of interest and value in identifying certain species of bacteria. The principal pigments produced by chromogenic bacteria which have been chemically studied are: red, yellow, violet, blue, and green pigments. All conditions which are unfavorable to the growth of the bacteria decrease their power of pigment production, as cultivation in unsuitable media or too low or too high a temperature, etc.

Alkaline Products and the Decomposition of Urea.—Aërobic bacteria sometimes produce alkaline products from albuminous substances in culture media free from sugar. Most species produce acids in the presence of sugar, neutral or slightly alkaline cultures thus often becoming acid at first, owing to the small quantity of sugar contained in the meat used for making nutrient media; and later when the sugar is exhausted they become alkaline again. The substances producing the alkalinity of cultures are chiefly ammonia, the amines, and the ammonium salts. The conversion of urea into carbonate of ammonia is due to the action of bacteria. Several organisms also have been isolated which separate ammonia from urea.

Ptomaïns and Toxins.—Brieger has recognized a number of complex alkaloids, closely resembling those found in ordinary plants, which are the products of bacterial growth; and these alkaloids he has named *ptomaïns* (from *πτῶμα*, a cadaver), because obtained from putrefying or dead bodies. Nencke, and later Brieger, Vaughan, and others, have succeeded in preparing organic bases of definite chemical composition out of putrefying fluids,—meat, fish, old cheese, milk, etc., as well as from pure cultures of bacteria. Some of these were found to exert a poisonous effect, and for a long time were looked upon as the specific bacterial poison, while others were harmless. The poisons are particularly interesting, as they may be present in the putrefying cadaver, and hence must be taken into consideration in medico-legal questions. They may also be formed in the living body, and if not rendered innocuous by oxidation may come to act therein as self-poisons or *leucomaïns*. Recent investigations have shown that these are not the substances to which are due the specific toxic effects of bacteria, which are designated *toxins* and have quite different characteristics.

The best-known ptomaïns are: *Collidin* from putrefying meat or gelatin, *cadaverin* from decomposing dead bodies; *neurin* and *muscarin*. The first two of these contain no oxygen, and are non-poisonous, while the last two ptomaïns contain oxygen and have a poisonous action the opposite of atropine. *Tyrotoxicon*, a ptomaïn decomposing milk, and found by Vaughan in poisonous cheese, is apparently derived from butyric acid. *Pyocyanin*, which produces the color of blue and green pus, is a ptomaïn pigment. Similar bodies may also be found in the intestinal contents as products of bacterial decomposition. Some of them are poisonous and can be absorbed into the body, where they play the part of self-poisons or leucomaïns; and it has been thought that the symptoms designated as coma and tetany may be ascribed to the absorption of substances of this nature. The name ptomaïn was formerly, and is still by some authors, applied to all bacterial poisons, as in cases of so-called food poisoning due to decomposing meat, sausage, cheese, or milk. But instead of ptomaïns, which are now commonly understood to include only the crystalline products of bacterial growths, these effects may be caused by the poisonous proteids or toxins, which are always formed in the beginning of putrefactive processes. Some of the ptomaïns obtained by chemists are not due to putrefactive changes at all, but to the chemical methods employed in separating them.

Toxins or *toxalbumins* may be divided into two groups: (1) *Bacterial proteids* (Buchner), which are poisonous substances of albuminoid nature developed by bacteria, not affected by heat and capable of producing fever and inflammation, and which are obtained by boiling for several hours potato cultures of the organisms and treating with a one-half-per-cent. solution of potassium hydrate. From the clear filtrate thus obtained the proteids are precipitated by dilute acid, and the precipitate washed and dried. The best-known bacterial proteid is Koch's *old tuberculin; mallein* is a similar substance. (2) *Toxalbumins* (Brieger and Fraenkel), which are amorphous poisons having an intense and often specific action—that is, an action identical with that produced by infection with the living organism—and obtainable through precipitation from bouillon cultures by agents separating albumin, as alcohol or ammonium sulphate. For this reason these substances were called "toxalbumins," and were regarded as analogous to the toxalbumins of vegetable origin, like ricin from the castor-oil bean and abrin from the jequirity bean. But the majority of investigators consider them to be unstable albuminous substances derived from the bacterial cells; and some have assumed that they were similar to the snake venoms or enzymes, inasmuch as like these latter bodies they are very sensitive to the action of heat, light, and chemical agents. For some time, however, there has been considerable doubt as to whether the so-called toxalbumins were only obtainable by precipitation from albumin, and whether they had anything to do with albumin at all. Recently Brieger and Cohn have succeeded in obtaining what they consider to be an almost pure toxin from the crude poison of the tetanus bacillus, by means of precipitation with lead acetate and ammonia, which does not respond to any of the ordinary tests for albumin and is apparently not an albuminous substance. In the same way the cholera and diphtheria toxins have been obtained and are now recognized as being non-albuminous. It is thus becoming customary to call all proteid bacterial products *toxins*, irrespective of their composition, and to ignore the existence of the above-described crystallizable poisons of simple constitution.

With regard to the other properties of these toxins, taking tetanus toxin as an example, it may be said that in aqueous solution it is not coagulated by heat, but is deprived in time of its poisonous qualities. The addition, and continued passage through it, of CO_2 or H_2S distinctly reduces its toxicity. When exposed to light and air, either in a dry state or in solution, the toxin deteriorates rather rapidly. It withstands a temperature of 70° C. for some time without being wholly destroyed; higher temperatures quickly decompose it. When protected from exposure to light and air it is slowly converted into an inactive substance; it is best preserved under absolute alcohol, pure ether, and the like. The toxicity of the purest tetanus toxin now obtainable is almost incredible and is perhaps the most powerful poison known; 0.00005 mgm. of it kills a mouse of 15 gm. weight; hence a man of 150 pounds weight, if he were equally susceptible, would be killed with 0.23 mgm. In order to appreciate the activity of this toxin, we have only to consider that it requires a dose of from 30 to 100 mgm. of strychnine to kill a man under ordinary circumstances.

Sulphuretted Hydrogen.—This is a very common bacterial product. It may be formed: (1) From albuminous substances; (2) from powdered sulphur; (3) from thiosulphates and sulphites. The presence of sugar in the culture media does not effect the production of H_2S, but saltpetre reduces it, with the formation of nitrites.

Reduction Processes.—All bacteria possess the property of converting sulphur into H_2S in the presence of nascent hydrogen. The following reduction processes brought about by bacteria also depend in part upon the action of nascent hydrogen: The reduction of blue litmus pigments, methylene blue and indigo to colorless substances; the reduction of nitrates to nitrites and ammonia, and even to free nitrogen. The so-called "cholera-red reaction" depends upon the reduction of nitrates to nitrites by the cholera spirillum together with the production of indol. When chemically pure nitric or sulphuric acid is added to nutrient peptone cultures of the cholera spirillum a rose-red or violet color is produced. The mineral acid splits up the nitrites present, setting free nitrous acid which, with the indol, gives the red reaction. Although called "cholera red," this nitroso-indol reaction is

not confined to the cholera spirillum, but may be applied to many other bacteria. Out of sixty species examined by Lehmann, twenty-three gave the indol reaction; but the test is of practical value in differentiating the cholera spirillum from several other similar species for which it may be mistaken.

Denitrification.—This process is brought about by a number of bacteria which separate nitrogen from the nitrates and nitrites. The practical significance of these organisms, the denitrifying bacteria, is that by their action large quantities of nitrates in the soil and in manure, which are necessary for plant food, may thus become lost through conversion into free nitrogen.

Assimilation of Nitrogen.—Although so far as we know none of the higher plants have the power of assimilating nitrogen from the atmosphere, this property is possessed by at least one species of bacteria, the *bacillus radicicola* of Beyerinck. This organism is found in the root nodules of various leguminous plants (peas, clover, lupine, etc.), and can be isolated from these. Different varieties of this bacillus exist in different kinds of legumes, each legume apparently having a special variety adapted to its needs. There are also certain neutral varieties, however, existing free in the soil. By the aid of these root bacteria, leguminous plants are enabled to assimilate nitrogen from the atmosphere, thus enriching sandy soils which are naturally poor in nitrogen, so that they yield good harvests.

Formation of Acids from Carbohydrates.—Many bacteria form free acids in culture media containing carbohydrates (sugar). Acid formation occurs sometimes with and sometimes without the production of gas. Excessive formation of acid may cause the death of the bacteria from the increased acidity of the media in which they are cultivated. All anaërobic and facultative anaërobic species form acids from sugar; the strictly aërobic species do not, or they do it so slowly that the acid is hidden by the almost simultaneous production of alkali (Theobold Smith). If after the sugar is used up not enough acid has been formed to kill the bacteria, the medium becomes again neutralized and finally alkaline. Among the acids produced the most important is lactic acid, also traces of formic, acetic, proprionic, and butyric acids, and not infrequently ethyl alcohol and aldehyde.

Gas Formation.—The only gas produced by bacteria in visible quantity in culture media free from sugar is nitrogen. In the presence of sugar, so long as lactic or acetic acid is produced, there may be no gas production; but frequently gas may be abundantly formed, especially by anaërobic bacteria or in the absence of air. About one-third of the acid-producing species also develop gas, consisting chiefly of carbon dioxide and hydrogen. Bacteria which decompose cellulose also produce marsh gas.

Acid Production from Alcohol.—It has long been known that the conversion of ethyl alcohol into acetic acid is due to the action of bacteria. The conversion of the higher alcohols—glycerin, mannit, etc.—into acids is also caused by bacterial action, as is also the conversion of the fatty acids and their salts into other acids, as for instance the salts of lactic, malic, tartaric, and citric acids into butyric, proprionic, valerianic, acetic acids, etc.

EFFECTS OF OUTSIDE INFLUENCES UPON BACTERIA.—*Electricity.*—Very little is known about the influence of electricity on bacteria; but the observations heretofore made on this subject would seem to indicate that there is no direct action of the galvanic current on micro-organisms, though the effect of heat and electrolysis may produce changes in the culture which finally sterilize it.

Slight *agitation* of cultures of bacteria seems to act favorably on their development, but protracted and violent shaking destroys the vitality of bacteria by causing a molecular disintegration of their cells.

Pressure exerts comparatively little influence on bacteria. A culture of the bacillus pyocyaneus subjected to a pressure of fifty atmospheres under CO_2 still grew at the end of four hours, but the power of pigment production was lost. After six hours' exposure to this pressure a few colonies still developed, but after twenty-four hours no growth occurred.

Light.—A large number, perhaps the majority, of bacteria are inhibited in growth by the action of diffuse daylight, still more by that of direct sunlight. Dieudonné found that the bacillus prodigiosus exposed to the action of direct sunlight during the months of March, July, and August were killed in an hour and a half; during the month of November, in two and a half hours. Diffuse daylight in March and July inhibited development after three and a half hours' exposure; in November after four and a half hours, and vitality was completely destroyed in from five to six hours. Exposure to the action of the electric arc light inhibited development in five hours and destroyed vitality in eight hours; incandescent light inhibited growth in from seven to eight hours and killed in eleven hours. Similar results have been obtained with other bacteria, as the bacillus coli communis, bacillus typhosus, and bacillus anthracis. The tubercle bacillus was found by Koch to be killed by the action of direct sunlight in from five minutes to several hours, depending upon the thickness of the layer exposed and the season of the year. Diffuse daylight had the same effect in from five to seven days. It has been shown that it is only the ultra violet, violet, and blue rays of the solar spectrum which possess bactericidal action; the green rays very much less, and the red and yellow rays not at all. The action of light is apparently aided in most cases by the admission of air; but anaërobic bacteria, like the tetanus bacillus, and facultative anaërobic species, as the colon bacillus, are able to withstand the action of sunlight quite as well in the absence as in the presence of oxygen. The mechanism of the action of light has been partially explained, at least, by the demonstration of the formation of hydrogen peroxide in cultures exposed to light for a short time.

Influence of One Species of Bacteria upon Another.—If we examine water, milk, or the contents of the intestinal canal of either sick or healthy persons, we invariably find several species of bacteria occurring together. This association may at first seem to be purely accidental; but on further investigation it will be found that there are among bacteria synergists and antagonists, or at least certain species which apparently assist or oppose one another mutually or one-sidedly. This action is sometimes spoken of as *symbiosis* and *enantobiosis* (Nencke). Thus it has been found that many species of bacteria will not grow at all or only scantily in cultures when in close proximity to other species, the action being mutual or one-sided. The practical application of this fact is, in making plates for the isolation of pure cultures or for the counting of colonies, to have the plates as thin as possible. Bacteria may also oppose one another antagonistically in the animal body. Emmerich has shown that animals infected with anthrax may often be cured by a secondary infection with the streptococcus. The symbiotic or co-operative action of bacteria is of still greater importance. Some bacteria thrive better in association with other species than alone. Certain anaërobic species, for instance, as the tetanus bacillus, grow even in the presence of air, if associated with aërobic species. Again, certain chemical effects of bacteria, as denitrification of nitrates, can be produced only when two species are associated together. In like manner it has been observed that some soil bacteria, though non-pathogenic in pure culture, when inoculated into animals in combination with other species may produce disease. Finally, slightly pathogenic species gain in virulence when cultivated with common saprophytic bacteria, as the attenuated tetanus bacillus with the proteus vulgaris.

Lack of Food and Desiccation.—Most bacteria, and especially the pathogenic species, which require much organic nutriment for their development, when placed in distilled water soon die; and even in sterilized water they live from eight to ten days only and rarely multiply. Desiccation affects bacteria in various ways. In dry culture media development soon ceases, although in media dried gradually at the same temperature bacteria may retain their vitality often for several months and in the absence of spores. Also under natural conditions, when these are favorable, many non-spore-bearing bacteria live a long time when exposed to desiccation. Spore-bearing species, however, are much more resistant to desiccation as also to other injurious outside influences such as heat, light, chemicals, etc.

Behavior toward Oxygen and Other Gases.—As already noted it is customary to divide bacteria into three classes according to their behavior toward oxygen: aërobic, anaërobic, and facultative aërobic and anaërobic species.

Aërobic bacteria grow only in the presence of oxygen; the slightest restriction of air inhibits their development, spore formation especially requiring the free admission of air.

Anaërobic bacteria grow and form spores only in the total exclusion of oxygen. Among this class of organisms are many soil bacteria, such as the bacillus of malignant œdema, the tetanus bacillus, and the bacillus of symptomatic anthrax. Exposed to the action of oxygen, the vegetative forms of these bacteria are readily destroyed; their spores, however, are very resistant. Anaërobic bacteria being deprived of the oxygen of the air, are dependent for their nutriment upon decomposable substances such as glucose. Hence for their cultivation they require, as a rule, media containing from one to two per cent. of glucose or some other equivalent.

Facultative Aërobic and Anaërobic Bacteria.—The greater number of aërobic bacteria, including most of the pathogenic species, are capable of withstanding, without being seriously affected, a considerable restriction of oxygen, and many grow equally well in the partial exclusion of this gas. Life in the animal body, for instance, necessitates an existence with a diminished supply of oxygen. Pigment production usually ceases with the exclusion of oxygen, but toxins are more abundantly formed. The presence of living or dead aërobic species may facilitate the aërobic growth of anaërobic species. Moreover, certain species which in their isolation at first show more or less anaërobic development, have been observed after a time to become aërobes, growing only on the surface of media. The simple fact, therefore, of an organism showing aërobic or anaërobic growth is not sufficient to make of it a distinct species.

Although all facultative as well as obligatory anaërobes grow luxuriantly in nitrogen or hydrogen gas, the same is not true of carbon dioxide gas. Many species do not grow at all but are inhibited or killed by CO_2, while others exhibit only a scanty growth, and very few are not affected. Sulphuretted hydrogen in large quantity is a strong bacterial poison, and in small amount even it destroys some species.

Effect of Temperature.—Every bacterial species makes certain demands on temperature for its growth. Vegetative life is possible within the limits of 0° and 70° C.; but there are some species of bacteria which grow at the lower and others at the upper limits of this range. The maximum and minimum temperatures for each species lie about 30° C. apart. Bacteria have thus been classified, according to the temperature at which they develop, into: (1) *Psychrophilic bacteria.* Minimum growth at 0° C., optimum at 15° to 20° C., maximum at about 30° C. To this class belong the water bacteria having the power of emitting light. (2) *Mesophilic bacteria.* Minimum growth at 10° to 15° C., optimum at 37° C., maximum at about 45° C. These include all the pathogenic species, the conditions for their growth in the animal body requiring acclimatization to the body temperature. (3) *Thermophilic bacteria.* Minimum growth at 40° to 49° C., optimum at 50° to 55° C., maximum at 60° to 70° C. This class includes many soil bacteria and almost exclusively spore-bearing species. They are found widely distributed in fæces.

By carefully elevating or reducing the temperature it is possible to extend the limits within which different species of bacteria will grow. Thus the anthrax bacillus has been made gradually to accommodate itself to a temperature of 42° C., and pigeons, which are comparatively immune to anthrax infection, on account of their high body temperature, when inoculated with this modified organism succumb to the disease. In the same way the anthrax bacillus has been acclimated to a temperature of 12° C., so that it killed frogs kept at this temperature (Dieudonné). A very virulent diphtheria bacillus has been so cultivated that it grew at 43° C. and produced strong toxin (Park).

Bacterial growth, though retarded by temperatures just below the minimum of the species, is not otherwise injured. Cultures of bacteria which readily die (as the streptococcus) are often preserved in laboratories by keeping them in the refrigerator at 4° to 6° C. Temperatures even far below 0° C. are only slowly injurious to bacteria, different species being affected with varying rapidity. Ordinarily, low temperatures, though arresting the growth, do not destroy the vitality of bacteria. Micro-organisms have been exposed for hours in a freezing mixture at 18° C. and have been kept in an open tube in liquid air at 175° C. for two hours, and yet have been found to grow when placed again under favorable conditions.

Temperatures from 5° to 10° C. over the optimum, however, affect bacteria injuriously in several ways. The effects produced are the production of varieties of diminished activity of growth, weakening of virulence, and decrease of the property of causing fermentation, and finally gradual loss of power of spore formation. One or other of these effects may predominate under varying conditions.

If the maximum temperature is exceeded the organism soon dies; the thermal death point for psychrophilic species being about 37° C., for mesophilic about 45° to 55° C., and for thermophilic about 75° C. There are no non-spore-bearing bacteria which, when moist, are able to withstand a temperature of 100° C. even for a few minutes. According to Sternberg, ten minutes' exposure to moist heat will kill the cholera spirillum at 52° C., the streptococcus at 54° C., the typhoid bacillus at 56° C., the diphtheria bacillus and gonococcus at 60° C., and the staphylococcus at 62° C., the last mentioned being the most resistant of pathogenic organisms without spores. When bacteria in a desiccated condition are exposed to the action of heated air the temperature required for their destruction is much above that needed when they are moist or exposed to the action of hot water or steam. A large number of bacteria are able to resist dry heat at a temperature of over 100° C. for an hour. A temperature of 120° to 130° C. maintained for an hour and a half is required to destroy all bacteria, in the absence of spores, if hot air is used.

Spores are far more resistant to all injurious influences than vegetative forms, and can withstand also a greater degree of both moist and dry heat. Many spores are able to resist a temperature of 130° C. dry heat, the spores of the anthrax and the hay bacilli requiring, for instance, an exposure of three hours to a temperature of 140° C. to insure their destruction. Moist heat at a temperature of 100° C., either boiling water or streaming steam, destroys the spores of all known pathogenic bacteria within ten minutes; the spores of some non-pathogenic species resist this temperature, however, for hours. While steam under pressure is more effective than streaming steam in practical disinfection, it is scarcely necessary to give it the preference, inasmuch as all known pathogenic bacteria and their spores are quickly destroyed by the temperature of boiling water. "Superheated" steam has about the same germicidal power as hot, dry air at the same temperature, and is less effective, of course, than moist steam.

Tyndalization; Fractional Sterilization.—Certain nutrient media, such as blood serum and the transudates of the body (ascitic and hydrocele fluids, etc.), and some fluid food stuffs, require at times to be sterilized and yet cannot be subjected to temperatures high enough to kill spores without suffering injury. The property of spores, when placed under suitable conditions, to germinate into vegetative forms, is here taken advantage of by heating the fluids to 55° or 78° C. for one hour on six consecutive days. By this means, upon each exposure, all the bacteria, which have grown in the interval, are killed in the vegetative form. Experience has shown that, with few exceptions, this method of fractional sterilization will completely sterilize all fluids thus treated.

Pasteurization.—It is often undesirable, however, to expose milk and other food stuffs to such a high temperature, because of the deleterious effects produced, and yet a partial sterilization is required. According to the method of Pasteur, however, milk, etc., may be heated for thirty minutes to 70° C., which will kill all vegetative bacteria present, allowing only the spores to remain alive. But even this partial sterilization greatly retards the process of fermentation or putrefaction.

Effect of Chemical Agents.—Many chemical substances when brought in contact with bacteria unite with their cell substance, forming new compounds and usually destroying the life of the organisms. Bacteria are much more easily killed by chemicals when in the vegetative than in the spore stage, and their life functions are inhibited by substances less injurious than those required to destroy their vitality. But both in the vegetative and spore forms they differ considerably in their resistance to chemical agents. The reason for this is but imperfectly understood, but it probably depends upon the composition of their cell substance, and is due to a true chemical combination taking place. Chemicals are more destructive to bacteria at a high than at a low temperature, and they act more quickly when the bacteria are suspended loosely in fluids than when in masses. In estimating the extent of the action of chemical agents upon bacteria we usually distinguish the following degrees:

1. *Attenuation.*—The growth is not permanently interfered with, but the pathogenic and zymogenic functions of the organism are diminished.
2. *Asepsis or Inhibition.*—The organisms are not able to multiply, but they are not destroyed.
3. *Antisepsis, or Incomplete Sterilization.*—The vegetative development of the organism is destroyed, but not the spores.
4. *Disinfection, or Complete Sterilization.*—Vegetative forms and spores are destroyed.

Many substances which are strong disinfectants become altered under the conditions in which they are used, so that they lose a part, if not all, of their germicidal properties. Thus quicklime and milk of lime are disinfecting agents only so long as sufficient calcium hydroxide is present. If this is changed by the carbon dioxide of the air into carbonate of lime it becomes inert. Bichloride of mercury and other chemicals form compounds with many organic and inorganic substances, which, though still germicidal, are much less so than the original substances.

DISINFECTANTS.—Among the more commonly used disinfectants may be mentioned:

1. *Mineral Disinfectants.*—*Bichloride of mercury.* This substance in the proportion of 1 to 1,000,000 in nutrient gelatin or bouillon, prevents the development of parasitic bacteria. In the proportion of 1 to 500,000 in water it will kill many species in a few minutes, but in bouillon twenty-four hours may be needed. With organic substances its power is lessened, so that 1 part in 1,000 may be required. Spores are killed in 1 to 1,000 watery solution within one hour. Corrosive sublimate is therefore less effective as a germicide in alkaline solutions containing much albumin than in aqueous solutions. In such fluids, besides loss in other ways, albuminate of mercury is formed, which is at first insoluble, so that a part of the mercuric salt is really inert. In alkaline solutions, such as blood, blood serum, pus, tissue fluids, etc., the soluble compounds of mercury are converted into oxides or hydroxides. The soluble compounds can therefore remain in solution only when there are present sufficient quantities of certain bodies (the alkaline chlorides and iodides, sodium and ammonium chlorides) which render solutions possible. The addition of a suitable quantity of common salt to the corrosive sublimate thus prevents the precipitation of the mercury. Compounds of mercury which, like the cyanides, are not precipitated with alkalies, because they form double salts, require no addition of salt. For ordinary use, solutions of 1 to 500 and 1 to 1,000 of bichloride of mercury will suffice to kill the vegetative forms of bacteria within fifteen minutes; when much organic matter is present the stronger solution should be used.

Biniodide of mercury is very similar in its effects to the bichloride, and is even more powerful.

Nitrate of silver in solution has about one-fourth the germicidal value of bichloride of mercury, but nearly the same antiseptic value.

Sulphate of copper has about five per cent. the value of mercuric chloride.

Sulphate of iron is a very feeble disinfectant.

Caustic soda in a thirty-per-cent. solution kills anthrax spores in about ten minutes; in four-per-cent. solution in about forty-five minutes.

Sodium carbonate even in concentrated solution kills spores with difficulty, but at 85° C. it kills spores in from eight to ten minutes; a five-per-cent. solution kills the vegetative forms of bacteria in a short time Ordinary soap suds have a slight bactericidal as well as marked cleansing effect. The bicarbonate of soda has almost no destructive action on bacteria.

Calcium hydroxide is a powerful disinfectant; the carbonate has little or no germicidal action. A one-per-cent. solution of calcium hydroxide in water kills bacteria in vegetative form within a few hours; a three-per-cent. solution kills typhoid bacilli in one hour; a twenty-per-cent. solution added to equal parts of fæces and thoroughly mixed completely sterilizes them in one hour.

Mineral acids, bulk for bulk, are more germicidal than vegetable acids. But any acid which equals 40 c.c. of normal hydrochloric acid will prevent the growth of all species of bacteria and will kill many. Twice this amount destroys most bacteria in a short time. A 1 to 500 solution of sulphuric acid kills typhoid bacilli within an hour. Hydrochloric, citric, tartaric, malic, formic, and salicylic acids are similar to acetic acid in germicidal properties. Boric acid destroys the less resistant bacteria in two-per-cent. solution and inhibits the growth of others.

II. *Organic Disinfectants.* — *Alcohol* in ten-per-cent. solution inhibits the growth of bacteria; absolute alcohol kills bacteria in the vegetative form in from several to twenty-four hours.

Chloroform, even when chemically pure, does not destroy spores, but a one-per-cent. solution will kill bacteria in vegetative form.

Iodoform has but little destructive action on bacteria, and upon most species has no appreciable effect at all. When mixed with pus from wounds, etc., iodoform is reduced to soluble iodine compounds, which partly act destructively upon the bacteria and partly unite with the poisons produced by them.

Carbolic acid in aqueous solutions 1 to 1,000 inhibits the growth of bacteria; in the proportion of 1 to 400 it kills the less resistant organisms, and in 1 to 100 solution destroys all vegetative forms. A five-per-cent. solution kills the less resistant spores in a few hours and the more resistant in from one day to four weeks; a slight increase of temperature aids the destructive action. A three-per-cent. solution kills streptococci, staphylococci, anthrax bacilli, etc., within one minute. Carbolic acid loses much of its value when in solution with alcohol or ether, but the addition of 0.5-per-cent. hydrochloric acid aids its activity. Carbolic acid is so permanent and comparatively so little influenced by the presence of albumin, that it is one of the best agents for general use in practical disinfection.

Cresol is the chief ingredient of so-called "crude carbolic acid." It is almost insoluble in water and has therefore little germicidal value. Mixed with equal parts of sulphuric acid to render it soluble it is a powerful disinfectant, but it is then strongly corrosive.