tissue, and this excess is removed gradually as the new-formed tissue becomes stronger and stronger, until finally the wound is marked by a line of white scar-tissue, the excess gradually passing into the blood-current.

"Ehrlich believed that the mechanism of immunity was explainable on a similar basis. It had become evident from the experiments of Wasserman with the tetanus bacillus that its toxin had an especial affinity for the cells of the central nervous system. Experiments with other bacteria pointed to the fact that the toxins of different species of bacteria had an especial affinity for the cells of different organs of the body. When the amount of poison entering the body is insufficient to destroy the cells which have an especial affinity for it, these cells may be injured only to such an extent as to permit subsequent repair. In order to comprehend Ehrlich's hypothesis it is necessary to conceive the cells of the body as having a complex structure which may be stated diagrammatically as consisting of a central mass or nucleus from which radiate a number of 'lateral chains,' or bonds, each of which serves to bind the cell to other substances. In the case of the cells of the central nervous system one of these lateral bonds has an especial affinity for tetanus toxin and suffers destruction. The cell now finds itself in unstable equilibrium, and at once proceeds to repair the damage wrought. As in the case of tissue repair, the new material produced is far in excess of the required amount. The excess finds its way into the blood-current. This material now circulating in the blood-current has the same affinity for tetanus toxin as when united with the central mass of a cell as its lateral bond, and can, therefore, combine with tetanus toxin floating in the blood-current, thus preserving other cells from injury. The union formed between the lateral bond of the cell (which is really the antitoxin) and the tetanus toxin results in the formation of a compound which is physiologically inert. According to Ehrlich's idea, therefore, the antitoxin is simply the excess of lateral bonds floating in the blood-current. This substance can neutralize the effect of the tetanus toxin in a test-tube just as readily as it does within the body."

Phagocytes.—The tendency of the white blood-cells, and in a less degree of the endothelial cells of the vessels, to destroy organisms is undoubted. This process of destruction is known as *phagocytosis*, and the destroying cells are called *phagocytes*. When infection occurs, the white blood-cells gather in enormous numbers at the seat of disease, encompass and surround the bacteria, and build a barrier to prevent dissemination of the microbes and general infection of the organism. The force which draws leukocytes to a region of infection also tends to draw them to an area where there is cellular degeneration or death. This force is called positive chemiotaxis. In very virulent infections the leukocytes may fail to collect and may actually be repelled and scattered under the influence of what has been called negative chemiotaxis. Phagocytes at the seat of infection try to eat up, carry away to a gland, and there digest and destroy bacteria. A battle royal occurs, the microbes fighting the body-cells with most active ferments; the body-cells endeavoring to devour and destroy the bacteria (Fig. 10). In some cases the bacteria win absolutely and the patient dies. In other cases they win for a time and overwhelm the organism; but presently the body-cells, whose movements were inhibited by the poison, regain their activity and successfully recur to the attack. It is probable that the defensive proteids thrown out by the white cells tend to destroy enzymes, to kill bacteria, and to neutralize toxic bacterial products. Those which kill bacteria are known as *alexins*, and those which neutralize toxic products are known as *antitoxins*. After the attack of disease has passed away the body-cells have been educated to withstand this poison, and new cells in the future retain this capacity; the weak cells were killed, the fittest survived. The new cells formed by the organism are insusceptible to the poison and the individual is said to be insusceptible or immune. The theory of phagocytosis immunity assumes an educated white corpuscle and body-cell. This view originated with Sternberg, but it is usually accredited to Metschnikoff. Lankester gave us the term "educated corpuscle."

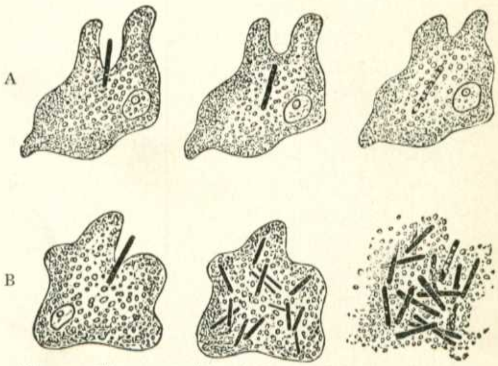


Fig. 10.—Phagocytosis: *A*, Successful; *B*, Unsuccessful (Senn).

Protective and Preventive Inoculations.—Our knowledge of protective inoculations for contagious diseases dates from Jenner's discovery in 1798. Preventive inoculations with attenuated virus are due to the experiments of Pasteur. This observer discovered the cause of chicken-cholera, and cultivated the micro-organism of this disease outside the body. He found that by keeping his cultures for some time they became attenuated in virulence, and that these attenuated cultures, inoculated in fowls, caused a mild attack of the disease, which attack was protective, and rendered the fowl immune to the most virulent cultures. Cultures can be attenuated by keeping them for some time, by exposing them for a short period to a temperature just below that necessary to kill the organisms, or by treating them with certain antiseptics. It has further been shown that injection of the blood-serum of an animal rendered immune by inoculation is capable of making a susceptible animal also immune.

A most important fact is that animals may be rendered immune to certain diseases by inoculating them with filtered cultures of the microbes of the disease, the filtrate containing microbic products, but not living microbes. By this method animals can be rendered immune to tetanus and diphtheria.

Pasteur's protective inoculations against hydrophobia owe their power to microbic products, and Koch's lymph contains them as its active ingredients. The chief feature in acquired immunity is the presence in the blood and tissues of elements which can neutralize the toxic products of or which can kill bacteria. These elements are "antitoxins" and "alexins." The knowledge of them arose from the discovery of Nuttall and Buchner that fresh blood-serum is germicidal, the power varying for different bacteria and being limited. A fixed amount of serum is capable of destroying a fixed number of bacteria only. It has been said that in tetanus injections of the serum of an immune animal may cure the disease. The above facts are of immense importance, for on these lines may be solved the problems of the prevention and treatment of microbic maladies.

Orrhotherapy, or **serum-therapy,** is an attempt to utilize therapeutically the germicidal properties of blood-serum. It is believed that when a person recovers from an infectious disease the alkaline blood-serum is saturated with protective material. If this belief is true, it is a proper deduction that blood-serum containing protective material should cure the disease if injected into a patient suffering from an attack. Instead of using the blood-serum itself, some observers have precipitated the curative material from the serum, and used the material in solution in fixed amounts. Instead of using the serum of persons rendered immune by an attack of the disease, many physicians have employed the serum of animals rendered artificially immune by injections of attenuated cultures of the bacteria. Some experimenters have employed even the serum of animals naturally immune to the disease. That Pasteur has devised a method which will usually prevent hydrophobia is certain (page 220), and that Murri, of Bologna, has cured a case of hydrophobia seems proved (page 220). Hosts of observers believe in the utility of tetanus antitoxin and diphtheria antitoxin.

Inconclusive experiments have been made in the treatment of syphilis by the serum of dog's blood, and by the blood-serum of men laboring under tertiary syphilis; in the treatment of pneumonia with the blood-serum of persons convalescent from pneumonia; and in the treatment of sufferers from septic diseases with antistreptococcic serum—blood-serum of animals rendered immune to septic infections. The real value of antistreptococcic serum is as yet uncertain. Occasionally it seems to do great good; at other times it appears to produce no benefit whatever. Tavel, in a recent elaborate research ("Klinische-therapeutische Wochenschrift" (Vienna), August, 1902), states that he obtained brilliant results in some cases, but no results in others. He does not undertake to explain this variability of action. He thinks the serum benefits staphylococcus as well as streptococcus infections. Malignant tumors (both sarcomata and carcinomata) have been treated with the blood-serum of dogs, which animals had been injected with fluid expressed from malignant growths (Richet and Hericourt). Von Leyden and Blumenthal obtain a serum by compression of a recent cancerous growth and treat human victims of cancer with it. They claim that the results are encouraging ("Deutsche medicinische Wochenschrift," September 4, 1902). Many claims made for serum-therapy in surgical diseases are exaggerated, sensational, and unscientific. That there is truth in the method seems highly probable, but how much of it is true is not yet definitely ascertained. It is our duty to study, experiment, and observe, and to reach a conclusion only after honest, careful, and thorough investigation. A little skepticism is as yet a safe rule.

Special Surgical Microbes.—Suppuration is caused by microbes. Can it exist without them? The answer is, No. Injection of a fluid containing dead organisms will form a limited amount of pus; injection of an irritant forms a thin fluid which may resemble pus, but which is not pus. In surgery pus is not met with without the micro-organisms, and the presence of pus proves the presence of micro-organisms. *Pus microbes*, or *pyogenic microbes*, possess the property of peptonizing albumin, and thus forming pus. The peptonizing action is brought about by bacterial ferments or enzymes. The inflammation which surrounds an area of pyogenic infection is caused by the irritant products of bacterial action (toxalbumins, ammonia, etc.). In the presence of the pyogenic peptones the coagulation of inflammatory exudate is retarded or prevented. The most usual causes of suppuration are the following micro-organisms.

Staphylococcus pyogenes aureus (Plate 1, Fig. 1, and Fig. 11), the golden-yellow coccus. This is the most usual cause of abscesses (circumscribed suppurations); 77 per cent. of acute abscesses are due to staphylococci

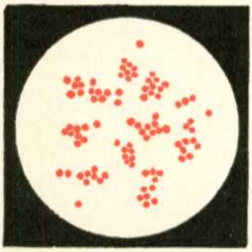


Fig. 11.—Micrococcus pyogenes aureus (× 1000).

Fig. 12.—Streptococcus pyogenes (× 700).

(W. Watson Cheyne). Staphylococci are found also in osteomyelitis, in a carbuncle, and in a boil. The staphylococcus pyogenes aureus is a facultative aërobic parasite which is widely distributed in nature, and is found in the soil, the dust of air, water, the alimentary canal, under the nails, on and in the superficial layers of skin, especially in the axillæ and perineum. It forms the characteristic color only when it grows in air. It is killed in ten minutes by a moist temperature of 58° C., and is instantly killed by boiling water. Carbolic acid (1 : 40) and corrosive sublimate (1 : 2000) are quickly fatal to this coccus.

Staphylococcus pyogenes albus, the white staphylococcus, acts like the aureus, but is more feeble in power. When this organism is found upon and in the skin it is called the *staphylococcus epidermidis albus*, an organism which Welch proved to be the usual cause of stitch-abscesses.

Staphylococcus pyogenes citreus, the lemon-yellow coccus, is found occasionally in acute circumscribed suppurations, but far more rarely than the other two forms. Its pyogenic power is even weaker than that of the albus.

Staphylococcus cereus albus is found occasionally in acute abscesses.

Staphylococcus cereus flavus is found occasionally in acute abscesses.

Staphylococcus flavescens is occasionally found in abscesses. Is intermediate between the aureus and albus (Senn).

Micrococcus pyogenes tenuis rarely takes the form of a bunch of grapes. Is occasionally found in the pus of acute abscesses.

Streptococcus pyogenes (Fig. 12) is found in spreading suppuration. Woodhead tells us (Treves' "System of Surgery") that six organisms, each of which bears a separate name, are discussed under this designation. Three of these organisms he places in one group, two in another, and says the sixth may be a separate species.

1st Group.—*Streptococcus pyogenes*, found especially in spreading suppuration and in very acute abscesses. Cheyne says that 16 per cent. of acute abscesses contain streptococci. Is easily killed by boiling, and can be destroyed by carbolic acid and corrosive sublimate. These organisms are normally present in the nasal passages, vagina, mouth, and urethra.

Streptococcus pyogenes malignus, an uncommon organism found in splenic abscess.

Streptococcus septicus has a strong tendency to break up into diplococci.

2d Group.—*Streptococcus of erysipelas*, is found in the capillary lymph-spaces in erysipelas. Many bacteriologists believe it to be identical with the streptococcus pyogenes.

Streptococcus of Septicemia and Pyemia.—Most observers maintain that it is identical with the streptococcus pyogenes and the streptococcus of erysipelas.

3d Group.—*Streptococcus articulorum*, found in the false membrane of diphtheria (see the article by Woodhead in the "System of Surgery" by Sir Frederick Treves).

The *micrococcus tetragenus* is thought to be the bacterium chiefly responsible for the suppuration of tubercular pulmonary lesions.

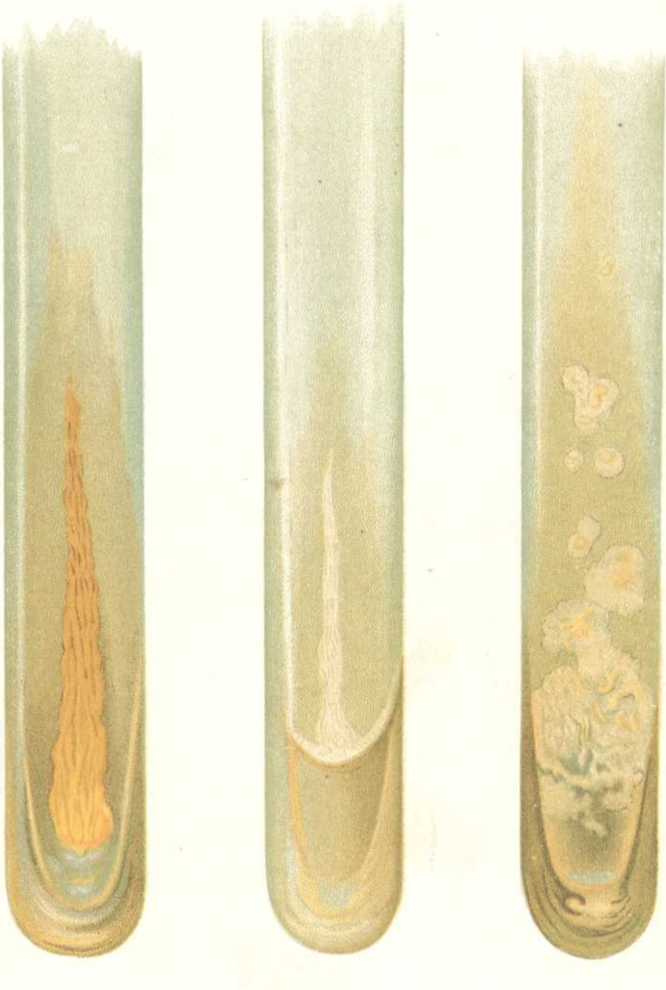
Bacillus pyogenes fœtidus, found especially in the pus of ischiorectal abscesses.

Bacillus pyocyaneus, found by Ernst in blue pus

The gonococcus, the pneumococcus, the bacillus of typhoid fever, and the colon bacillus have pyogenic power.

Other Surgical Microbes.—*Streptococcus of erysipelas* (Fehleisen's coccus), as stated before, is thought by many to be identical with the streptococcus pyogenes. Their difference in action is believed by Sternberg to be due to difference in virulence induced by external conditions and by the state of the tissues of the host. The coccus of erysipelas is somewhat larger than the ordinary form of streptococcus pyogenes. Infection takes place by a wound, often a very trivial wound of the skin or mucous membrane. The organism multiplies in the small lymph-channels. This organism will cause puerperal fever in a woman in childbed when it gains access to "an absorbing surface in the genital tract" (Senn). The streptococcus may cause suppuration in erysipelas, mixed infection not being necessary to induce pus-formation.

The *gonococcus* (Fig. 13, the bacillus of Neisser), the diplococcus which causes gonorrhea. Bumm proved the causative influence of the gonococcus. He reproduced the disease in a healthy female urethra by inoculation with



1. Staphylococcus pyogenes aureus.
2. Staphylococcus pyogenes albus.
3. Bacillus tuberculosis on glycerin-agar.

(Warren's *Surgical Pathology*.)

the twentieth generation in descent from a pure culture. Diplococci are found often in the secretions of apparently healthy mucous membranes, and simulate very closely gonococci. Gonococci cannot be cultivated upon ordinary media but grow best upon human blood-serum. In gonorrhea the organisms are found both within and outside of pus-cells and mucus-cells. It seems reasonably certain that the gonococcus is pyogenic, although it is possible that the pus formed in gonorrhea is due to mixed infection. Gonococci stain easily and are readily decolorized by Gram's method.

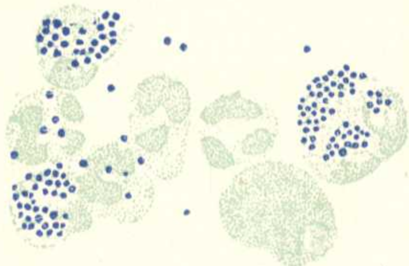


Fig. 13.—Gonococci from gonorrheal pus.

Streptococci are found in noma. No specific organism has been isolated for traumatic spreading gangrene or hospital gangrene.

The *bacillus of tetanus* (Fig. 14, Nicolaier's bacillus), an anaërobic organism, found especially in the soil of gardens, in the dust of old buildings, in

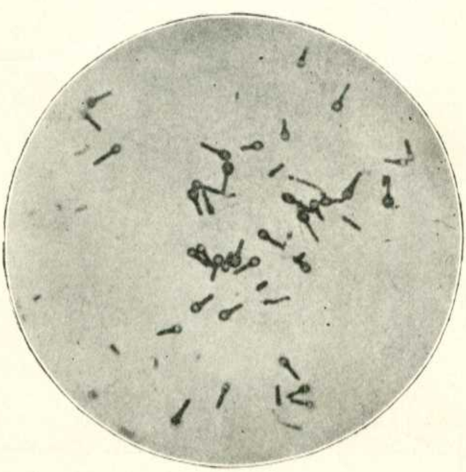


Fig. 14.—Bacillus of tetanus, with spores.

street dirt, and in the sweepings of stables. Spores develop at the ends of these bacilli. The bacilli are capable of producing toxins of deadly power. The spores are very resistant and it is difficult to kill them. The drug which is most certainly fatal to tetanus bacilli is bromin.

The *bacillus tuberculosis* (Koch's bacillus, Plate 1, Fig. 3), the cause of all tuberculous processes, is met with especially in dusty air which contains the dried sputum of victims of phthisis. This infected air is the chief means of transmission of the disease, though it may be conveyed by the milk of tuberculous cows and the meat of tuberculous animals. Wounds may open a gateway for infection. Fig. 15 shows tubercle bacilli in sputum.

Bacillus anthracis (Fig. 16), the cause of malignant pustule, or splenic fever.

Bacillus mallei, the cause of glanders.

Bacillus of syphilis (Lustgarten's bacillus). That syphilis is due to a micro-organism is highly probable, but that we have found the causative

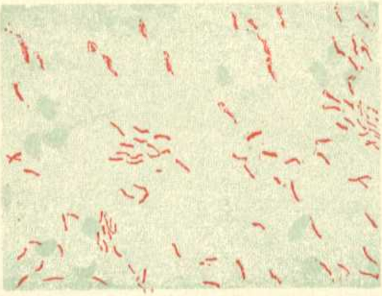


Fig. 15.—Tubercle bacilli in sputum (Ziegler).

organism in Lustgarten's bacillus is by no means sure. A fact which points strongly against its causative power is that it is found rather in non-contagious tertiary lesions than in contagious secondary lesions.

Diplococcus pneumoniæ is believed to be the cause of pneumonia and acute meningitis. It is found normally in the human saliva. This organism is often spoken of as Fränkel's bacillus and also as the diplococcus lanceolatus.

The *bacillus coli communis*, called also the bacterium coli commune, the colon bacillus, or the bacillus of Escherich (Fig. 17). Feces invariably con-

Fig. 16.—Bacillus anthracis. × 1000.

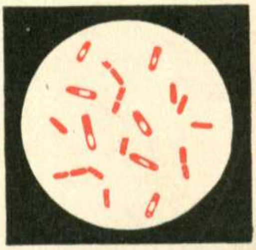


Fig. 17.—Bacillus of malignant edema.

tain this organism. It is believed by many observers to be the cause of appendicitis, peritonitis, abscesses about the intestine, many ischiorectal abscesses, some perirenal abscesses, certain cases of cystitis, cholangitis, and cholecystitis. From the pus of appendicitis we may obtain a pure culture of Escherich's bacillus, but usually find also streptococci, staphylococci, or pneumococci. The colon bacillus has pyogenic power.

The *bacillus of malignant edema* (Fig. 17) (the vibrione septique of Pasteur), found especially in stagnant water and certain varieties of soil. In the disease known as malignant edema there is a mixed infection with the bacilli of malignant edema and saprophytic organisms, and the latter form considerable quantities of gas in the tissues. The bacilli of malignant edema may cause spreading gangrene.

The *bacillus of typhoid fever* (Eberth's bacillus) is responsible for some cases of gangrene, some of embolism, and not a few of bone and joint disease. It has pyogenic power.

We may mention, in conclusion, as of occasional surgical importance, the bacillus of influenza, bacillus of diphtheria, bacillus of bubonic plague, bacillus of leprosy, bacillus of rhinoscleroma, bacillus of fetid ozena, bacillus of hemorrhagic septicemia, bacillus lactis aërogenes (an occasional cause of

Fig. 18.—Bacillus coli communis.

peritonitis), and the bacillus aërogenes capsulatus. The latter organism causes gangrenous cellulitis, a spreading gangrene accompanied by gas-formation.

The putrefactive organisms are responsible for many septic intoxications.

Infections with Protozoa.—Protozoa is a name given to the lowest forms of animal life. The protozoa are minute unicellular organisms. The cell has a definite nucleus and is composed of protoplasm and a more or less dense cell-wall. Many species have organs of locomotion (cilia or flagella). Protozoa are known to cause malaria and dysentery. Some observers maintain that they cause cancer, and it is thought probable that they may produce smallpox.