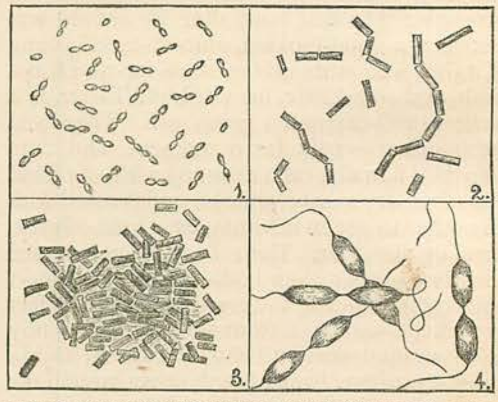
DISEASE GERMS, AND HOW TO COMBAT THEM.*

AT the very confines of organic nature, the lowliest of the low among plants, comes a series of minute and simply formed bodies called bacteria. From them we receive great benefits, and from them also proceed some of our greatest evils. They are the active agents in producing that circulation of matter so essential to the continuance of organic life, since by the decompositions they effect the earth is freed from the dead matter which would otherwise encumber it, while the matter itself is turned into the great reservoir from which all life draws. In addition to this, recent experiments make it doubtful whether our seeds could germinate without their aid; and yet, it must be confessed that, as a class, they are not in good repute. They spoil our meats in warm weather, turn sour our milk, and vex the housewife by exciting revolt among her choicest preserves; and we are now in possession of facts which prove that some among them actually cause disease of an infectious nature. This is no longer inferential, but proved for at least half a dozen diseases; and the proof is positive and absolute in that number of cases, while in many others we need but a few more facts that we may be equally assured.

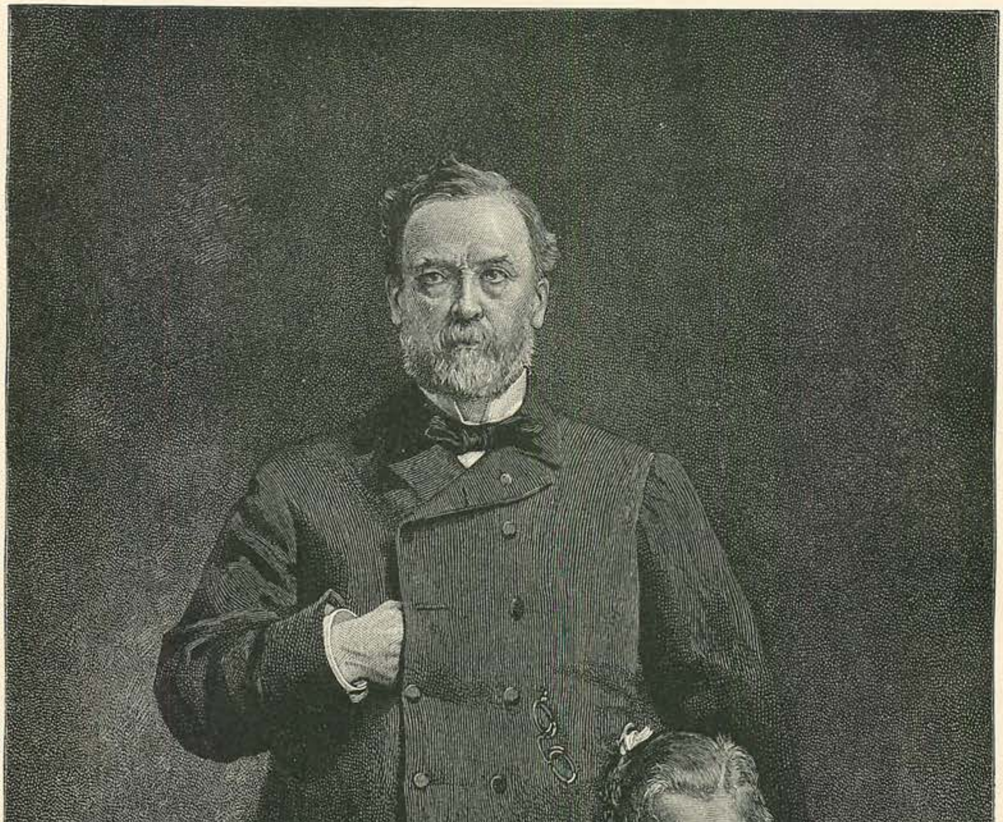
Taking a little filtered beef bouillon, clear as crystal to the eye, and showing under the microscope not a trace of life, let us place it in a glass flask and, boiling it repeatedly to destroy any germs it may contain, set it aside in a warm place with the mouth of the flask open. In a few days the liquid previously so limpid becomes very turbid. If we take a drop and magnify it 1000 diameters we shall see that the liquid is crowded with life, and the few ounces of bouillon contain a vaster population than our greatest city can boast. All is incessant activity; the whole field of the microscope is crowded with moving bodies, some shooting rapidly past in straight lines, others moving slowly backward and forward, while others twirl and spin during the whole time of observation. The sight itself is interesting, but the question that springs at once to the mind is still more so. Whence comes all this active life? It was here that the theory of spontaneous generation took its last stand; it was here that it made its most desperate resistance; here also it has been most signally defeated. Has the life sprung from some new arrangement of the complex principles in the broth? No. Science again reiterates the dictum that there can be no life without antecedent life. The broth has been contaminated by air germs, and from a few falling into it has come this prodigal life. Starting from no matter how complex a substance, once kill all the germs it contains and supply it with air freed from germs, and no life will ever appear. Here, then, is a test for the number of germs air or water may contain in seeing how much is required to start life in an infusion perfectly free from germs. On this principle the numbers presently to be stated have been obtained. We must clearly understand, lest we become needlessly alarmed, that the majority of bacterial life, as such, is perfectly harmless to man. Almost every fermentation and putrefaction has a special bacterium inducing it. The ripening of cheese is produced by bacteria and yet is perfectly harmless. What, then, does it signify to count bacteria in air and in water? It is useful simply because where harmless bacteria are found multiplying there we are assured conditions are generally favorable for the increase of harmful varieties too.



1. Bacterium Termo X 1000 Diameters. 2. Hay Bacillus X 1000 D. 3. Same (zoogloea) X 1000 D. 4. Bacterium Termo X 3000 D. (Dallinger.)

Returning to our infusions and microscope, let us look more closely at this lowly life. We have shown in Figure 1 the appearance of beef bouillon in which bacteria called "bacterium termo" are growing, while Figures 2 and 3 show a growth of what is called "hay bacillus," since the germs are very abundant in hay; and here, so our readers may not become

* When not otherwise credited, the drawings were made by the author directly from the microscope.



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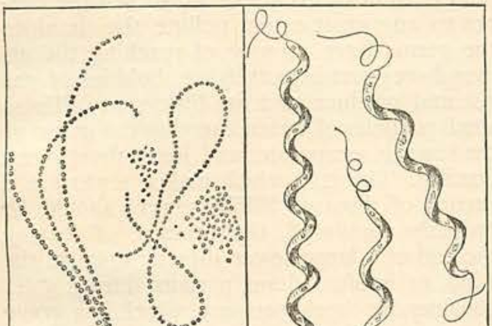
PASTEUR AND HIS GRANDDAUGHTER.

confused with the different names, we will say that bacteria are divided according to their *shape* into four classes: the micrococci (the word means little grains) are round, bacteria proper are very short cylinders, bacilli are longer, while the spirillum is shown in Figure 6. The micrococci, of which we show the species inhabiting the mouth in health (Figure 5), are always seen as small spherical bodies about $\frac{1}{20000}$ of an inch in diameter. Like all the bacteria, they are little masses of vegetable protoplasm surrounded by a thin cell wall. Their number in the mouth is almost incredible, but to human beings they are perfectly harmless; however, if we inoculate a few drops of saliva under the skin of a rabbit, in about two days it dies and we find its blood crowded with these minute cells.

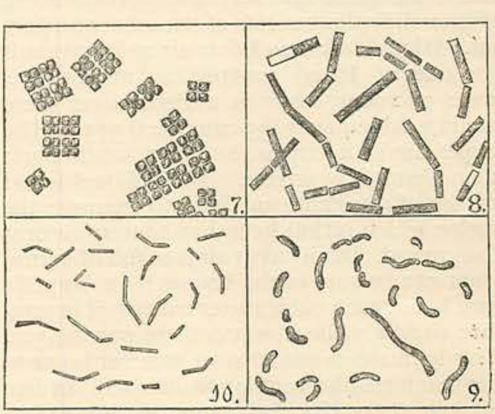


5. Micrococci from Mouth X 1000 D. 6. Spirillum Volutans X 500 D. (Cohn.)

The bacterium and the bacillus (Figures 1, 2, and 3) resemble one another, the bacterium being shorter, however, while the spirillum is totally different, much larger and twisted, and in the species figured attains a length of $\frac{1}{300}$ of an inch, which makes it a giant among the bacteria. The method by which these little plants multiply deserves notice. The chains formed by the micrococcus (Figure 5) first attract attention, and show a very common method of growth among the bacteria. This is called fission: the cell elongates and then divides, the new cell does likewise, and so a long string is formed, the micrococci under the microscope looking like minute pearls. Sometimes the division takes place in two directions, and we then have — what Figure 7 shows very plainly — a grouping in squares. The method which interests us most, however, is reproduction by spores, which are to the adult bacilli as seeds to a plant; and as the seed can survive what will kill the plant, so spores withstand degrees of heat, dryness, and disinfection fatal to full-grown bacteria: the spores forming in the bacilli look sometimes like peas in a pod, and escape through the cell wall.

Some of the bacteria are motionless; others seem to possess untiring activity, caused in some cases by flagellata, as shown in Figures 4 and 6.

Let us now pass to some of the forms accompanying disease. Those figured are the bacillus anthracis, causing splenic fever, in Figure 8; the comma bacillus, the probable cause of cholera, according to Koch, shown in Figure 9; the spirillum, causing relapsing fever, in Figure 11; while in No. 10 is seen the bacillus tuberculosis of consumption.



7. Sarcina Ventriculi X 1000 D. 8. Bacillus Anthracis X 1000 D. 9. Comma Bacillus (Cholera) X 1000 D. 10. Bacillus of Consumption X 1000 D.

It will be asked, How do these minute plants kill? In diseases like splenic fever their rapid multiplication actually fills and plugs the capillaries; in their life processes many of the disease germs evolve poisonous products. The mechanical effect of foreign matter in the blood must not be overlooked; and, as bacteria cannot grow without nutriment, all this must come from the fluids and the tissues of the body.

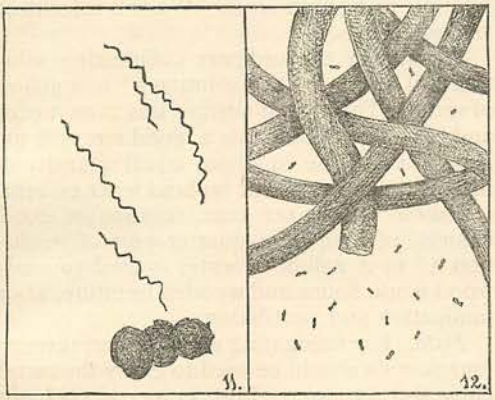
We have spoken of the methods of growth and must now mention its marvelous rapidity. Cohn has seen the hay bacillus in infusions at blood heat divide every twenty minutes. We have calculated this rate for twenty-four hours, and have found that at the end of the first day there would be as the descendants of a single bacillus 4,722,366,482,869,645,213,696 individuals; and though we can pack a trillion (1,000,000,000,000) in a cubic inch, this number would fill about 2,500,000 cubic feet. This is clearly not what they do, but simply what they are capable of for a short time when temperature and food supply are favorable.

Since the multiplication of bacteria is so favored by warmth, the summer season requires special sanitary precautions; but plants need soil as well as warmth, and the soil which best fosters these is an accumulation of vegetable or animal refuse. The longer such garbage is kept, the better for their growth and the worse for the neighborhood. In summer, therefore, it is of the first importance that garbage should be removed daily. A great step would be gained if garbage could be burned as soon as made; and as this is almost impossible in its wet state, we notice with pleasure an invention by which it is dried and then burnt, a water seal, it is claimed, preventing the escape of all odors in either operation. This is certainly a desideratum in country places with no garbage collection, where from this cause the immediate surroundings of a house often nullify the benefits of the otherwise pure air. Miquel has found that air at Montsouris (outside of Paris) contains, as an average, 1092 microbes, while in a Paris street there are in a cubic meter (35 cubic feet) 9750. The upper air in a city is, however, much purer than that of the streets. Thus Miquel found on top of the Pantheon but 364 germs to the meter, which is thus freer than country air near the ground. But if street air is so full of germs, what can be said of the houses? In Miquel's own house each cubic meter contained in summer 49,800, while in winter there were 84,500. This increase in winter over summer is due to the much smaller ventilation allowed. In free air, country or city, the germs are three to four times more numerous in summer than in winter. These figures help us to appreciate the necessity for thorough ventilation, especially in cases of infectious disease. Tightly closing the room to prevent the contagion from spreading will but add to its concentration and greatly increase the danger to the attendants. Doors and windows opening into halls or other rooms are wisely closed, but those communicating with outside air should be opened as widely as possible, and if the patient is in an upper room, much of the danger of infection is avoided. It would seem best, where hospitals are built in a thickly inhabited section of the city, to take the air supply used in ventilation, especially of the surgical wards, from a superior level by means of a tall chimney. With such air, and with walls of glazed brick instead of absorbent plaster, unfavorable results after operations, already so reduced in number by antiseptic methods, would be still further diminished.

That sunshine is a germicide as well as a tonic has but recently been proved: if we take two flasks containing the bacillus anthracis with spores, and keep one in the direct sunshine for a long time, while the other exposed to the same heat is kept from the sun, we find the sun-exposed spores have lost their virulence, while the others remain active. Is there need to further press so patent a lesson? As bacteria grow best in the presence of considerable moisture, we may expect to encounter them in greater abundance in water than in air. Rain water contains 60,000 to a quart, the Vanne four times as many, while the polluted Seine from 5,000,000 to 12,000,000.

Our readers will wish to know if sewage itself can be worse; but this, when fresh, contains 75,000,000 to a quart, and, allowed to stagnate, would soon show itself a hundred times as bad, since it contains an abundant food supply for the microbes. The necessity, therefore, for rapid and complete removal of all bodies entering the sewer becomes apparent: this is best effected by having the sewer of comparatively small size (which will admit of frequent flushing), of sufficient pitch, and as smooth as possible within. It is in putrefaction that the danger to health resides. Fresh sewage cannot to any great extent pollute the air, since the germs have no way of reaching the atmosphere; but in putrefying, bubbles of gas rise and produce each its little spray. These small particles of water, carrying the germs of the sewage, evaporate, and leave their germs floating. This it is which makes sewer gas a carrier of disease. While sewers should be properly ventilated, the practice of leaving the end of a large sewer directly open to the wind, as is often done, permits during gales considerable back pressure, which is a grave source of peril.

The minute size of the bacteria renders it very difficult to effect by mechanical means the purification of waters containing them. While strongly insisting upon the use of the purest water attainable, necessity may forbid a choice and compel the use of a doubtful supply. Two methods are then open for improvement — filtration and boiling. No disease-producing bacteria or spore can withstand a boiling temperature for an hour, so that it is advisable to boil all doubtful water. To the question whether filtration, which is much more convenient than boiling, and which also avoids the flat taste, will not purify, I would answer both yes and no. Yes, if done rightly; no, as generally effected. Figure 12 shows filter paper and bacteria submitted to the same magnification. The folly of using a small filter of some loose material to purify a large stream of water is at once apparent; it may stop off sand or straws, but not disease germs. A filter close grained enough properly to purify must be of good size to supply a family with drinking-water. Tiles of unglazed porous porcelain give by filtration water free from germs, but for an adequate quantity a good size must be used. Animal charcoal was formerly in good repute, but porous iron has great oxidizing power, will last longer, and yields nothing, while charcoal yields much to the water. Small filters yielding a large amount of water are to be uniformly mistrusted; spongy iron, unglazed porcelain, and close-grained natural porous stones are among our best filtering agents, and all filter slowly. The filtering material, whatever the form used, should be accessible for cleaning, since in time all become fouled. If water is positively bad, boiling is the safer course.



11. Blood-Corpuscles and Spirilla Obermeyeri X 700 D. Relapsing Fever. (Koch.) 12. Filter Paper and Bacterium Termo X 500 D.

It is certainly fighting fire with fire to combat an infectious malady with its own contagium, but it has now been demonstrated past cavil that in splenic fever and fowl cholera, both due to specific germs, we can so mitigate the virus that by its inoculation animals and fowls may be protected against the original severe form. Mitigating virus is simply reducing the vital power of the bacteria by surrounding them with unfavorable conditions of growth. Oxygen is not congenial to some bacteria; hence Pasteur, in modifying the virus of fowl cholera, exposed cultures of this microbe to air for weeks and months. In the case of the bacillus anthracis of splenic fever, heat and antiseptic substances have both been used with success. Two vaccinations with varying strengths of this modified virus protect for at least a year against the acute form of the disease. As the virulence is diminished by unfavorable so will it return by cultivation under specially favorable circumstances. Unsanitary conditions may thus not only afford a suitable medium for multiplying the germs, but may also increase their virulence. In regard to hydrophobia, Pasteur, proceeding on the supposition of its germ origin, has endeavored to modify the virus by exposure to dry air. The results obtained, especially in his experiments on animals, go far to prove the supposition true and the mitigation real; but since the germ has not been differentiated nor obtained in pure cultures, we think the time for presenting the subject to the public among things proved in bacteriology is not yet come. Will protective inoculation become in the future our great safeguard against disease? We confess that we are not so sanguine as Pasteur, who, having contributed so much to our knowledge of the subject, is naturally enthusiastic at its promise. The most extensive experiments in this direction have been in protecting animals from splenic fever, which, successful in the majority of cases, has so far been accompanied by a percentage of deaths not altogether insignificant. There is thus the chance of the germ regaining its lost virulence and spreading the disease among unprotected animals, so that protection, while possible in anthrax, may not be so expedient as a vigorous warfare by means of isolation and thorough disinfection. The method will prove of value, we think, rather in special cases than as a universal safeguard.*

Not so, however, is it with disinfection and

* The life-history of Louis Pasteur belongs to the romance of science.

Born in the French town of Dolé in 1822, his father, the village tanner, had hopes and plans for his boy far beyond the common.

"He shall be a professor at Arbois," the father would say; and a professor he indeed became, but not for Arbois, a small provincial college, but in the faculty of the celebrated *École Normale*. Here it was that he attended as a scholar, devoting himself chiefly to chemistry, and accepting the position of assistant in that department in 1846. During the next few years Pasteur was occupied by investigations on tartaric acid, and at the age of thirty-two was made Dean of the *Faculté des Sciences* at Lille, one of the chief industries of which is the manufacture of alcohol. Desirous of rendering his course popular, Pasteur devoted his time to the study of fermentation, and henceforward his life was to be connected with that microscopic life which, according to its character, induces here a fermentation, there a putrefaction, and again a disease.

Studying first the ferment of lactic acid, Pasteur soon advanced to acetic fermentation — that by which vinegar is produced. Both of these he proved to be due to microscopic life, and his researches led not only to the overthrow of the old theories of fermentation, but also to practical improvements in the manufacture of vinegar. In 1857 Pasteur was called to Paris, and given a chair in the *École Normale*, and was soon in the thick of the fight concerning spontaneous generation, carrying off the prize offered in that subject by the Academy of Sciences.

Resuming his studies on fermentation, the diseases of wine were investigated and found to be caused by microbes, each special disease having its own germ, and the cause once known the remedy was not long in forthcoming.

The silk industries of France are so enormous that when an epidemic appeared among the silk-worms in 1849, and steadily increased, it became a national disaster. By the entreaties of Dumas, Pasteur was induced to study the disorder, and again microscope life was found at the root of the disease, again was a remedy indicated and the industry saved; but Pasteur isolation. The latter needs no discussion; and while the value of disinfection is as universally admitted, its practice is in most cases exceedingly faulty. The policy of intimidation does not affect disease germs, and the smell of carbolic acid from a little in a saucer on the mantel does not so much frighten them as annoy us. The solutions and methods recommended are from actual experiments on germs by the American Public Health Association committee on disinfection. As to the many solutions and preparations sold in the pharmacies for disinfecting purposes, this committee reports that of fourteen such articles tried nine of them failed in a fifty per cent. solution, while of the five showing disinfecting power three owed their strength to corrosive sublimate, which, while a good disinfectant, is much cheaper to buy under its proper name. This disinfectant we recommend, but it is a powerful poison and must be kept out of children's reach. The high price, odor, and low germ-destroying power of carbolic acid accounts for its omission in the list of disinfectants, although as an antiseptic it may have considerable value. To the directions appended to this article we refer those who require the detailed information given; the more general reader we will not weary, but conclude by saying that as all germ diseases are contests for supremacy between the normal cells of the body and the foreign cells invading it, all that tends to heighten our vitality is of direct aid in enabling us to withstand the inception of these maladies. It is by depressing the system that fear operates so injuriously in epidemics. He who fears, therefore, in such crises more than the fear which is the parent of caution is simply surrendering to the enemy before being attacked. Looking to the future we can at least hope for the time when such a fear will be as impossible as it is now injurious — impossible because of the conquests made in the realm of preventable disease by our further study of microörganisms.

PRACTICAL HINTS ON DISINFECTION.

First. Corrosive sublimate (mercuric chloride), sulphate of copper, and chloride of lime are among our best disinfectants, the first two being poisonous. At wholesale drug houses in New York single pounds can be obtained, mercuric chloride costing seventy-five cents, the others ten cents, a pound.

Second. A quarter of a pound of corrosive sublimate and a pound of sulphate of copper in one gallon of water makes a concentrated solution to keep in stock. We will refer to it as "solution A."

Third. For the ordinary disinfecting solution add half a pint of "solution A" to a gallon of water. This, while costing less than a cent and a half per gallon, is a good strength for general use. Use in about equal quantity in disinfecting choleraic or typhoid fever excreta.

Fourth. A four per cent. solution of good chloride of lime or a quarter pint of "solution A" to a gallon of water is used to wash wood-work, floors, and wooden furniture, after fumigation and ventilation.

Fifth. For fumigating with sulphur, three to four pounds should be used to every thousand cubic feet air space. Burn in an old tin basin floating in a tub of water; keep room closed twelve hours, to allow the fumes to penetrate all cracks. Then open a window from the outside and allow fumes to escape into air.

Sixth. Soak sheets, etc., in chloride of lime solution, wring out, and boil.

Seventh. Cesspools, etc., should be well covered on top with a mixture of chloride of lime with ten parts of dry sand.

Eighth. Isolate the patient in an upper room from which curtains, carpets, and stuffed furniture have been removed.

Ninth. The solution of mercuric chloride must not be placed in metal vessels, since the mercury would plate them.

Lucius Pitkin.

himself, worn out by incessant work, was stricken by paralysis (October, 1868). Then came the war, and for several years, broken in health and crushed in spirits by his country's disasters, but little was done; but with returning strength work was again begun, and after a couple of years at his old favorite fermentation studies, the problem of contagious disease was attacked. Pasteur's paper on splenic fever was read in 1877, and since that time this department of research has absorbed all his energies. The later work on hydrophobia is well enough known through the newspapers, but before beginning this an exhaustive investigation of fowl cholera was made.

Pasteur was not the first to enter his later field, the German Koch having, in 1876, contributed a very remarkable paper on splenic fever, and since that time has been, so to speak, Pasteur's rival, the work of Koch on cholera and consumption being marked by the clearness and conclusiveness which were the prominent characteristics of Pasteur's earlier researches. The *technique* of the German school of bacteriology differs considerably from the method in vogue in France, and commands greater confidence among scientific men. *The* important feature of Pasteur's later work has been his discovery of the mitigation of virus and its possible use as a "vaccine," which is briefly outlined in the article. Viewed both as to their scientific and their commercial value, the discoveries made and the results achieved by Pasteur rank very high. Professor Huxley is quoted as saying that the indemnity of 5,000,000,000 francs paid to Germany is covered by the value to France of Pasteur's discoveries. But France alone has not been the gainer, nor indeed can the future prove less in value than the past. Concerning what has been done for humanity, it will be enough to say that the antiseptic system of Lister was, according to its author, based on the researches of Pasteur. For what of suffering has been saved to mankind by this improvement in surgery thanks must be given not only to Lister but also to Louis Pasteur.