A MANUAL

OF

HYGIENE AND SANITATION.

BY

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TO THE

MEMORY OF MY FATHER,

TO WHOM I OWE SO MUCH; TO WHOM I CAN REPAY SO LITTLE,

THIS VOLUME

IS MOST AFFECTIONATELY

DEDICATED.

PREFACE.

For a number of years past it has seemed to the author that there was need for a manual or text-book which would give a plain statement of the fundamental principles and facts of Hygiene and Sanitation, together with such explanations and details, based on American practice, as would serve to make the work clear and readable.

Of all the medical sciences that is clearly the most important which prevents disease instead of curing it, and deals with communities as well as with individuals. The vital interest and comparative simplicity of this science have already attracted the laity in great numbers, as well as the medical profession, and to this intelligent interest are largely due the remarkable advances which recent years have witnessed in methods of preserving the public health.

The desultory and often unauthoritative articles in the daily press or monthly magazines are scarcely fit material for satisfying this desire for knowledge, nor, on the other hand, can we expect any extensive study of the larger volumes on the subject. Smaller works exist, but they are either diffuse and lacking in system, or they detail methods and devices adopted abroad and out of harmony with conditions here. It is important for the medical student, at least, that the information given in such a text-book as the present should be as concise and systematic as possible, and that it should devote special attention to those conditions with which he is practically concerned.

For these reasons, and because I have as yet found nothing which exactly comprises my idea, I have ventured to offer this volume not only to my classes, but to all who are desirous of doing what they can to better the health of themselves and of those about them. The volume deals with personal as well as public health.

In the preparation of the work the principal text-books have been fully consulted, as well as such recent magazine and other articles of authority as were pertinent. Quotations have been credited and references indicated, in order that the reader may know where to seek for further details or fuller information than the limitations of this work will permit. Indeed, I should do wrong were I to give any one the idea that this volume is thoroughly comprehensive, or even a compendium of the whole scope of hygiene or intended to be so. The science is already too great and too important to be treated entirely in a single volume, and, as it is so intimately concerned with every one's personal welfare, it is the author's earnest hope and desire that not only his students but others may use this as an adjunct to further and more extensive reading, and that, inasmuch as hygiene is destined to be even more important in the future than it is now, all should make use of all possible sources of authoritative information.

Whatsoever may be the faults or shortcomings of the work, the labor expended upon it will not have been altogether in vain if it induces any one to take greater interest in the study of all that which pertains to "the preservation and promotion of health and the prevention of disease."

The illustrations have been selected with special reference to the text, and those of special devices or apparatus have been chosen as trustworthy representatives of their respective classes. For the four photo-micrographs of bacteria I am indebted to the skill and courtesy of Dr. William Gray, of Washington, D. C., to whom, and to all my other friends and associates who have aided me in the preparation of the work, I have many thanks to extend.

SENECA EGBERT.

PHILADELPHIA, MAY, 1898.

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A MANUAL OF HYGIENE AND SANITATION.

CHAPTER I.

INTRODUCTION.

Hygiene may be defined as the *art* and *science* that considers the preservation, promotion, and improvement of health and the prevention of disease. It treats of the laws of health in the broadest sense, and under the general term may be included a number of subdivisions. For instance, Sanitation or Sanitary Science is usually taken to be concerned with matters pertaining to the general public health, while Personal or Domestic Hygiene is more closely related to the affairs of the individual or household.

A little thought will show that under the general head we may consider: 1. The preservation and promotion of health. 2. Practical disinfection and the means of avoiding preventable diseases. 3. Adaptation of diet to the prevention and cure of perversions of nutrition; and that under one or another of these headings will fall the discussion of the air we breathe, the water we drink, the food we eat, the soils and surroundings of our dwellings and communities; and at the same time, the study of the means of recognizing, avoiding, correcting, or removing all impurities affecting any of these. In addition, there must be the study of climate and meteorology; of clothing and shelter; of the care of the sick, that they may not endanger the well; the dangers of the abuse of stimulants, narcotics, etc.; the desirability of chaste and temperate living, exercise, rest, etc.

Parkes says that, "taking the word 'hygiene' in its largest sense, it signifies rules for the perfect culture of mind and body. It is impossible to dissociate the two. The body is affected by every mental or moral action; the mind is profoundly influenced by bodily conditions. [So is the moral conduct of individuals or communities.] For a perfect system of hygiene we must train the body, the intellect, and the moral faculties in a perfect and balanced order." Again, he says: "Looking only to the part of hygiene which concerns the physician, a perfect system of rules of health would be best arranged in an orderly series of this kind. The rules would commence with the regulation of the mother's health while bearing her child, so that the growth of the new being would be as perfect as possible. Then, after birth, the rules (different for each sex at certain times) would embrace three epochs: of growth (including infancy and youth); of maturity, when for many years the body remains apparently stationary; of decay, when, without actual disease, though doubtless in consequence of some chemical changes, molecular feebleness commences in some part or other, forerunning general decay and death. In these several epochs of his life the human being would have to be considered: *First*, in relation to the natural conditions which surround him, and which are essential for life, such as the air he breathes, the water he drinks, etc.; in fact, in relation to nature at large. *Second*, in his social and corporate relations, as a member of a community with certain customs, trades, etc.;

subjected to social and political influences, sexual relations, etc. *Third*, in his capacity as an independent being, having within himself sources of action, in thoughts, feelings, desires, personal habits, all of which affect health, and which require self-regulation and control. Even now, incomplete as hygiene is, such a work would, if followed, almost change the face of the world."

The student will readily see that the scope of the science is so vast that, in a limited work like the present one, it would be impossible to go over the entire ground completely and thoroughly. The most that can be attempted will be to discuss its fundamental laws as we now understand them, especially those that are most closely connected with the conscientious physician's duties and practice, and to show the reason of or the advantages resulting from the pursuit of hygienic and sanitary methods based on those laws and our experience. Hygiene is, however, a science, in the study of which common sense must be freely used, and if one but bring this to his aid and add to it sincere attention, he will speedily find that there is little that is difficult, beyond his grasp, or less than really fascinating.

It always has been, as it always will be, an art to preserve health and to ward off disease. Hippocrates, about 400 B. C., in his treatise on *Airs, Waters, and Places*, was the first to define principles of public health or sanitation; he summed up the knowledge of his day concerning hygiene under six headings, viz.: Air, Aliment, Exercise and Rest, Sleep and Wakefulness, Repletion and Evacuation, and the Passions and Affections of the Mind; and he even pointed out that there must be an exact balance between food and exercise, and that "disease would result from excess in either direction." The excellence of the

Mosaic code of the Hebrews is acknowledged by all sanitary authorities, and its effects are seen to this day in the comparative longevity of the race. The Greeks cultivated to the extreme both the physical and mental faculties, and had for their motto *A sound mind in a sound body.* The Romans, in their aqueducts for conveying water to the city and in the Cloaca Maxima, have left some wonderful examples of sanitary engineering, which are, in certain respects, not yet surpassed.

The development of hygiene as a science, however, has been within comparatively recent years. Perhaps the first great impulse among English-speaking peoples, especially in matters pertaining to sanitation or "State medicine," can be traced to the labors of Dr. William Farr, and to the establishment, through his efforts, of the British Registrar-General's office in 1838. Since then the task of determining the principles and laws of health has been carried on with unflagging zeal by workers both here and abroad, and within the last dozen of years or so the knowledge gained in the new study of the bacteria, especially that regarding the causation and true nature of infectious diseases, has furnished us with a wealth of facts with and by which we may make the foundations of our science more unchangeable and lasting.

It would be wrong, however, to give the impression that hygiene is, as yet, an exact science. While it is rapidly attracting popular notice and attention, and has attained within comparatively recent years a dignity that it did not hitherto have in this new world, it is already on a somewhat firmer basis in the old. But the brightest minds of the day are still busy with many of its problems, and facts and laws are being made clear that more firmly fix or altogether change some of our beliefs and our practice.

Especially is such new knowledge to be sought for in the study of the prevention of disease, the domain of bacteriology, parasitic diseases, and the chemistry of the animal alkaloids and kindred compounds.

Perhaps a few statistics will help one to realize that the study is not in vain, and that the promise of the future is even more brilliant than the results and achievements of the past. Three centuries ago the death-rate of London was more than eighty per thousand; now it is about twenty. It is computed that in the eighteenth century—the one preceding the introduction of vaccination—fifty millions of people were killed in Europe by smallpox alone; now it is practically almost an extinct disease. In 1872 Sir John Simon estimated "that the deaths which occur in England are fully a third more numerous than they would be if our existing knowledge of the chief causes of disease were reasonably well applied throughout the country, and that of deaths which in this sense may be called preventable the average yearly number in England and Wales is about 120,000." In confirmation of the accuracy of this statement, official reports show that the average death-rate of England and Wales from 1862 to 1871 was 22.6 per 1000, and that of 1881 was 18.9, this giving a saving of 92,000 lives annually; while for 1889 the death-rate was 17.9, indicating a yearly saving of at least 125,000 lives, even with the correction for the lowered birth-rate. Moreover, the death-rate from the seven principal zymotic (infectious) diseases had dropped from an average of 4.11 for 1861 to 1870 to 2.40 for 1881 to 1885, and that of typhoid fever from 0.39 per 1000 in 1869 to 0.137 in 1892. This for England and Wales. In Munich from 1866 to 1881 the average yearly hospital admissions of typhoid-fever cases were 594, or 3.32 per

1000 of population, and the average deaths from this disease were 208 or 1.15 per 1000. From 1881 to 1888, following the introduction of improved systems of sewerage, the average hospital admissions (typhoid) were 104, or only 0.42 per 1000, and the average deaths were 40, or only 0.16 per 1000 of population.

In this country a like improvement is to be noted, though it is only within the last few decades that much attention has been given to sanitary affairs. The death-rate of most of our cities is being progressively lowered, though the populations are constantly increased by large numbers of ignorant and uncleanly immigrants from abroad. Improved sanitary laws are being enacted and enforced, streets better paved and cared for, houses more properly constructed and ventilated, more attention given to isolating the sick and protecting the well, and the people in general are widely awakening to the importance of improving as well as maintaining the public health. New York has reduced her death-rate within the last decade (1887 to 1897) from 26.32 to 19.50; Chicago, from 20.27 to 13.46; Philadelphia, from 21.85 to 18.72.[1]

Nevertheless, there is still much to be done. Tuberculosis, which causes from one-seventh to one-fourth of all the deaths in the world, is practically a preventable disease, and we now not only know its cause, but also have efficient means for a cure in a large proportion of cases, as well as for its general prevention. So with a number of the other infectious diseases. Every day marks an increase in our knowledge of their etiology and the securing of immunity from them, and not only must physicians make use of this knowledge as they acquire it, and use their

[1] From the Board of Health Reports of the respective cities.

utmost endeavors to secure the enactment and enforcement of sanitary laws and regulations, but they must realize that a large part of their work lies in the enlightenment and education of the people in all matters pertaining to the public health.[1]

In the preparation of a study like the one on which we are about to enter there is some question as to just what may be the most advantageous order and arrangement of the subjects to be treated. For instance, it would be interesting to discuss our science in its relation, in turn, to the individual, the household, and the people in general —that is, personal, domestic, and public hygiene; and to show wherein the treatment of these subdivisions is similar and wherein they differ; and such a threefold consideration would be not only logical, but extremely instructive.

However, since the bacteria have been shown to have so important a part in many of the processes intimately connected with health or disease, it will doubtless be advisable to devote the opening chapter to a brief review of the science of bacteriology. This done, it seems to the writer that we shall, as beginners, obtain a more comprehensive and thorough view of our subject if we pursue a method somewhat as follows : First, to discuss air, water, and food —three things absolutely essential to life—in all the varying conditions and circumstances under which they may affect the bodily welfare, either for good or bad, of the individual or of the community. Then, to take up in

[1] It is encouraging to find that, although 10 per cent. of the whole number of deaths recorded in Philadelphia in 1895 were caused by consumption, a progressive and marked lowering of the death-rate from this disease in that city is taking place, and that, notwithstanding an increase in population of almost 40 per cent., the fatalities from this disease are actually less in number than they were sixteen or seventeen years ago. For example, the deaths from pulmonary tuberculosis in 1880 numbered 2692, a rate of 3.178 to the 1000 living; while in 1897 there were only 2388 deaths, or a rate of less than 2.1 to 1000 living.

such order as may seem best the other themes, whose consideration is only a degree less important than the above in the preservation of health and prevention of disease; such as climatology, habitations, disinfection and quarantine, disposal of sewage, clothing, exercise, school hygiene, etc. In this way, while the whole ground may not be covered, the importance of the various subdivisions may be estimated in their relationship to one another, and we shall be the better prepared to pursue the study as opportunity may offer in the future.

It is doubtless in place just here to review briefly the reasons why it is the special duty of the physician to be able to recognize and remove insanitary conditions wherever they may be found, and why he should make particular and constant study of this science in all its branches and developments.

Every true physician soon finds that the respect and affection of his patients and associates are worth far more than mere mercenary gain, and that his highest aim should be to prevent disease rather than simply to cure it. And, though this may seem to militate against his personal interests, he is unworthy the name of physician if his object and purpose is solely or primarily to make money. However, the observer quickly learns that in a community kept in good health and hygienic condition there will always be more or less need of a doctor's services, in spite of every effort to prevent sickness, and that such a community will pay more promptly and more liberally for such services than one in which all sanitary precautions are neglected. Health means ability to work and to earn good wages; and a healthy community means more business, more money, and more comforts. Moreover, as a rule, good wages ensure prompt and cheerful payment of the doctor's bills, as well as of others. We may note here the close relations existing between sanitary science and social and political economy—a relationship which is very intimate, as we shall see from time to time in our work, for as the physical condition of a people is bettered it becomes more easy and more certain that they will likewise improve both mentally and morally.

Again, though the science of hygiene and sanitation is comparatively a new one, public attention is being strongly directed toward it, not only because it vitally interests every one, but because new discoveries and new applications of the laws pertaining to it are being constantly made, which are, in time, swiftly given to the world by both the scientific and the popular press. This creates a demand for first-class teachers, which demand is bound to increase in the near future and promises materially to exceed the supply. In fact, within a very few years not only the medical, but the academic and scientific colleges of the country will be compelled by powerful public opinion to establish in their faculties well-equipped and well-endowed chairs of hygiene and sanitary science, and it will be from the ranks of the educated physicians of the country that these teachers must naturally come. It will not be long before the people in general realize that it is as important that the college student or graduate be instructed how to do his part in taking care of the health of himself, his future family, and the community in which he is to reside, as that he shall be well read in the abstract principles of theology or the classics of dead languages.

So, also, considerably more time and attention than are now accorded to it should be given to hygiene in the work of the various normal schools for teachers. The graduates of these schools will have much of the physical as well as the mental welfare of thousands of young and growing children in their keeping, and it is unquestionably their duty to prevent or obviate the ills of school-life as far as is in their power, and to give instruction in and inculcate habits of living which will continually tend to improve and preserve the physical health of those under their care. One need scarcely intimate that, as the subject and its study are comparatively new and the demand for instructors is likely to be in excess of the supply, the recompense of the latter should be accordingly lucrative.

Lastly, the time has come when a physician must necessarily have a knowledge of hygiene, preventive medicine, and sanitary science. Many States require as thorough examinations in this as in any other branch of medicine, before granting the right to practice within their boundaries. So do the army, navy, and marine hospital services of the Government. Moreover, the people generally, as I have intimated, are awakening to an interest in sanitary matters and the prevention of disease, and expect their physicians to be well versed on all pertaining subjects; if they find a doctor lacking in knowledge or interest in this respect, they are apt to think, rightly or wrongly, that he will also be deficient in the other branches of medicine.

Happily these causes all combine to place preventive on the same high plane with curative medicine, and the time is fast passing in which the chair of hygiene fails to have a primary place in any thorough medical school.

It is evident that the successful physician and practical student of hygiene must have a thorough knowledge of three things: 1. Health and its laws; how to obtain and preserve it. This, of course, implies a knowledge of the human body and its functions, viz., of anatomy, physiology, and physiological chemistry. 2. He must study disease and its causes and nature. He must also understand the distinction between diseases due to causes external and those due to causes internal to the body; and that, while some of these causes may be prevented or modified, others, with our present knowledge, may not be so readily overcome. 3. He must be conversant with and know how to use the therapeutic agents, both preventive and curative, that he has at his disposal, including not only drugs, but also all substances and forces that he can make efficacious to his purpose. The workman must know his tools to be able to use them intelligently.

Health is "that condition of the body and its organs necessary to the proper performance of their normal functions," and disease may be defined as "a condition of the body marked by inharmonious action of one or more of the various tissues or organs, owing to abnormal condition or structural change." It is, accordingly, well to consider briefly the nature and causes of disease, that we may the better understand the influence upon its prevention or production of all those varying phases and conditions of our environment which we hope to study in our work.

Disease is an entity, not a spiritual thing; a condition, not a theory. Consequently, it is to be combated with matter, force, and physical means, though not necessarily with violence. In fact, when once we understand the minuteness and delicate structure of the ultimate cells and tissues affected, we realize that oftentimes the gentlest application of the forces and means employed may be the most helpful and efficient. But when one has seen the ravages caused by it, as revealed in the pathological laboratory and at autopsies, not to speak of its manifestations in the living, as seen in the sick-room and in hospitals, I am sure that he cannot logically, or even for a moment, give credence to those who proclaim that it can be dissipated by the mere action of mind or of faith; nor to those others who declare that by subdividing and diluting and subdividing again a single grain of substance, whether primarily powerful or inert, you endow it with a miraculous power to remove the "ills that flesh is heir to." Virchow gave a priceless boon to modern medicine in his theory of cellular pathology and in showing its superiority to the old humoral theories and *à priori* reasoning. He wrote "whatever outside of a cell acts upon it (abnormally) works a mechanical or chemical change within it, which change is disorder or disease."

For convenience sake, diseases may be divided into two main classes, somewhat different in their origin, nature, and character, although the dividing line between the classes is not always as marked as it would appear to be at first sight. The first class arises within the body through some alteration or disturbance of nutrition and assimilation, or of function, and may be called *autogenetic.* The second class comprises those which are due to causes from without, favored, it may be, by either internal or external predisposing conditions, but of necessity depending upon the reception or inoculation of the special cause, which cause has the power of reproduction and development, of vitality and virulence. Such diseases are called *contagious, infectious, specific,* or *zymotic.*

A third class might also be indicated, which would include those maladies which are almost purely psychical and whose symptoms are largely notional and the result of perverted imagination. But it is a question whether the primary cause of such disorders is not an altered and abnormal nutrition of the general nervous economy of the body, or else the reflex manifestations of irritative disturbances of distant organs.

In the first class, with our present knowledge, we should place such maladies as rheumatism, gout, diabetes, neurasthenia, etc.; while into the second will obviously fall all that are now known to be due to living "germs" or organisms, such as cholera, typhoid fever, malaria, etc. However, we must not overlook the numerous impulses often given to the causation of certain members of the second class by faulty conditions of nutrition or assimilation, as is especially exemplified in many cases of tuberculosis. The character of the soil may influence the growth and product of the plant almost as much as the species itself.

Prophylaxis is "the use of hygienic or other precautions conducive to the prevention of disease;" or it may be defined as "a series of methods or procedures whereby disease is restricted and prevented by suppressing or removing its predisposing conditions, and destroying or modifying the exciting causes." Its first function, of suppressing or removing predisposing conditions, is accomplished by *sanitation;* the second, that of destroying or modifying exciting causes, is carried out by *disinfection.* The words "predisposing conditions" should be used instead of "predisposing causes," because these conditions cannot in themselves originate a disease, though they may make the system more susceptible to the exciting causes of a disease.

As we have, as yet, very little definite knowledge of the real nature of the exciting causes of autogenetic diseases, they being developed and elaborated within the body, and as disinfection, or the destruction and modification of these exciting causes, is an essential feature of prophylaxis, we, at present, naturally look for more satisfactory results in the application of prophylaxis to the second class of diseases; but it does not prevent or restrict the employment of certain prophylactic measures in regard to the first class, such as the selection of proper diet, clothing, climate, etc., and the removal or counteracting of all causes favoring malnutrition. We may, therefore, say that sanitation is the defensive, disinfection the aggressive part of prophylaxis.

To remove and suppress predisposing conditions and to prepare the body to resist and repel the action of exciting causes, we must not only strengthen its resisting powers, but also make all external media as favorable to it and as hostile to the exciting causes as possible.

The resisting powers of the body must lie in the individual cells and tissues of the body, including the vital fluids, and it is but natural to suppose that this repellent action to noxious substances is best performed when the cells and tissues are in most perfect health and most vigorous. This is not only good logic, but all our experience and scientific research go to show that it has a firm foundation in fact.

We shall soon learn that purity of the external media and environment of the body is essential to its health and that of its component tissues, and that conditions of impurity in these media predispose to disease. We shall also learn that a proper and sufficient supply of wholesome food is essential to health, and that certain other factors, as sex, age, clothing, climate, etc., may or may not predispose to disease. In other words, if we strengthen the resisting powers of the system to the fullest extent and remove all predisposing conditions, in all probability the exciting causes will be inoperative, and there will be no incurrence of disease. This is the essence of sanitation: to secure perfect health, to increase the inherent power to resist noxious and harmful influences, and to make all the surroundings and environments of the body pure and free from depressing factors. This applies equally to both classes of disease; for with healthy cells and proper food there will not be faulty nutrition and assimilation and the consequent production of the exciting causes of autogenetic disease; and with a vigorous resistance and pure surroundings there is little opportunity for the germs of contagious maladies to obtain a foothold within the system long enough to reproduce themselves and cause their characteristic diseases. The best means of preventing disease is to learn and apply the best means of attaining and retaining a healthy and vigorous state of the system, viz., to learn and observe the laws of hygiene.

CHAPTER II.

BACTERIOLOGY.

THE increase in the knowledge concerning the lowest forms of life, and the discovery within recent years that these often have a truly causative action in the excitation of many maladies, have greatly facilitated the study of the causes and prevention of disease. In fact, it is largely to this advance in knowledge and to the confirmation of the germ theory that much of the success of modern hygiene and sanitation is due.

The unicellular, vegetal micro-organisms divide themselves into two general classes with respect to their manner of reproduction, viz., those that multiply by budding—the *blastomycetes*, and those that increase by simple division or fission—the *schizomycetes*. In the former class we have the hyphomycetes or mould-fungi, and the saccharomycetes or yeasts, examples of these being familiar to every one. However, it is with the fission-fungi or bacteria, as they are now more generally known, that we are most concerned as sanitarians, since they practically include almost all those vegetal micro-organisms that are more or less closely connected with the production of disease, comparatively few of the yeasts and moulds being pathogenic, and then only indirectly or in a minor degree.

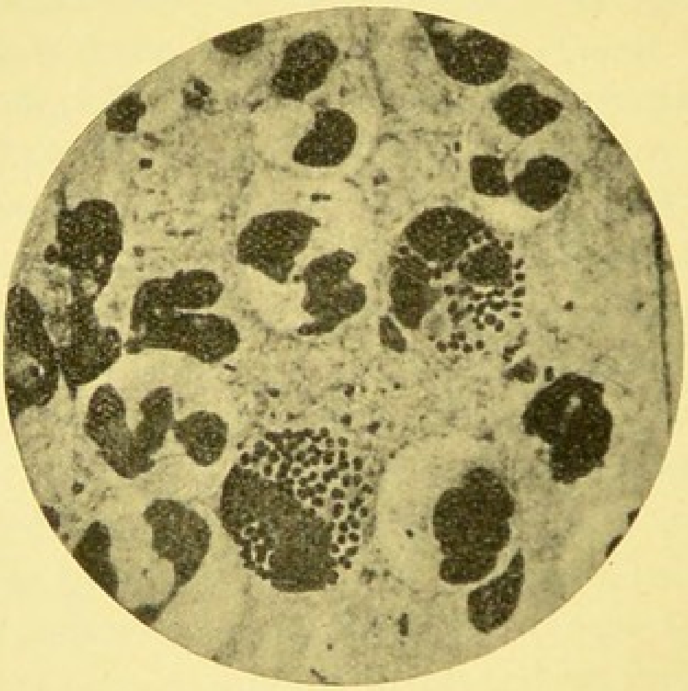
Bacteriology, then, is the science of those unicellular, vegetal micro-organisms that multiply by direct division (fission), or, as occasionally happens, by the development of spores. Its study consists in the examination by means of the microscope of the form and method of growth of these minute plants, in their artificial cultivation on or in suitable media, and in the determination of the effects of the inoculation of pure cultures upon animals. To this may be added another field of research that gives promise of rapid development in the near future, viz., the study of the chemistry of the bacterial products and the reactions produced by them in culture media and in living tissues.

Although more than two centuries have elapsed since the discovery of the bacteria by Leeuwenhoek (about 1680), and though Plenciz advanced what is practically the germ theory of to-day as early as 1762, most of our knowledge concerning the physiology, methods of cultivation, and differentiation of the bacteria have been acquired within the last fifteen or twenty years. It is true that some advance had been made in sterilization, and that Cohn, by establishing the fact of spore-formation, demolished the last arguments in favor of spontaneous generation, and confirmed the science of bacteriology; but until the few years just preceding the last decade we had but little knowledge as to the means of separating and isolating the different species and making pure cultures, or of preparing culture media, staining, etc.

As already intimated, the bacteria are unicellular organisms, usually multiplying by a process of cell-elongation and fission. Being deprived of chlorophyll, they cannot absorb and decompose carbonic acid and ammonia, as do the higher plants; but require for their growth and nutrition organic matter — usually soluble albumin — in the presence of moisture. Hence they must be either saprophytes or parasites. As the combination of albuminous organic matter and water is extremely common, so the distribution of the bacteria over the earth is widespread and practically universal.

Some of the bacteria may, however, under adverse conditions, such as lack of nutriment or moisture, too alkaline or acid a medium, extremes of temperature, etc., or, on the other hand, as a result of the attainment of a stage of maximum development, produce spores which are much more strongly resistant to deleterious influences than the bacteria themselves. In this way the spore-forming bacilli may

FIG. 1.



Micrococci (gonococcus) in pus-cells. × 1000.

often survive the action of disinfectants or other agencies that are sufficient to destroy other bacteria. Upon the resumption or recurrence of favorable conditions the spores develop into cells similar in form and nature to their parent cells.

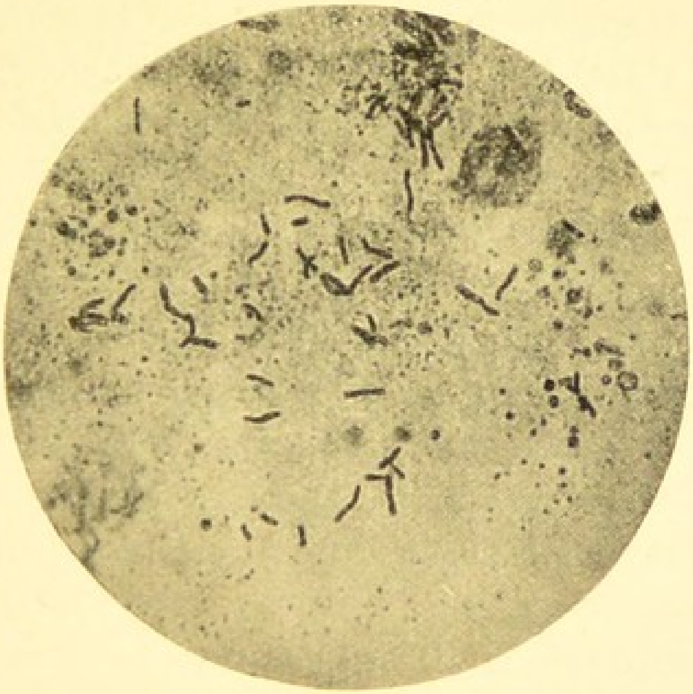
It is to be remembered that spores do not reproduce spores, and that "a single cell produces but one spore."[1]

[1] Abbott: "Principles of Bacteriology," 1st ed., p. 31.

Under the microscope the spores are seen as highly refractive, spherical bodies that stain with difficulty, and evidently have a very resistant envelope, probably of cellulose. The interior of bacteria and spores is protoplasm. So far as we positively know at this time, only certain bacilli form spores, though there is a possibility that a few of the spirilla and one or two species of micrococci have the same faculty.

Again, under certain peculiar conditions some organisms may develop another morphological change, the so-called

FIG. 2.



Tubercle bacilli in sputum. × 1000.

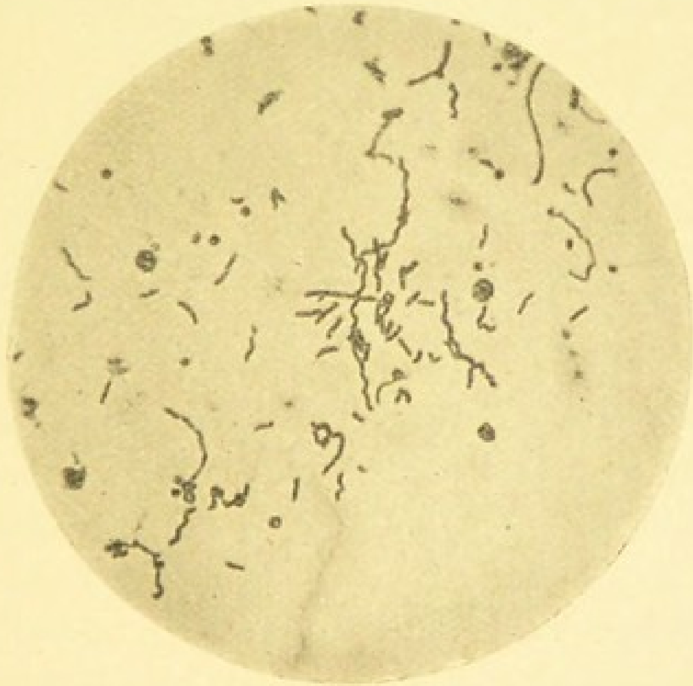
involution forms. These are doubtless pathologically distorted cells, with probably less than normal resisting powers, but which will again revert to the normal under favorable conditions, providing the unfavorable environment does not first kill them.

Lastly, there are times when certain individuals of a species seem to have departed from the typical form, these departures being only different phases in the normal development. Thus a young bacillus may be shorter than the adult and look much like a coccus, or a coccus about to undergo division may be oval in shape and considerably larger than the quiescent members of its species. But one form of bacteria never permanently takes that of another—micrococci are always micrococci, bacilli always bacilli, etc.

A thoroughly scientific classification of the bacteria is scarcely possible as yet, owing to our incomplete knowledge of their character, method of growth, physiology, etc. However, there are a number of ways in which we may subdivide them, none of them exactly scientific, perhaps, but still sufficiently accurate and convenient for our purpose. If we consider them as to form we have: (*a*) micrococci, spherical in shape; (*b*) bacilli, which have one diameter longer than another; and (*c*) spirilla, spirals or segments of spirals. We shall have more to say hereafter of the characteristics of each of these subdivisions. Accordingly as they live best with or without air or oxygen they are aërobic or anaërobic. Again, they may be named according to their product; *e. g.*, some produce colors, *chromogenic*, others pus, *pyogenic*, etc. Lastly, they are either saprophytic or parasitic. Some of the micrococci are named according to the manner in which they grow. If in pairs, they are called diplococci; in fours, tetracocci; in threads, streptococci, etc. Groups or masses of micrococci or bacilli held together by a gelatinous substance are called *zoöglea*. With one or two exceptions we know but little about the spirilla. The germ of cholera—the comma bacillus (?)—belongs to this class, and the cause of relapsing fever is also probably a spirillum.

Most of the bacteria thrive best in culture media that are neutral or only slightly alkaline, though a few species seem to do better in slightly acid surroundings. So, also, they do best at temperatures ranging between 20° and 40° C. (68° and 104° F.), though they may grow between 5° and 43° C. (41° and 109.4° F.). Any marked deviation in the culture media from the neutral point or continued exposure to extremes of temperature may either check the

Fig. 3.

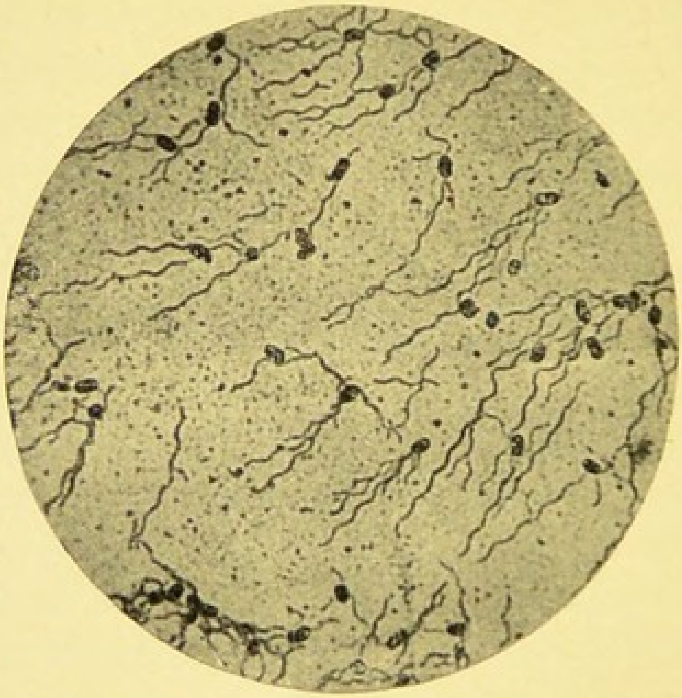


Spirillum of Asiatic cholera. × 1000.

growth of the organisms altogether, and eventually destroy them, or may cause spore formation, or the production of involution forms, or may cause a change in the composition and the character of the chemical products which the bacteria normally produce. This also holds good with respect to any other condition or substance that may be deleterious to the bacteria in their normal state; and we shall see that this is important as having a decided influence in lessening the virulence of pathogenic bacteria and bringing about a condition of immunity to their attacks.

As it is rare to find isolated individual species anywhere except in artificially prepared pure cultures, it is evident that we must devise some way of separating the different kinds of organisms one from another. This is best accomplished by the method suggested by Koch, viz., to introduce the mixed kinds into some melted culture medium,

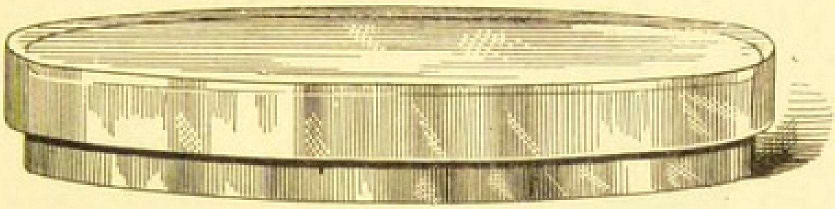
FIG. 4.



Bacilli of hog cholera showing flagellæ. × 1000.

like nutrient gelatine, which solidifies on cooling, but whose melting point is not sufficiently high to destroy the vitality of the germs. If the fluid be then shaken, the various species will be distributed through it, and upon cooling each individual or group of individuals of the same kind (zoöglea) will be fixed in its place and become the starting point of a colony of that special kind; and if the gelatine be poured out before cooling upon sterilized glass plates or into flat (Petri) dishes (Fig. 5), the subsequent work of counting, examining, and making cultures from the colonies will be greatly facilitated. Moreover, this process may be repeated until absolutely pure cultures are obtained of each species in the original mixture.

FIG. 5.

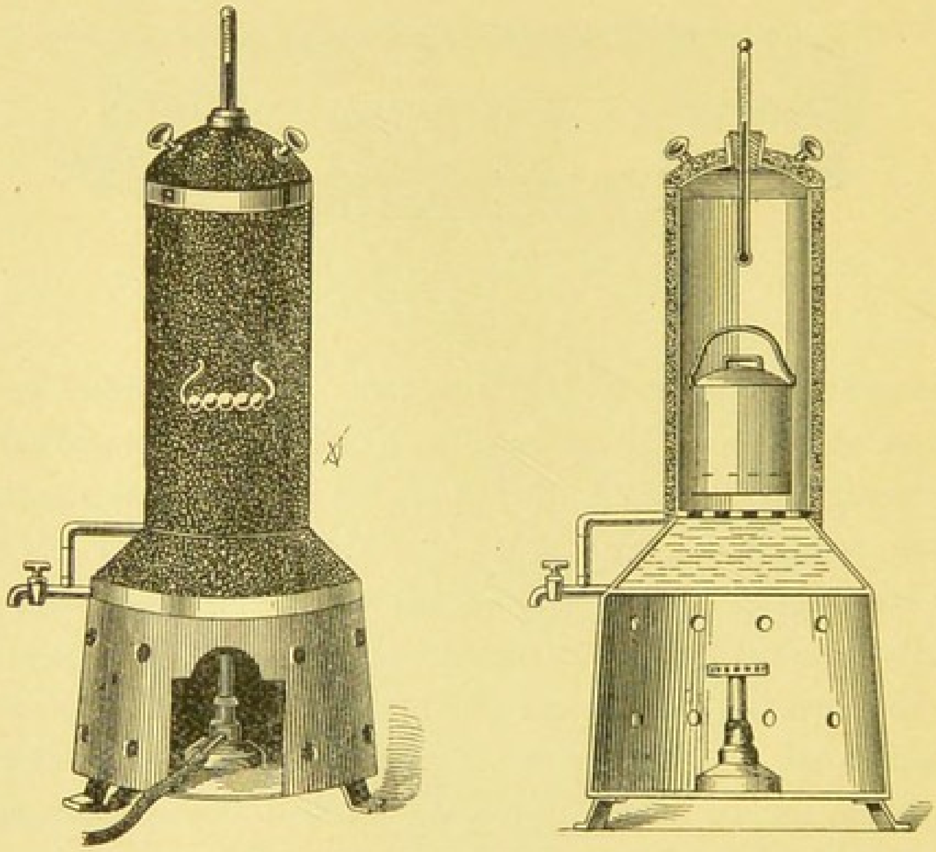


Petri double dish, now generally used instead of plates.

Special care must be taken in this, as in all other bacteriological methods or operations, to prevent contamination of our cultures, media, or apparatus by other organisms, which are almost omnipresent, and which would prevent any accurate results or deductions whatever, were they not rigidly excluded or destroyed. Obviously, we may not use the ordinary chemical disinfectants or antiseptics as a means of destroying and removing these interfering microbes, for by their action we should destroy or check the growth of the bacteria we desire to cultivate ; but must sterilize by heat all the articles we use, together with their contents. This, if properly done, does not affect the nutrient properties of the culture media, while it removes the danger of subsequent contamination.

In sterilizing we may use either dry or moist heat, the latter being by far more preferable in most cases (Figs. 6 and 7), since to be effectual it does not require so high a temperature nor so long a time as does the former. Moist heat, especially in the form of steam, is more penetrating than dry heat; beside, the dry heat requires to be of so high a temperature that it may spoil for culture purposes such substances as the nutrient gelatine. Glassware and the like, however, may be quickly and advantageously sterilized by dry heat. On the other hand, certain sub-

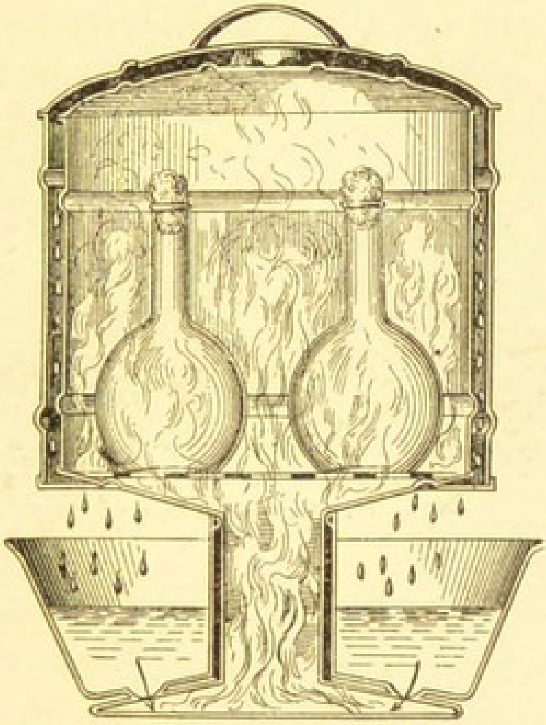
FIG. 6.



Steam sterilizer, pattern of Koch.

stances, like blood-serum, are ruined by moist heat continued long enough to destroy the spores possibly present, as the latter need a much higher temperature to sterilize them than the former. So we resort to fractional sterilization in such cases, exposing our materials for only a short time to a temperature just sufficient to destroy the bacteria, repeating the process after an interval which is sufficient to allow the spores to develop into bacteria, say, twenty-four hours, and sterilizing again a third time after a like interval. Having thus sterilized the culture media and apparatus, we prevent the access of contaminating germs to the interior of our tubes and vessels by plugs of sterilized cotton-wool, covering these, when necessary, with rubber caps to prevent the evaporation of fluids or of moisture from the gelatine, etc.

FIG. 7.

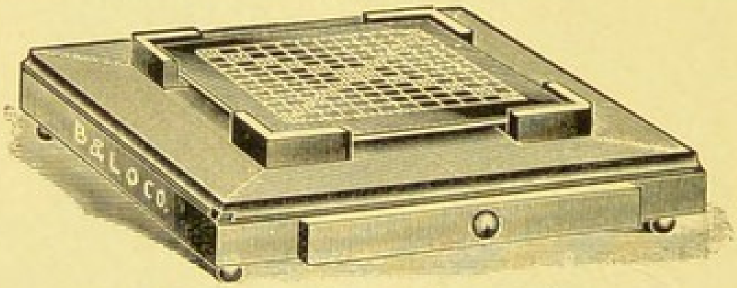


Arnold steam sterilizer.

As a basis for a number of culture media, we may use beef-broth or bouillon, which is a fluid especially favorable to bacterial growth, in that it contains an abundance of albumin in solution. When a solid medium is desired, either gelatine or agar-agar (a sort of vegetable gelatine from Japan) may be added to this, giving us nutrient gelatine and nutrient agar-agar. Of these, the gelatine has a melting-point below the temperature of the human body, while the agar has not, so we have to employ the latter when it is desired to cultivate germs that grow best at the body-temperature, although the development of most bacteria is usually more rapid and characteristic upon the gelatine. Sterilized and solidified blood-serum is also used for the cultivation of certain organisms, like the diphtheria bacillus, and there are certain others which can only be differentiated by their difference in growth upon boiled potato, milk, etc.

The differentiation of the various species of bacteria is to be made by noting their appearance and form under the

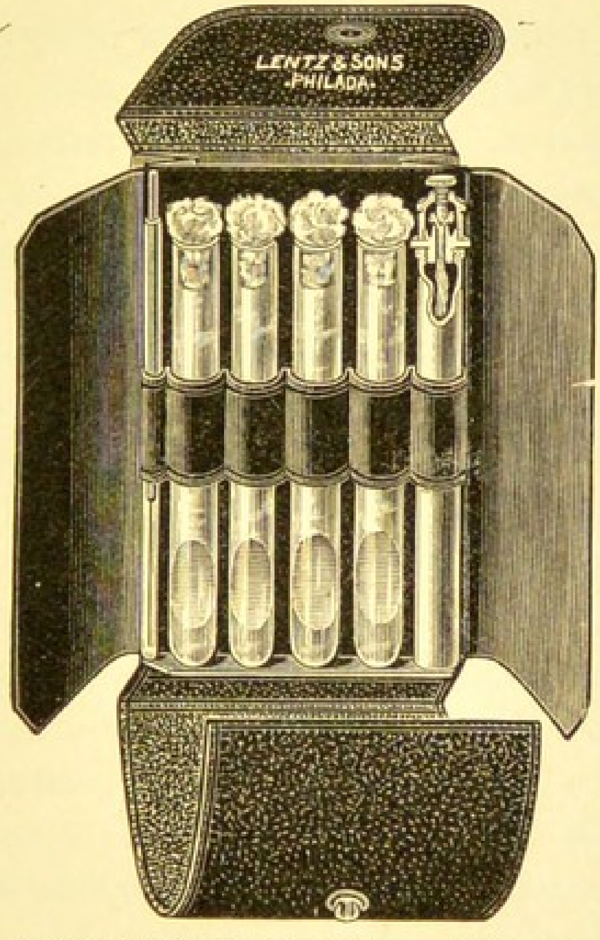
FIG. 8.



Ruled square for counting colonies.

microscope, whether they are motile or not, how they take different stains, etc.; by observing their methods of growth in or upon different culture media, whether they are aërobic or anaërobic or facultative; at what temperatures they do best, etc., and finally by studying their action and the action of the substances they produce upon living animals. In this way we may determine the characteristics of each individual or species, and will eventually have the groundwork and material for a strictly scientific classification of the schizomycetes. For example, the organisms causing suppuration are micrococci, occurring in clusters (staphylococci) or in chains (streptococci); the cause of typhoid fever is a bacillus, and the cholera germ belongs to the spirilla. The tubercle bacillus stains with marked difficulty, but when stained is not readily decolorized by a weak solution of nitric acid as are almost all other bacilli. Some bacteria liquefy nutrient gelatine, others do not, and almost none liquefy agar-agar. This liquefaction is not

FIG. 9.



Pocket-case containing sterilized culture tubes, platinum needle, and small alcohol lamp used for obtaining cultures for diagnosis, etc.

a melting, but rather a probable peptonization, since the gelatin will not solidify again after it occurs, as it will after being subjected to moderate warming. Again, some bacteria produce one color or chemical substance in the presence of oxygen, and another in its absence; some only produce color in the light, others only in the dark, etc. Finally, as we already know, different pathogenic microbes produce different maladies when inoculated in animals or human beings, and the same germ may produce different results in animals of different species or families.[1]

The subdivision of the bacteria into saprophytes and parasites has been already noted, and it must be remembered that not all of these microscopic plants are disease-producers, much the larger proportion, in fact, being benefactors rather than otherwise to the human race.

The function of the saprophytic organisms is to break up dead organic matter into simpler chemical compounds and ultimately into carbonic acid, ammonia, and water; these latter substances being once more utilized in the nutrition of the higher forms of vegetable life, which are, in turn, necessary to the existence of animal life upon the globe. Indeed, it is only when the student of hygiene fairly realizes the great scope of the functions of these minute but almost omnipresent scavengers that he can comprehend the important part they play in the purification of our environment. In the air they possibly help the oxygen to destroy the harmful effluvia and exhalations of men and animals and the floating débris of organic substances; in the soil, the common receptacle of the wastes and refuse of vital activity, they quickly and continually convert these noxious additions into foods of the highest value to growing plants; in running streams and quiet pools they are of the greatest importance in the removal of the dangerous impurities washed from the surface of the land or recklessly discharged from human habitations, factories, and the like. And not only do the saprophytes help mankind in this way, but members of

[1] See Kenwood's "Hygienic Laboratory," pp. 466–70; also McFarland's "Pathogenic Bacteria," pp. 46–57.

the class are beneficent in many others. For example, they enable those plants, the leguminosæ, which yield us the largest supply of vegetable proteids, to derive much of their nitrogen almost directly from the atmosphere; they have much to do with the flavor and value of dairy products, and new uses in which they may be employed in the domestic or commercial affairs of life are being announced from day to day. And thus we find this class of the bacteria, which comprises by far the greater number of species, to be our benefactors and indispensable servants both in preventing the accumulation of noxious and harmful substances upon the earth and in really helping to produce the food which we eat.

The parasitic bacteria, on the other hand, have their habitat in or upon highly organized living matter, and exist at its expense. They also produce in their growth substances called *toxins*, that are either locally or generally poisonous or harmful to the organism that is their host. It is needless to say that it is in this class that we find the disease germs, or *pathogens*, as some would call them. It should not be forgotten, however, that the saprophytes, in the decomposition of complex organic bodies, may also produce *ptomaïnes*, more or less toxic to animal life. Of these latter we may instance as good examples the dangerous tyrotoxicon, a by no means uncommon product in the decomposition of milk, ice-cream, etc., the cadaveric poisoning of the dissecting-room, etc. But, while these ptomaïnes are more or less characteristic of the respective bacteria that produce them, each varies in its composition and properties according to the substance upon or in which it is produced.

We say that an organism is *optional* when it is at one time a saprophyte and at another a parasite, or at one time aërobic and again anaërobic; and that it is *obligate* when it has not this property of changing its nature according to surrounding conditions.

Considering for the present the pathogenic bacteria alone, we are naturally brought to the discussion of the germ theory, which is, that the exciting cause of each contagious or infectious disease is some specific parasitic organism, and that these diseases are communicated only by the transference to and development of the specific parasite or germ within or upon the infected individual. Consequently, such diseases are transmitted from one person to another, or, in some cases, from animals to men, or *vice versa*, by means of these micro-organisms, and the transference is by the air, water, food, or other fomites, or by direct contact. It is evident that, if facts and knowledge establish the truth of this theory, the prevention of infectious diseases is greatly simplified, and becomes merely a matter of combining effective sanitation, of which we have spoken, with the destruction of the specific exciting causes, viz., disinfection. Nor is it essential that we any longer make the distinction between the terms contagious, infectious, zymotic, and specific, that formerly obtained, but all may be practically used synonymously. The first of these terms used to be applied to those diseases which were thought to be transmitted by direct contact only, and "infectious" to those in which the transmission was by fomites. But we now know that germs of the former class may be transmitted by air, water, food, etc., and of the latter by direct contact, though the reverse is what usually happens in the respective classes. The term "zymotic" was formerly applied to those diseases occurring in epidemics, and supposed to be due to fermentative processes; if used at all, it should be given to any disease due to a living germ. The term "specific" should only be given to those maladies which have a specific origin —*i. e.*, which have been proved to be due solely to a single organism.

That most communicable diseases are due to such germs or kindred animal organisms is more than probable, and, while there are some in which it has not been fully proved, it is scarcely possible that any of these may arise from insanitary causes without the presence of a living organism.

Our reasons for believing in the germ theory are based on empirical and logical facts as well as theoretical hypotheses. Leaving out, at present, the work already done, it is evident that the matter that causes a disease, the *contagium*, must, when introduced into a susceptible person or animal, increase in quantity to an enormous extent. Note, for instance, the amount of positively virulent matter thrown off from a case of smallpox or scarlet fever, and yet how very little is required to initiate a disease. No dead chemical substance has the power of being increased to such an extent by simply finding a lodgement in a suitable medium. The poison of contagion, whatever it may be, evidently must have life and the power of reproduction. Moreover, these causes of disease when freëd from the body may be carried long distances, and may exist for years, and still retain their power for harm, only waiting to find a suitable field before beginning to multiply and cause the same identical malady as before. Such causes must, therefore, be capable of entering a state in which vitality is latent or dormant, and in which the reproductive functions are for a time inactive. But we do know that the spores of many bacteria, and sometimes the bacteria themselves, may be carried long distances, kept long periods of time, and even exposed to considerable extremes of temperature, without being killed or losing their power of reproduction and rapid multiplication. Again, we know that substances that are poisonous to or that prevent the development of these bacteria and kindred low forms of life, do, when properly applied or used, prevent or remove the danger of contagion.

There is also in the development and progress of any infectious diseases a direct analogy to the phenomena of fermentation, whose causative organisms are of the same order as these which we are considering; the same rapid multiplication of cells in suitable media at proper temperatures, a period of incubation, and then changes in the culture medium, which, after going on to a certain extent, check the further growth of the organism in that medium. What it is in the medium that checks the growth of the germ, we may not be able to determine *à priori*, but we may assume it to be something hostile to the contagium, as alcohol above a certain percentage is hostile to the yeast-cell.

Lastly, if the proof of Koch's postulates is essential to the acceptance of a given micro-organism as the cause of a given disease; on the other hand, we must believe that a certain germ is a cause of that disease, if not the only one, if these postulates be proven about that germ in connection with the disease.

To determine whether a certain organism is or is not pathogenic it is necessary to experiment on living animals. To do this we must use pure cultures of the organism and carry out all our processes, including inoculations and autopsies, under strictly antiseptic precautions. We must examine the blood and various tissues of a diseased animal microscopically; if bacteria be present in any of these, we must make cultures from them, and if more than one kind of bacteria be present, the various kinds must be isolated and pure cultures made from each kind. When a pure culture is at last obtained, it is studied both microscopically and as to its characteristics on various media and at different temperatures. Finally, healthy animals known to be susceptible to the disease are inoculated from the pure culture, and, after the period of incubation, carefully watched for symptoms of the disease in question. Should these manifest themselves, the animal is killed and the blood and tissues carefully examined for the inoculated organisms.

The *postulates of Koch*, which are necessary to prove that a germ is the cause of a given disease, are: 1. The micro-organism must be found in the blood, lymph, or diseased tissues of a person or animal sick or dead of the disease. 2. The micro-organism must be isolated from the blood, lymph, or tissues and cultivated in suitable media outside of the animal body. These cultivations must be carried on through several generations until a pure culture of the germ is obtained. 3. A pure culture thus obtained must, when introduced into a healthy animal, produce the disease in question. 4. In the inoculated animal the same organism must again be found.

In the cases of many diseases peculiar to human beings alone the third condition must remain undetermined and our chain of proof be broken, because we cannot endanger human health or life by our inoculations. But in diseases common to men and animals the experiments necessary can be completely carried out, and where a germ can be proved to be the cause, according to these postulates, of the malady in animals, we can also fairly conclude that it is the cause of the same disease in human beings. The specific germs of a number of maladies common to man and beast have thus

4

been determined, together with those of a large number of affections peculiar to animals alone.

After infection or the reception of the contagium by a susceptible animal there is a period of incubation before the manifestation of the characteristic symptoms of the disease, which period is variable according to the kind of germ, and during which the micro-organisms are rapidly increasing in numbers and their consequent power for evil. After the pathological process is well under way we shall find one of two conditions existing, viz., that "in which the blood is the chief field of activity of the organisms,"[1] and the vessels of the victim are swarming with the microbes—in other words, a true *septicæmia;* or else one where "the poisonous results are not necessarily accompanied by the growth of organisms in the tissues," these latter, in all likelihood, not extending beyond the lymphatic glands nearest to the point of inoculation—*i. e.*, a *toxæmia.* A good example of the former condition is furnished by a case of anthrax or of pyæmia, and of the latter, in diphtheria. However, we shall find in either condition that if we isolate the peculiar product or toxin of the specific germ, either from artificial growths upon culture media, or from the blood or tissues of an animal sick or dead of the disease, and inoculate this into a susceptible animal, the general symptoms and results produced are practically the same as in an ordinary case of the disease. This goes to prove that the products of pathogenic bacteria are toxic in character and poisonous to the tissues, either locally or generally, and that infection must be accordingly a chemical and toxicological process. Another point to note just here is that these toxins are

[1] Abbott, loc. cit.

apparently harmful to the bacteria themselves whenever they exceed a certain amount, as is shown by the fact that most of the infectious diseases are self-limiting and by the cessation of growth and even the death of the germs in the various culture media after a certain length of time. It is but right to state, however, that there is another possible explanation of this latter phenomenon, viz., an increase in the resistance of the infected body to the action of the germs and toxins, and, in the case of culture media, the marked change in reaction caused by the bacterial products.

Having thus obtained some knowledge of the exciting causes of contagious diseases and of how they act, one of the most important considerations is in relation to the prevention of the incurrence of these diseases by the well, and to the antagonizing or checking of the further action of the cause in those already infected. It is well to disinfect and destroy disease-germs whenever and wherever it is possible to do so, but it will be still better so to strengthen and fortify the human body that the microbes, even though received into it, will be unable to attack it or do it harm. That we have the means of producing such immunity in the case of one disease, at least, is well shown by the history of vaccination, and the abundant work of numerous investigators in recent years indicates that the promise of similar results in many other maladies is by no means vain. Certain it is that many animals and, in some cases, men have been rendered apparently immune to other fatal diseases, and the indications point to the probability that the human race will shortly have the same protection against most of the contagious maladies that it now has against smallpox.

With the knowledge that immunity to infectious diseases may be produced accidentally or intentionally, and may be practically applied without a definite understanding thereof, we need not consider the method whereby the body brings about such immunity. Nevertheless, several theories have been advanced in the attempt to explain the phenomenon. Of these two have been practically disproved, viz., the *exhaustion* theory of Pasteur, which was that the pathogenic germs in their process of growth in the body removed some material from the latter necessary to their existence; and the diametrically opposite *retention* theory of Chauveau, which was that the germs produced some substance which gave immunity as long as it was retained in the tissues. On the other hand, there are still strong adherents to both the *phagocytosis* theory of Metchnikoff and the *humoral* theory of Büchner.

The phagocytosis theory is "that immunity against infection is essentially a matter between the invading bacteria on one hand, and the leucocytes of the tissues on the other; that during the first attack of the disease the white blood-corpuscles gain a tolerance to the poisons of the bacteria, and so are able to resist the next incursions of the enemy." Büchner has apparently shown that the blood-plasma, especially that of immune animals, is actually bactericidal to many virulent germs, and he attributes this effect to the presence in the fluid of certain proteid substances akin to globulin. These he terms *alexins*, from a Greek word meaning to protect. Further, he believes that they act chemically in causing the death of the disease germs, and that the increased amount of alexins in the blood of those who have acquired immunity is brought about by a stimulation or "reactive change" in certain cells due to the presence of the bacteria or their products. Moreover, this humoral theory serves to account for the natural immunity possessed by some individuals and animals, their body juices presumably containing, through some cause or other, an extra quantity of the protective proteids.

There is, however, another theory, that of the *antitoxins*, which, in view of recent developments and the fact that it is the most capable of practical application, is probably the most important of all. It is well known that the human system has the power of tolerating or accommodating itself to the action of almost any toxic substance—provided the latter be administered in sufficiently minute doses gradually increased until it can in time withstand quantities that would quickly prove fatal to one unaccustomed to the poison. Ehrlich has further shown that, with the alkaloids of certain higher plants, after a certain degree of tolerance is attained the administration of the drug may be much more rapidly increased, and that while up to this point no change occurs in the blood, now, when the tolerance becomes so much exaggerated, a new substance is produced which is capable of neutralizing the poison in that individual not only, but also in others into whose blood it may be introduced. Many experiments have shown that this same production of antidotal or antagonizing substances may be brought about by the slow administration of the toxins of pathogenic bacteria—something not hard to understand when we remember that the bacterial toxins are just as much the products of plant-life as are the alkaloids that Ehrlich used, and very much like the latter in formula or composition.

On the other hand, the antitoxins, as these new substances antidotal to the toxins are called, have been found to be albuminoid in character and very similar to the nucleins. In fact, some attempts have been made to employ the latter in place of or in conjunction with the antitoxins, with results which have not been altogether without success and to which reference may hereafter be made.

Much credit must be given to the labors of Behring, Roux, Kitasato, and others, for the development of practical methods of using the anitoxins, methods which are now recognized as eminently proper and even superior to any others in the treatment of some of the most virulent diseases. The great reduction in the mortality from one disease alone—diphtheria—already attained through the application of this treatment almost exceeds expectation and belief, and the promise seems now to be that the results with respect to tetanus and cholera and other deadly maladies will be equally brilliant and add further glory to this new science of bacteriology.

To some it may seem that either the humoral or the antitoxin theory is identical with the discarded retention-theory of Chauveau; but it should be noted that, according to the latter, the invading microbes themselves produce the antidote or antagonizing substance, while Büchner's theory attributes this production to the integral cells of the body, which furnish the alexins normally in minute quantities to the blood, and insists that the latter are germicidal to the bacteria themselves; and, on the other hand, the antitoxins, though produced by body-cells like the alexins, act chemically in neutralizing the bacterial poisons, and are dependent upon the prior presence in the body of the toxins and are a result of its acquired tolerance to the latter. With alexins or antitoxins it is evident that the immunity will last as long as these substances remain in the blood.

Nor is there any reason why the phagocytosis, humoral, and antitoxin theories should not mutually support rather than tend to discredit one another. There seems to be good evidence of the phenomena upon which each of the three is based, and, even with our present incomplete knowledge of the blood and its component parts, it is not difficult to conceive that while the alexins, and later the antitoxins, protect the leucocytes by respectively weakening the vitality of the microbes and neutralizing their products, the leucocytes, thus guarded and in full vigor, attack and make way with the bacteria, which have lost their virulence and power for evil. In other words, if the production of the toxins of an infectious malady is not too rapid, all three of these agents may combine to overcome the enemy and not only to limit the disease but also to give subsequent immunity for a more or less prolonged period.

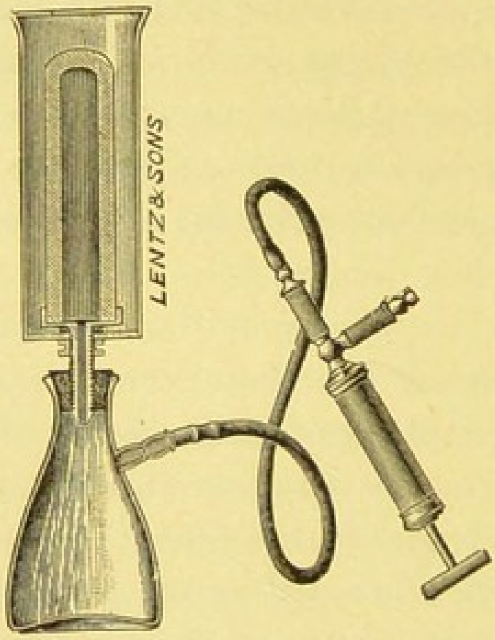
Nevertheless, experience will continue to show that, whether one or all of these theories may be finally accepted, or whether new methods by which the body protects itself may be discovered, sanitation and a condition of perfect health throughout the system are of the utmost importance in warding off attacks of or securing immunity from any of the pathogenic organisms, and in withstanding their ravages, should disease be incurred. A sound body, therefore, is a most vitally active and not a passive agent for the prevention of such diseases.

Within a comparatively short space of time the antitoxins have been discovered, tried, and apparently practically adopted by the medical profession of the civilized world as a safe and efficient means for the prevention or alleviation and cure of several of our most dreaded diseases. A short account of the usual methods of preparing them will, therefore, probably not be uninteresting.

In the first place, it is necessary that the toxin of the disease should be produced, which is commonly done by growing the specific organism in a peptone-bouillon.

When this has attained a powerful and definite virulency, as determined by the effect on small animals of known weight when inoculated with it, the organisms are destroyed by some germicide, such as trikresol, or more commonly the bouillon containing the toxins is filtered carefully to remove the germs. A small quantity, say one cubic

FIG. 10.



Filter for removing bacteria from fluid culture media.

centimetre, of the filtered bouillon is then injected into a large animal, such as the horse, which should be in good health and, preferably, should have been tested previously by inoculations of tuberculin and mallein to eliminate the possibility of the presence of tuberculosis or glanders. The animal manifests the disturbances peculiar to the disease in question for a few days, but usually in a minor degree, since the dose was quite small in proportion to its weight; as soon as recovery is evident, another inoculation of an increased dose is made, and so on until experiment shows that the animal can withstand practically an unlimited dose of the toxic bouillon and one which would have been quickly fatal before the first inoculation. This is evidence that the antitoxin exists in approximately sufficient degree in the blood-serum. A quantity of blood is then taken with the strictest antiseptic precautions from the jugular or other large vein of the animal, the latter returned to its quarters, and the blood set aside on ice to coagulate. This done, the clear serum containing the antitoxin is drawn off, and to it is added a small quantity of trikresol or other harmless preservative.

It is now necessary to determine the strength of the serum. The fatal dose of toxin for guinea-pigs is readily found by experiment. Behring, therefore, suggested, in the case of diphtheria antitoxin, that the immunizing unit be taken to be 1 c.c. of a serum of which 0.1 c.c. would prevent œdema and death in guinea-pigs when injected simultaneously with ten times the fatal dose of toxin. In other words, the immunizing unit was to be sufficient to overcome one hundred times the amount of the toxin required to kill a guinea-pig.

FIG. 11.

Roux aseptic hypodermic syringe for administering antitoxin.

The antitoxin serums now administered are, however, much stronger than this normal serum of Behring's, 10 c.c., the amount usually injected, containing from 600 to 2500 or even more immunizing units, the weaker strength being used for immunizing those who have not as yet incurred the disease. Much depends upon the early use of the specific antitoxin in cases of diphtheria, and probably also for the other diseases for which this method of treatment will be found valuable. It is not to be supposed that the remedy has any power to repair the organic lesions which have been caused by the action of the powerful toxins. That the antitoxin treatment is invaluable cannot be doubted. The statistics of Prof. Welch, of Johns Hopkins Hospital, founded on a very large number of diphtheria cases, "show an apparent reduction of case-mortality of 55.8 per cent.," and where the application was made in the first three days of the disease the mortality was only 8.5 per cent. in over 1100 cases, as against a mortality of 30 per cent. or more under former methods of treatment. Another interesting report is that of the Chicago Department of Health for 1896. In that city in that year there were 2436 cases of true diphtheria verified bacteriologically. The antitoxin was administered to 2302 of these, with a resultant mortality of only 6.56 per cent., or 151 deaths. Moreover, 2016 other persons exposed to the disease were inoculated with the antitoxin in order to immunize them, and of these only 14 subsequently contracted the malady, and none died. Further comment seems unnecessary.

Another practical method of securing immunity, advocated and employed by several noted investigators, is as follows: To produce, by cultivating the pathogenic bacteria under abnormal conditions, toxins of much less than normal virulence, and then, after filtration or sterilization of the latter in order to isolate them absolutely from the causative microbes, to make a series of inoculations of progressively increasing strength, and thus directly bring about a state of accommodation to or protection against the germ and its toxin without serious risk to the subject.

CHAPTER III.

THE ATMOSPHERE—AIR.

THE composition of the atmosphere surrounding the earth is remarkably uniform. It is practically always the same everywhere, provided no obstacle be interposed to the action of those natural forces by which this uniformity is maintained. This atmosphere is estimated to be about forty miles in depth, and its weight-pressure, of which we have a visible manifestation in the action of the barometer, upon the total surface of the adult human body is equivalent to that of about fourteen tons. Any considerable variation in this pressure may give rise to disturbances of health more or less serious, such as the cardiac derangements and "mountain sickness" experienced by strangers visiting high altitudes, or the "caisson disease" of those who work in a compressed atmosphere. In fact, it is not improbable that some of the vague disturbances of comfort to which a large class of persons are subject will hereafter be found to be due to the minor variations in this pressure which are constantly occurring everywhere.

The average composition of the air in its normal state is about as follows: Oxygen, 20.96 per cent. by volume; nitrogen and argon, 79 per cent.; carbon dioxide, 0.04 per cent.; aqueous vapor, the amount varying with the temperature; a trace of ammonia, and a variable amount of ozone, organic matter, sodium salts, etc. The variation in the percentage of oxygen may extend from 20.87 in towns to 20.98 in pure mountain air or far out at sea;

in the percentage of CO_2, from 0.02 to 0.05. So far as we know at present, the nitrogen variation is almost infinitesimal. The air is a mechanical, not a chemical mixture, and, as indicated, there is always some change taking place in the proportions of the various constituents. However, the mixture is maintained in its wonderful uniformity by the interdependent action of plants and animals, and by the diffusion of gases, the law of which is that "a gas expands into a space in which there is another gas as freely and as rapidly as if there were a vacuum." Though this agency, like the other, is continually operating, its results are greatly facilitated by adventitious air-currents and by the application of heat. When a gas is thus diffused it will not separate again from the others under ordinary circumstances.

Oxygen is the most important of the above constituents. It supports all animal life; oxidizes, destroys, and renders harmless organic impurities, and, by oxygenating the blood and oxidizing the food for our tissues, gives us heat and energy, the sources of all our thoughts and actions. The supply to the atmosphere is constantly maintained by the higher plant life, which decomposes carbon dioxide and gives off oxygen to the air. In man the greatest limit of life without oxygen or air is about four minutes. A decrease in the proportion of oxygen in the air does not manifest itself by untoward symptoms until there is less than 13 per cent. by volume ; then, as it falls lower and lower, the respirations become slower, deeper, and more difficult, less oxygen is absorbed by the blood, and there are dyspnœa, asphyxia, and death. This may occur within a short time when the percentage goes below 8 per cent., and asphyxia supervenes very rapidly when there is as little as 3 per cent. of oxygen.

The main function of the nitrogen of the atmosphere seems to be to act as a diluent and to prevent the too energetic action of the oxygen. We know now, however, that by the aid of certain bacteria at least one family of plants, the leguminosæ, is able to take nitrogen almost directly from the air and to store it up for animal use in the form of proteids. The ammonia ever present in the air is also a source of nitrogen for some plants.

The gaseous element, *argon*, recently discovered by Lord Rayleigh and Prof. Ramsay, comprises about 1 per cent. of what has heretofore been considered atmospheric nitrogen. Thus far little is known concerning it except that its atomic weight is probably somewhat less than 40, its density about 20, and that it is very inert, though Berthelot has succeeded in making it combine with nascent vapors of benzene under the influence of an electrical discharge. That it is a constant component of the atmosphere for some definite purpose is more than probable, but what this purpose may be is, as yet, unknown.

The carbonic acid present in pure air is of no direct use to animals, but is essential to the support of vegetable life, furnishing the carbon necessary for the formation of the carbohydrates and proteids, which are, next to water, the main constituents of plants. The proportion of carbonic acid in pure air varies somewhat from time to time, owing to the changing conditions. It is washed out of the air by rain, and there is, therefore, less after a heavy storm; plants absorb it by day, and some give off a slight quantity of it by night; the strata of the atmosphere near the ground receive an excess of it from the soil-air; it is a constant product of the decomposition of organic matter by saprophytic bacteria, etc. Though heavier than air, it is comparatively evenly distributed through the atmosphere by the force of diffusion.

The normal proportion in the atmosphere varies from 0.02 per cent. to 0.05 per cent., but we may take the average to be about 0.04 per cent. Should, however, any important tests of the amount in-doors be required, the percentage in the out-door air at that particular time and place should also be determined for the sake of accuracy. Within the limits just given the carbonic acid cannot be considered as an impurity of the atmosphere, for it is ever present in the air, and is as necessary to plant life as oxygen is to animals. It is derived from the combustion of carbonaceous materials, from the exhalations and excretions of animals and men, and, as was indicated, in large measure from the action of the saprophytic bacteria and also of the budding fungi upon organic matter. Moreover, any excess above the percentage given is to be regarded not so much as an impurity as an indication that certain processes are at work, which, by their products, may make the air impure and unsafe for human use.

The amount of aqueous vapor in the atmosphere varies constantly because the factors governing it—condensation and evaporation—are constantly in action, these depending, of course, mainly upon the continual variations in temperature. There is probably never a perfectly dry air, unless it is made so artificially, and precipitation occurs the moment the degree of complete saturation is exceeded. The range of relative humidity is probably from 30 per cent. to 100 per cent., this being equivalent, according to the temperature, to a water content of from one to twelve or fourteen grains to the cubic foot of air. The best proportion for health has not been experimentally determined, but is generally considered to be from 65 to 75 per cent.

In all normal air there is at least a trace of ammonia, either free or combined, a small amount of the salts of sodium (especially near the sea) and of other minerals, and a trace of organic matter. This last is part of the animal and vegetable débris of the earth ; when it rises above a trace it is to be treated as an impurity, as should any excess of ammonia.

Minute particles of almost every substance known are being constantly thrown off into the atmosphere, and it is only the unceasing action of nature's purifying powers that keeps the proportion within the limits of safety to the human race. Solid particles, lifted up by the winds, fall to the earth again, or, if organic, are partially oxidized and decomposed by the oxygen and ozone. The gases are diluted and diffused so as to be no longer harmful, or are decomposed, or are washed back to the earth by rain or snow. The great volume of carbonic acid is kept within bounds by the action of the vegetable world. The natural purifiers of the atmosphere, therefore, are the force of gravity, diffusion, dilution by the air itself, winds, oxidation, rain, and the action of plant life; and so exactly are these related to their work that never, when they have opportunity to act, does the composition of the air vary much from the normal for any great length of time.

The impurities in the atmosphere that are especially liable to have a deleterious influence upon health may be classed as follows: 1. Suspended matters. 2. Gaseous and semi-gaseous substances, including: 3. Those especially due to respiratory, combustion, and decomposition processes and which are particularly liable to contaminate the air of dwellings or inhabited apartments.

The most important suspended matters are sand, dust, soot, pollen of various plants, micro-organisms of all kinds, particles of epithelia, and other excreta thrown off from animal bodies, and dusts or finely divided substances characteristic of certain trades or industries. These may do harm by clogging up the air vesicles of the lungs, and thus obstructing respiration, though it is doubtful whether their action is ever so mild or simple; by their irritant action upon the respiratory passages; by being in themselves poisonous or hostile to the system, or, as in the case of micro-organisms, by the power they have in the causation of disease. Such germs may lodge in the respiratory passages to do their harm, or may be swallowed, and so cause maladies, such as typhoid fever or cholera, which primarily affect the digestive tract.

It is, however, questionable whether pathogenic organisms, especially the bacteria, are commonly to be found dissociated from other substances floating in the air. Experiments by Cornet and others seem to show that such microbes are apt to be adherent to dust particles, particularly those of organic nature, and it is probable that free bacteria could not long maintain their vitality in the outdoor atmosphere deprived of nutriment and exposed to the action of light and oxygen. Beside, they are so quickly diluted and reduced in numbers in proportion to any reasonable volume of air, that the occasions must be rare indeed when they could there cause disease. In-doors, especially where ventilation is neglected, the case is different, and there is no doubt that the air frequently becomes the carrier of the dangerous pathogens.

We must also make a distinction as to whether the other solid impurities are found in the out-door air or in enclosed spaces; and, if in the latter, whether in healthy dwellings, in sick-rooms and hospitals, or in workshops and factories. Out-of-doors, dust, sand, soot, pollen, waste dirt from dwellings, street refuse, and the remains of plant and animal life will predominate; in-doors the particles will be more limited in variety, but not in importance. Among them will be epithelium and other cells, possibly pus-corpuscles, hair, bits of clothing, upholstery, food, etc. One might also find arsenical or other poisonous dust from wall-paper or paint. In hospitals there will probably be pus-cells, mycelia, bacteria, etc. Mills, factories, and mines have their special atmospheres filled with particles peculiar to the materials or occupation, which have a marked effect for harm, in many cases, on the health of the workers.

The gaseous and semi-gaseous impurities of most importance are those resulting as products of human respiration and cutaneous exhalations, as products of combustion, peculiar gases from sewer- or soil-air, organic emanations and vapors from decomposing animal and vegetable matter, and the volatile substances that characterize the various atmospheres in and about gas-works, factories, and other industries. Chemically, they may be classified as the various compounds of carbon with oxygen or hydrogen, and of these with sulphur, and as ammonia compounds, volatilized minerals and mineral acids, and many gaseous and semi-gaseous matters of organic nature but indeterminate composition.

Inasmuch as certain of these impurities, viz., human exhalations, combustion products, and not infrequently the so-called sewer-gas, are particularly liable to be found together as contaminants of the atmosphere of inhabited rooms and dwellings, it will be advisable to consider them in a class by themselves, and to study their effect upon health both collectively and singly. The volatile excreta from the lungs and skin are carbonic acid, aqueous vapor, and a considerable amount of nitrogenous organic matter, to which the term "crowd-poison" is sometimes given. As products of combustion from the ordinary lighting and heating apparatus of dwellings we may have carbonic acid (dioxide), carbonic oxide (monoxide), sulphur dioxide, ammonia (with possibly its sulphide), and aqueous vapor. Of sewer-gas and soil-air we shall speak later.

Carbonic-acid gas, contrary to the general opinion, cannot be said to be directly poisonous or harmful to health in the proportions in which it is likely to be found in any dwelling or inhabited apartment. Although present to the extent of not over 0.05 per cent. in normal out-door air, numerous experiments indicate that both men and animals may inhale much larger proportions than this without apparent harm, provided the percentage of oxygen in the air be maintained at or above the normal; an increase of the carbonic acid from other sources than respiration and combustion seems to have no appreciable effect upon the system till it reaches more than 2 per cent., and many work daily in atmospheres containing almost this amount as a result of their peculiar occupations, and dyspnœa does not begin to occur, and then only in some, until the percentage goes above 3 or 4 per cent. In quantities above these figures there is much difference of opinion as to the effect of the gas upon the human economy, and the writer is not aware that it has ever been determined beyond question as to just what percentage is fatal. Prof. Parkes states the lethal proportion to be from 5 to 10 per cent.; while another states that animals may be kept for a long time in an atmosphere in which there is a high percentage of carbon dioxide, provided the percentage of oxygen be increased at the same time. Dr. Hime says that "it may be assumed that 10 or 20 per cent. is a dangerous amount,"[1] but Wilson[2] shows that air having from 25 to 30 per cent. may be inhaled with impunity. It is to be understood that the above percentages are all *by volume.*

According to his size, an adult man at rest absorbs from fifteen to eighteen cubic feet of oxygen and exhales from twelve to fourteen cubic feet of carbonic acid in twenty-four hours. Reichert[3] says: "The amount of O varies from 600 to 1200 grammes (15 to 30 cubic feet) per diem, and that of CO_2 from 700 to 1400 grammes (12.5 to 25 cubic feet)—approximate averages being about 750 grammes of O and 875 grammes of CO_2." The minimum excretion may, therefore, fairly be taken to be about seven-tenths of a cubic foot of carbonic acid for adult men and six-tenths of a cubic foot for women, or for each person of a mixed assemblage. Now, it is evident that it would require many hours before a room of, say, 1000 cubic feet capacity would lose enough oxygen to or gain sufficient carbonic acid from a single adult occupant to produce even the slightest apparent harmful results upon him, even though any ingress of fresh air were absolutely prevented; and yet experience tells us that long before the lapse of time necessary to thus add sufficient carbonic acid to do harm, the air of such a room will become exceedingly foul and actually harmful to health. Moreover, carbonic-acid gas is odorless, while the air of inhabited, unventilated rooms is characterized by a decidedly offensive smell that remains for some time, even after adequate ventilation has been secured and when chemical tests show the percentages of

[1] Stevenson and Murphy, vol i. p. 945.
[2] American Journal of Pharmacy, 1893, p. 561.
[3] American Text-Book of Physiology, p. 536.

carbonic acid to have been reduced to nearly the normal. "The chemical analyses of the air of over-crowded rooms, and the experiments upon animals made by many investigators, indicate that the evil effects observed are probably not due to the comparatively small proportions of carbonic acid usually found under such circumstances. . . . The proportion of increase of CO_2 and of diminution of oxygen which has been found to exist in badly ventilated churches, schools, theatres, etc., is not sufficiently great to satisfactorily account for the great discomfort which such conditions produce in many persons, and there is no evidence that such an amount of change in the normal proportion of these gases has any influence upon the increase of disease and death-rates which statistical evidence has shown to exist among persons living in crowded and unventilated rooms."[1]

Therefore, it must be something other than carbonic acid that dangerously pollutes the air of our dwellings and necessitates the provision of some system of ventilation. However, with our present knowledge, we cannot say that a diminution of oxygen and an increase of carbonic acid in the atmosphere which one breathes habitually does not tend to lower the general tone and perhaps the bactericidal powers of the body, and thus render it more susceptible to deleterious influences; and there is some evidence that as the carbonic acid in the atmosphere increases there is a lessening of the amount of this gas excreted from the body; so that, on general principles, it will be always wiser to use every reasonable means to maintain the normal proportion of the various gases in the atmosphere.

1 "The Composition of Expired Air and its Effect upon Animal Life," Drs. Mitchell, Billings, and Bergey, No. 989, vol. xxix., Smithsonian Contributions to Knowledge.

Aqueous vapor is another of the substances excreted continually from both the lungs and the skin, but it is obvious that, in itself, it cannot be directly harmful to the system, for we find it ever present in all natural atmospheres, and are continually replacing its loss from our bodies by imbibition. The quantity daily thrown off from the lungs and skin will depend on the temperature and humidity of the atmosphere, the quantity of air inspired and water imbibed, and many other factors, but under ordinary conditions the average excretion will be from 100 to 1700 grammes (about 3.5 to 60 fluidounces), though increased exertion might cause even the larger amount to be greatly exceeded. It is accordingly possible that this large quantity of moisture, tending to saturate an atmosphere already humid, might act indirectly upon the system by preventing evaporation from the skin, and thus reflexly checking the excretion of the waste matters by the sweat-glands, the retention of these wastes in the system probably helping to produce the depression, headache, and other symptoms experienced by those breathing foul air. It has been noticed that these symptoms due to foul air are more readily manifested when the temperature of the atmosphere is much below or much above the usual room temperature of 65° to 70° F. At low temperatures it is easy to saturate the air, and beside, the excreting action of the skin is much lessened by the cold; at high temperatures the humidity is often already near the saturation point, while the external heat tends to increase the quantity of water given off by the lungs and skin. "At high temperatures the respiratory centres are affected where evaporation from the skin and mucous surfaces is checked by the air being saturated with moisture—at low temperatures the consumption of oxygen increases, and the demand for it becomes more urgent."[1] At 70° F. the aqueous vapor from an adult body would completely saturate from 350 to 600 cubic feet of air having the not unusual relative humidity of 75 per cent., while at 80° F. an equal or even greater volume would doubtless gain its maximum of moisture from the increase of perspiration due to the extra heat.

The third contaminant given to the air from human bodies is an indefinite volume of offensive organic matter, and until quite recently this has been looked upon as by far the most harmful part of animal exhalations. But lately a number of experiments by various investigators have seemed to indicate that this organic effluvium is not so dangerous as it has hitherto been considered, and that part, at least, of the symptoms due to air vitiated by respiration is to be attributed to the conditions already mentioned, viz., a decrease of oxygen and an increase of carbonic acid, heat, and moisture. It is also doubtful whether much, if any, of this organic matter comes from the *lungs* of healthy persons. "In ordinary quiet respiration, no bacteria, epithelial scales, or particles of dead tissue are contained in the expired air. . . . The cause of unpleasant, musty odors in rooms may in part be due to volatile products of decomposition from decayed teeth, foul mouths, or disorders of the digestive apparatus, and in part to volatile fatty acids given off with or produced from the excretions of the skin, and from clothing soiled with such excretions."[2] However, whatever may be the exact source of this contamination, we know this concerning it,—that it is decidedly offensive to the sense of smell, that it is organic and nitrogenous, yielding ammonia, darkening sulphuric acid, decolorizing permanganate of potash, and

[1] Drs. Mitchell, Billings, and Bergey, loc. cit.

[2] Ibid.

rendering offensive pure water through which vitiated air has been drawn. Moreover, it must in fairness be stated, that, in spite of the later experiments, it has seemed to such careful investigators as Brown-Séquard, D'Arsonval, Merkel, and others, to be directly poisonous to lower animals. In general, it is given off proportionately with the carbonic acid from the body, though this rule is not infallible; it is apt to be unevenly distributed throughout the atmosphere of the apartment, and is probably, therefore, not truly gaseous, but more like an impalpable dust; it oxidizes but slowly, being evident for some time after fresh air has been admitted and the carbonic acid has been almost reduced to the normal, and, while neither condensed nor dissolved in the aqueous vapor from the body, it is especially attracted and retained by hygroscopic substances, such as wool, paper, feathers, etc. Its smell is generally perceptible when the respiratory carbonic acid reaches 0.03 or 0.04 per cent., sometimes before this point is reached, especially in sick-rooms or hospital wards, and is decidedly offensive when the total carbonic acid approaches 0.1 per cent.

The most important of the impurities resulting from the combustion of coal, the principal fuel substance, are soot and tarry matters (to the extent of 1 per cent. of the coal consumed), carbon monoxide and dioxide, aqueous vapor, and more or less ammonium sulphide, carbon disulphide, hydrogen sulphide, sulphur, sulphur dioxide, and sulphuric acid. The relative amounts of the oxides of carbon—as well as of the other gases—will depend upon the perfection of combustion; "but it has been calculated that for every ton of coal burnt in London something like three tons of carbon dioxide are produced," and as that city's coal consumption is over 30,000 tons per diem, we can see that its atmosphere must receive the enormous daily contamination of 300 tons of soot and 90,000 tons of carbonic acid. No wonder they have an *occasional* fog there!

The combustion products of wood are in the main simply carbon monoxide and dioxide, and water, while those of coke and of gas are practically the same as of coal. From our heating apparatus, if properly constructed and arranged, these products pass off almost directly to the exterior of our dwellings and are rapidly dissipated, in spite of their excessive volume, for "diffusion and the ever-moving air rapidly purify the atmosphere from carbon dioxide," and, in fact, from the others also, with the exception of the soot and tarry products.

Should, however, combustion be incomplete, or should the stoves or other heaters be imperfect, the gases may seriously or even dangerously contaminate the house-air, the deadly carbon monoxide being particularly liable to leak not only through the crevices but actually through the heated cast-iron plates, etc., of stoves and furnaces. Theoretically, a pound of coal requires 160 cubic feet of air for its complete combustion, but practically from one-half to as much more must be supplied.

On the other hand, practically all the devices for artificial illumination, with the exception of the incandescent electric light, give off their combustion products, which are much the same as those from coal, directly to the air which surrounds them, and this contamination is, consequently, a positive factor in the vitiation of in-door air. "Every cubic foot of coal-gas yields, on combustion, roughly, half its own volume, or 0.52 cubic foot, of carbon dioxide, and 1.34 cubic foot of water vapor," beside some little carbon monoxide when ordinary burners are used. "Speaking generally, it may be said that each cubic foot of gas burnt per hour from the ordinary burners vitiates as much air as would be rendered impure by the respiration of an individual; it, at the same time, will raise the temperature of 31,290 cubic feet of air 1° F., and yields 217 calories (a kilogramme of water heated 1° C.) or 860 British heat-units (a pound of water heated 1° F.)."[1]

The following table[2] will indicate the influence of various lighting agents with respect to the condition of the room-air:

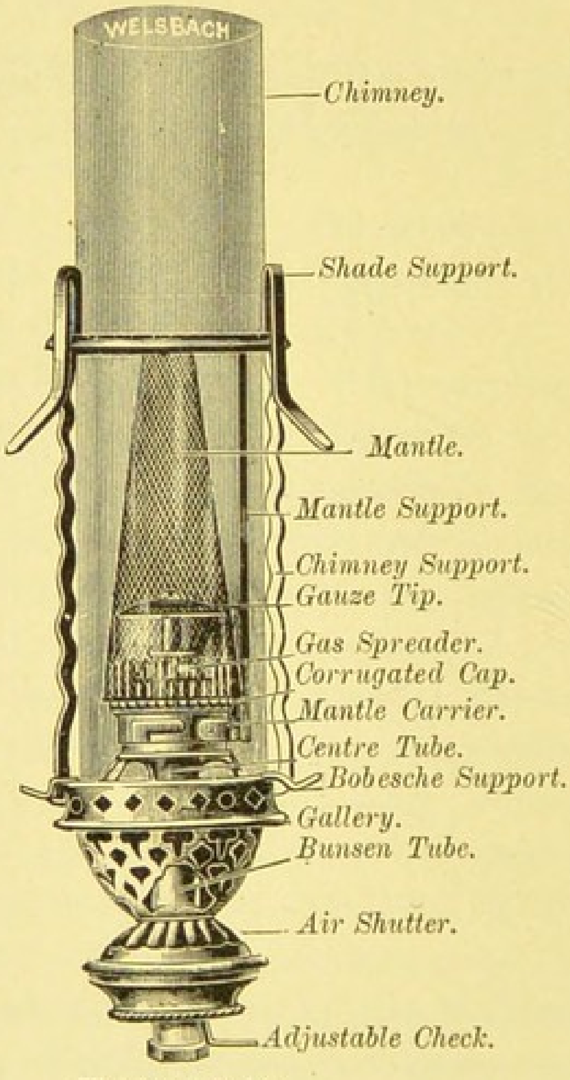
	Quantity consumed.	Candle power.	Oxygen removed.	CO_2 produced.	Moisture produced.	Heat calories produced.	Vitiation equal to adults.
			Cu.ft.	Cu.ft.	Cu.ft		
Tallow candles	2200 grains	16	10.7	7.3	8.2	1400	12.0
Sperm candles	1740 "	16	9.6	6.5	6.5	1137	11.0
Paraffin oil lamp	992 "	16	6.2	4.5	3.5	1030	7.5
Kerosene oil lamp	909 "	16	5.9	4.1	3.3	1030	7.0
Coal gas, No. 5, batwing burner.	5.5 cu. ft.	16	6.5	2 8	7.3	1194	5.0
Coal gas, Argand burner	4.8 " "	16	5.8	2.6	6.4	1240	4.3
Coal gas, regeneration (Siemens) burner.	3.2 " "	32	3.6	1.7	4 2	760	2.8
Coal gas (Welsbach incandescent).	3 5 " "	50	4.1	1.8	4.7	763	3.0
Electric incandescent light	0.3 lb. coal	16	0.0	0.0	0.0	37	0.0

From this table it will be learned that the incandescent light is the most satisfactory from a hygienic point of view, and there is no doubt that its very general introduction of late has done much toward removing a constant source of vitiation, especially in those rooms of buildings which require much artificial light, and are at the same time

[1] Notter and Firth: Treatise on Hygiene, p. 140. [2] Ibid., p. 141.

difficult to ventilate. It is said that in a large bank in London, in which several hundred persons are employed, the absences on account of illness have been so far reduced, apparently by the introduction of the incandescent electric light, that the extra labor gained has more than paid for

FIG. 12.



Welsbach light.

the increased cost of lighting. The electric arc light is said to form nitric acid; but even so, its effects are not so harmful as those of the ordinary gas-burner, or lamp, or candle. Next to the incandescent electric light in importance are the Welsbach and Siemens gaslights; but of these the latter has not the illuminating power, nor is it so fitted for house use as is the former. The Welsbach light makes use of the Bunsen flame (in which, by the way, the carbon of the gaseous fuel is completely consumed and converted into carbonic acid) to render incandescent a non-combustible mantle or network, made of the salts of certain rare earths which have the property of becoming intensely luminous when sufficiently heated. It gives a very white light of great illuminating and considerable actinic power, and of practically unvarying intensity. In fact, this quality of steadiness, in which it surpasses even the incandescent electric light, is by no means the least of its hygienic advantages, since such steadiness is an important factor in the conservation of the eyesight.

Sewer-Gas and Soil-Air. What is commonly called sewer-gas is but a mixture of a number of gases, such as carbonic acid, carburetted hydrogen, ammonium and hydrogen sulphide, nitrogen, etc., together with a considerable amount of fetid organic matters, the volatile or semi-volatile products of animal and vegetable decomposition, varying according to the condition of the sewer, the kind of matter received therein, the amount of surplus water, etc. The air from a closed cesspool may be extremely foul and poisonous, so much so that the emanations have not infrequently brought death to those who inhaled them in full concentration; on the other hand, the atmosphere of a properly constructed and well-flushed sewer may be almost as pure as that above the surface. Bacteria are present in varying numbers, with always the possibility of some of them being the germs of specific diseases. But fresh sewage is not so likely to contaminate the air above it with these microbes as that in which decomposition has begun, since Frankland has shown that solid or liquid particles are not liable to be scattered into the air by any disturbance the sewage is likely to be subjected to until gases of decomposition are produced. The bursting of bubbles of the gas on the surface may then throw the bacteria into the sewer-air. It has also been shown that "bacteria can undoubtedly grow up the sides or walls of damp nutrient sewers, and if these latter become at all dry, air currents readily detach and disperse them."

Another class of impurities that may at times be found in the air of dwellings are those coming from the soil and soil-air. The *soil*, in hygiene, refers to all that portion of the earth's crust that can in any way affect the health. All soils contain more or less air—soft sandstones from 20 to 40 per cent., loose sands from 40 to 50 per cent., and loose soils often many times their actual volume of air.

As the soil is the recipient of most of the solid and liquid waste of all animal and vegetable life, and as the myriads of saprophytic bacteria that inhabit its upper strata are constantly working to convert this dead organic matter into simpler compounds suited to the nourishment of plant-life, the soil-air, taking the atmosphere above as a standard, will usually be far from pure. It is rich in carbonic acid and in organic vapors and gases, while the proportion of oxygen seems to be always less than that of the air above-ground. Moreover, the carbonic acid increases and the oxygen decreases the deeper below the surface the sample is taken. As much of the carbonic acid evidently is derived from the organic pollutions, it might be supposed that this gas could be taken as an index of the degree of the latter, and so it might if other conditions, such as permeability of soil, rate of circulation, etc., were always the same. But they are not, and so the composition of the soil-air is practically not the same for any two places, nor for the same place at different times. It is constantly in circulation, even to a considerable depth, but there is a hinderance to its free movement and diffusibility, and this, together with the great variation in the distribution of oxidizable and other contaminating matters, causes the variations in its composition. The carbonic acid, therefore, cannot be taken as an index of the relative purity. Owing to evaporation from the ground-water, the soil-air is always quite humid, and, according to some writers, may also be laden with bacteria and other light substances lifted up by the ascensional powers of evaporation.

The forces that maintain the circulation of the ground-air are the wind, the daily change of surface temperature, the fall of rain, and, especially in winter, the local and artificial conditions of civilization. A very slight wind will drive the air through the soil for long distances, the rise and fall of the ground-water has its obvious effect, and the movement due to even slight changes of temperature is likely to be quite extensive and positive.

As sewage, house-wastes, and dirt of all kinds are particularly liable to contaminate the soil about any used dwelling, the air of that soil will be more than likely to be impure, and care must be taken that it is not drawn up into the house. This is especially apt to happen in cold weather when the house fires are lighted and the indoor air is thus made much warmer than that outside, the tendency then being for the soil-air to pass, if possible, through the cellar walls and floors. These should be made as near air-tight as possible, and special attention should be given to the space underneath and about the furnaces. As an instance of the importance of these precautions, Dr. Hime[1] gives an account of the fatal poisoning of four persons. Sufficient illuminating (coal) gas was drawn through fifteen feet of soil and the foundation walls of the dwelling from a broken pipe, although there were only eight or ten inches of tramped earth above the latter and the only aspirating force was the difference of temperature within and without the house.

There is no direct evidence that the emanations from bone-yards, soap-factories, garbage-incinerators, etc., are really harmful to health, but they may be very decided nuisances to those living near by, and all such places should be properly controlled by the proper sanitary authorities.

The atmosphere of mines and other excavations is subject to contamination by the excess of carbonic acid in the soil-air, by gases from fissures in the rock and from blasting agents, and by the products of respiration from men and animals working in the mines, etc. The air in the holds of ships is also likely to be foul, owing to the difficulty of changing it sufficiently often, and frequently also to the insanitary character of the cargoes. In such cases proper ventilation should be secured by all means available, and special care taken that the impure air does not affect passengers or crew.

Diseases Caused by Impure Air. As a rule, the human system has the power of accommodating itself, through habit, to withstand influences which, in one unaccustomed to them, would soon produce serious results. But in spite of this, if the body be exposed for any considerable length of time to conditions of impurity or deterioration in its supply of air, water, or food, such conditions

[1] Stevenson and Murphy : Treatise on Hygiene, vol. i. p. 949.

will always tend to undermine health and increase the susceptibility to disease, even though they cause no more serious results. "Statistical inquiries on mortality prove beyond a doubt that of the causes of death which are usually in action, impurity of the air is most important. No one who has paid any attention to the condition of health, and the recovery from disease of those persons who fall under his observation, can doubt that impurity of the air marvellously affects the first, and influences, and sometimes even regulates, the second. . . . The air may affect health by variations in the amount or conditions of its normal constituents, by differences in physical properties, or by the presence of impurities. While the immense effect of impure air cannot be for a moment doubted, it is not always easy to assign to each impurity its definite action. The evidences of injury to health from impure air are found in a larger proportion of ill health—*i. e.*, of days lost from sickness in the year—than under other circumstances; an increase in the severity of many diseases, which, though not caused, are influenced by impure air, and a higher rate of mortality, especially among children, whose delicate frames always give us the best test of the effect of food and air."[1]

The definitely marked diseases caused by the solid impurities in the atmosphere are almost all such as affect the respiratory passages and organs, with the possible exception of those engendered by specific bacteria and other minute organisms. Much, therefore, depends upon the physical character of the dust and solid impurities. Soft particles and those with edges smooth and rounded, like soot and coal-dust, may apparently do nothing more

[1] Stevenson and Murphy: vol. i. pp. 121 and 122.

than clog up the air vesicles and finer bronchial tubes, and in this way diminish the area of lung tissue exposed to the inspired air, although it is questionable whether any foreign matter in the lungs does not cause more or less actual irritation. With most of us, however, such impurities are of little account if pains be taken to develop the full respiratory capacity of the chest; but where the air is heavily charged with such dust, it has a real effect upon health and duration of life. In 1862 Sir John Simon stated that with one exception "the 300,000 (coal) miners of England and Wales break down as a class prematurely from bronchitis and pneumonia, caused by the atmosphere in which they live. The exception is important. The colliers of Durham and Northumberland, where the mines are well ventilated, do not appear to suffer from an excess of pulmonary diseases, or do so in a slight degree only." Happily, since this was written satisfactory ventilation systems have been placed in most of the collieries of Engand, and the condition of the miners correspondingly improved; but coal miners are still, as a class, particularly liable to bronchitis, pneumonia, asthma, emphysema, and fibrosis (fibroid phthisis), though they seem to be but slightly subject to tuberculosis of the lungs or other organs.

On the other hand, if the particles of dust in the air are hard, angular, and sharp, the lung-tissues are readily lacerated, inflammatory processes are quickly set up, and the opportunity for the inoculation of tubercle bacilli and other disease-germs is very great. The mortality from tubercular phthisis among metal miners, needle-cutters, steel- and tool-grinders, cotton-spinners, etc., is remarkable; though they are also especially subject to asthma and emphysema. Among Cornish tin miners, 68 per cent. of all sick are consumptive; of needle-makers, over 60 per cent.; of flint- and glass-cutters and polishers, and of grindstone makers, from 80 to 90 per cent., etc. It is said that a mixture of minerals and metallic dust seems to be more harmful than metallic dust alone, perhaps because of the increased clogging of the air-vesicles by the mineral matter.

Likewise, with other occupations where there is much irritative dust floating in the air, the effect upon the health of the worker is marked, and we will find lung troubles prevalent and many sick and dying from phthisis, as, for instance, among cotton-spinners, flax- and hemp-dressers, pottery-makers, etc. Bad ventilation, accumulations of noxious gases, improper habits, insufficient disinfection of sputa, and often the excessive humidity of the air necessary in some of these pursuits, doubtless have something to do with the high sick- and death-rates, but withal, the marked effect of the solid atmospheric impurities cannot be denied.

Again, workers in poisonous metals, compounds, or gases, such as paintmakers and painters, type-setters, gilders (using mercury), brass-founders, and coppersmiths, etc., are subject to the respective poisons and the symptoms produced by them, with a correspondingly increased mortality.

Among the diseases that may be caused by the inhalation or swallowing of specific micro-organisms floating in the atmosphere are erysipelas, measles, scarlet-fever, diphtheria, whooping-cough, infectious pneumonia, phthisis and other forms of tuberculosis, and very probably epidemic influenza; and, although the germs of cholera, typhoid fever, and yellow fever are usually carried by the drinking-water or food, they do sometimes find their way into the system from a contaminated atmosphere. Malaria also is now practically proven to be due to a minute organism, which, though not one of the bacteria, and though usually introduced by the mouth with the drinking water, is undoubtedly often present in the air of malarial districts, and may be carried long distances thence by the winds.

Lastly, the spores of certain fungi, which have been found in the air of hospitals and elsewhere, are known to cause skin diseases, such as the tineas and favus in men; and it is almost as certain that the irritating or poisonous pollen of certain grasses and other plants have much to do with the causation or aggravation of such maladies as hay- and rose-fever.

From what has already been said, it will be surmised that it is scarcely possible, at present, to specify the exact effect upon the health of each of the impurities given to the air by the human body, and that the symptoms observed to be due to air thus vitiated are very probably an evidence of the combined action of these factors rather than of any one of them singly. However, the writer feels that the headache and oppression so commonly experienced are often fairly attributable to the increase in the temperature and humidity; that the disturbed nutrition and febrile condition, lasting for hours and sometimes days after exposure to air thus vitiated, are either effects of the organic matter acting as a poisonous waste when taken into the system, or results of the suppression of cutaneous excretion dependent upon the high content of moisture in the air; and that the respiratory carbonic acid in itself can but rarely have much influence upon comfort or health.

If the respiratory and cutaneous vitiation be sufficient to produce any acute effects, the immediate symptoms will be a discomfort and sense of oppression, followed by headache and not rarely nausea and a rather decided rise of temperature, all three of which may last for some time, even after going into perfectly pure air. Those who habitually live in such an atmosphere are almost uniformly languid, pallid, and anæmic, subject to headaches, nausea, and loss of appetite, and often to skin eruptions and disorders, and are undoubtedly markedly predisposed to phthisis, pneumonia, bronchitis, scrofula, rachitis, etc. Moreover, such an atmosphere apparently favors the rapid spread, increases the severity of and retards the convalescence from such diseases as diphtheria, scarlet fever, measles, typhus, smallpox, etc. This may be due either to the accumulation or to the actual multiplication by growth of the disease germs in the foul air, or to its causing a decrease of bodily resistance and an increase in predisposition to such maladies.

When the proportion of impurities is very great, the results may be very serious and even fatal, as in the well-known cases of the "Black Hole of Calcutta;" of the prison in which 300 captives of war were crowded after the battle of Austerlitz (260 dying very soon after being placed therein), and of the steamer "Londonderry," in which, of 200 steerage passengers who were temporarily crowded into a cabin (18 x 11 x 7 feet) during a storm, seventy-two were dead and others dying when the cabin was opened.

As regards the influence of combustion-products on health, it will suffice to detail the symptoms produced by the inhalation of the various gases. It will be difficult to show that these gases, together with the coincident soot, have any general effect upon health when escaping into the out-door atmosphere, even when produced in such enormous quantities in cities as has been already indicated. It is possible that the sulphur dioxide and other sulphur gases might favor or aggravate attacks of bronchitis or asthma in those living in the vicinity of gas-works, chemical factories, etc., but too little comes from ordinary chimneys to do much, if any, harm.

In-doors the case is different, for the gases from lights and fires become more and more concentrated as the ventilation is insufficient. The possible effects of varying percentages of carbonic acid have been noted. We have no evidence of cases of chronic poisoning by this gas, although, as Parkes says: "The presence of a very large amount of CO_2 in the air may lessen its elimination from the lungs, and thus retain the gas in the blood, and thus in time possibly produce serious alterations in nutrition."

In cases of acute poisoning by this gas—*i. e.*, where it is in great excess in the atmosphere—there is an almost immediate loss of muscular power, and the person may be unable to remove himself from the place of danger, while others who go to help him may also succumb and more than one be asphyxiated. Consequently, volunteer rescuers should remember to act with coolness and great rapidity, and always to provide means for the prompt removal not only of the one they would save, but of themselves. Fortunately, when one who has been overcome by carbonic acid is brought into an atmosphere of pure air before life is extinct and is aided by artificial respiration, he usually recovers rapidly and completely.

Cases of poisoning by carbon monoxide are much more serious. Recovery from its effects is slow and uncertain, because this gas unites with the hæmoglobin of the red blood-corpuscles, paralyzing them, as it were, and rendering them unable longer to act as oxygen carriers to the tissues; while the union of carbon dioxide with the blood is always an unstable one and readily broken as soon as an interchange with a normal atmosphere is available. Less than one-half per cent. of carbon monoxide in the air has caused symptoms of poisoning, and more than one or two per cent. is quickly fatal to animals. "It appears that the gas, volume for volume, completely replaces the oxygen in the blood, and cannot again be displaced by oxygen, so that the person dies asphyxiated; but Pokrowsky has shown that it may be gradually converted into carbonic dioxide and be got rid of."

The symptoms of carbonic oxide (monoxide) poisoning are feebleness, oppressed breathing, trembling, and inability to swallow; then "loss of consciousness, destruction of reflex action, and finally paralysis of the heart." "Hirt says that at high temperatures (25° to 32° C.= 77° to 90° F.) it produces convulsions, but not at low temperatures (8° to 12° C.=46° to 54° F.)." The blood and muscles are made a brilliant red by this gas, darkened by carbon dioxide. Claude Bernard says that a mixture of these two gases is more destructive than either separately, probably because it interferes with the conversion of the monoxide to the dioxide in the blood, as was shown by Pokrowski.

Illuminating or coal-gas—composed of hydrogen, light and heavy carburetted hydrogens, a little nitrogen, and carbonic acid, and from 5 to 7 per cent., or even more, of the carbon monoxide—rapidly causes, when inhaled, giddiness, headache, nausea and vomiting (?), confusion of intellect, loss of consciousness, general weakness and depression, partial paralysis, convulsions, and the usual symptoms of asphyxia. Mixed in large proportions with the air, death may ensue comparatively quickly, probably because of the large content of carbon monoxide; and it is well to remember that the so-called water-gas, now so extensively manufactured for fuel purposes and also for diluting coal-gas, contains a much larger percentage of carbon monoxide (sometimes from 30 to 40 per cent.) than the latter, and that the symptoms resulting from its inhalation will be in all likelihood more marked, more rapid, and more deadly than with the undiluted coal-gas.

"The effects of constantly inhaling the products of gas combustion may be seen in the case of workmen whose shops are dark, and who are compelled to burn gas during a large part of the day; the pallor, or even anæmia and general want of tone, which such men show, is owing to the constant inhalation of an atmosphere so impure."

Sulphurous acid gas (SO_2) and sulphuretted hydrogen (H_2S) are each fatal to life, the latter when in a comparatively concentrated state; but they are offensive and irritating to the senses, and thus give warning of their presence, so that there is less danger of their causing serious results. Men can accustom themselves to much larger proportions of sulphuretted hydrogen in the atmosphere than can animals, but continued exposure to it is liable to give rise to vertigo, headaches, slow and weak pulse, sweatings, and loss of strength.

When sewer-gas or soil-air escape into the outer air they are usually soon diluted beyond any power for harm; but if either gains access to closed rooms or unventilated dwellings, its effects upon the inmates is depressing and decidedly bad. In either case, concentration of the impurities may cause acute symptoms, such as vomiting, purging, severe headache and prostration, and either soil-air or sewer-gas may at any time carry the germs of infectious diseases. Their influence, however, is usually insidious, owing to dilution with the house-air, and the more common symptoms will probably be pallor, languor, frequent headaches, loss of appetite, diarrhœa, impaired health, and often chronic anæmia. Children especially suffer in nutrition, and with them febrile attacks may be frequent; but with all the power of resisting such diseases as typhoid fever, diphtheria, etc., is lessened and the susceptibility to them increased, the sickness more severe, and the convalescence more prolonged. Indeed, sewer-gas and soil-air probably aggravate all diseases.

In this connection Alessi has shown that when small animals, such as rabbits, rats, and guinea-pigs, have been exposed to sewer-air for some days, by far the larger majority when inoculated with only a small quantity of a slightly virulent typhoid culture contract the disease and die, while almost none of those treated similarly in every way excepting by the exposure to sewer-air, succumb. He also showed that the inoculations were more deadly when the previous exposure to the noxious gas had been less than two weeks than when it exceeded that period, indicating that persons accustomed to such contamination are not apt to manifest the symptoms due to it so rapidly or so seriously as are those who experience it for the first time, a fact well known to all observers.

"There is undoubtedly a poisonous agency at work when sewer-gas is inhaled, which, though it may not directly act, yet so prepares the soil that the system is unable to resist the invading organism when it comes."[1]

[1] Notter and Firth, p. 159.

CHAPTER IV.

VENTILATION AND HEATING.

As we are not usually able practically to destroy the impurities of the atmosphere as fast as they are produced, we have recourse to ventilation as a means for their dilution and prompt removal. We must not think, however, that we do all that is necessary if we only renew the air within our dwellings, for unless the source and supply from which we take that which is to replace or dilute the vitiated air be pure and clean, any system of ventilation which we may adopt will be of little value.

External ventilation of our buildings, streets, and cities is of importance, then, as well as that which relates only to the interior of our dwellings, workshops, and places of assembly. Numerous investigations and statistics, both here and abroad, show that "the health of a town largely depends upon the width of the streets, the general height of the buildings, and the amount of yard space at the rear of each which separates it from its opposite neighbor." It is also hard to overestimate the value of wide streets, numerous diagonal ones, and frequent parks or open spaces, especially in the most thickly inhabited portions of a city. In this connection I may refer with advantage to some work of Dr. H. S. Anders, of Philadelphia, in which he shows that "the number of deaths from phthisis on a very wide street is proportionately small compared with those on almost any one narrow street," and "that there is plainly and generally a high mortality rate from consumption associated with street narrowness in not a small part of Philadelphia, and that the relation between a high mortality and narrow streets is a positive and vital one." His statistics, covering a period of fifteen years, show that in one city ward, certainly favored as to location, the ratio of deaths from phthisis per square or block on streets over to those on streets under forty feet in width, was approximately as 3 is to 5.

As regards *internal* ventilation, it will be well to determine at the outset the meaning and limitations of the term. Parkes says: "It will be desirable to restrict the term ventilation to the removal or dilution, by a supply of pure air, of the pulmonary and cutaneous exhalations of men, and of the products of combustion of lights in ordinary dwellings, to which must be added, in hospitals, the additional effluvia which proceed from the persons and discharges of the sick. All other causes of impurity of air ought to be excluded by cleanliness, proper removal of solid or liquid excreta, and attention to the conditions surrounding dwellings." With the function of ventilation thus limited, it will not be necessary to make provision for such an abundant supply of pure air as might otherwise seem advisable. It is evident, also, that the purity of in-door air must almost always be relative and not absolute, especially in a climate like ours, which, for a considerable portion of the year, necessitates the warming of the air and some consequent economy in its use.

It seems strange that more attention has not been given to the possibility of purifying a vitiated atmosphere by means of fire rather than by the removal or dilution of the impurities, especially as we so often employ heat as an agent to destroy or alter the harmful qualities of other substances intimately concerned with our welfare. The objection that many would offer at first thought to such a plan is that the fire would rob the air of all or most of its oxygen, but a little calculation and consideration will show that this is by no means a necessary result, and that a proper apparatus might actually require but comparatively little of this gas and give off but little carbonic acid as a combustion product to the atmosphere. So far as the writer knows, but one device on the market has this function professedly embodied in it, and it apparently does what is claimed for it in this respect. The possibilities of the suggestion invite further investigation.

To discover the quantity of air desirable and consistent with the requirements of good ventilation and the non-interference with health, two factors must be determined: (*a*) The extent to which the air of a room is contaminated in a given time by the impurities it receives, and (*b*) the limit of permissible impurity beyond which there will be a possible risk or detriment to health. In accordance with the above limitations of Parkes, the contaminating substances will usually be comparatively few in number, but the same rules are to be applied in the case of any detrimental substances in the atmosphere at any time, provided their source or cause cannot be directly removed.

Although it is extremely difficult to determine quantitatively the organic matter given off by human exhalation in any given time, the carbonic acid, as has already been stated, is usually given off in a reasonably constant ratio with it, and can, therefore, be used as an *index* of the amount contaminating the air. Taking Pettenkoffer's figures, viz., 0.6 cubic feet of carbonic acid per hour per head for a mixed assemblage at rest, 0.7 cubic feet for adult males, and increasing amounts according to the physical work done, which have been substantially confirmed by other investigators, we have the first factor (*a*) of our problem determined for all cases where the products of respiration are the only contaminants.

In establishing the limit of permissible impurity—the second factor (*b*)—it will naturally be advisable to require that the supply of air from without shall be sufficient not only to be thoroughly consistent with health, but that there may be no perception of impurity by the senses, the air of the room remaining apparently as fresh and pure as that out of doors. To this end Dr. de Chaumont made a large number of observations (over 450), and found that as long as the carbonic acid due solely to respiratory impurity did not exceed 0.02 per cent., the in-door air did not differ sensibly from that without, but that when the respiratory CO_2 reached 0.04 per cent., the air was rather "close," and the organic matter was becoming perceptible to the sense of smell. Subsequent investigations have shown that as long as the respiratory CO_2 does not exceed 0.02 per cent. it has no perceptible effect upon the health; consequently, we may take this amount of carbonic acid over and above the amount normally present at the time in the outer atmosphere as our limit of permissible impurity in inhabited apartments.

Having now the two factors of our problem, it becomes a simple matter of proportion to determine the amount of fresh air to be supplied to each individual, provided there are no other sources of contamination. The equivalent of 0.02 per cent. is 0.0002 of a cubic foot of carbon dioxide in each cubic foot of air. In a mixed assembly each person exhales 0.6 cubic foot of carbon dioxide per hour. Consequently, to dilute this respiratory CO_2 properly, each person will need $\frac{0.6}{0.0002}$ or 3000 cubic feet of fresh air per hour. If the individuals are all adult males, or if they are working, there must be a corresponding increase in the air supplied, running up to 6000 or even 9000 cubic feet or more per head in certain laborious occupations. This is the theoretical amount necessary for good ventilation, but in practice we find that we can get along with safety and comfort with somewhat less fresh air, because some of the bodily impurities are at once carried away and out of the room by the draughts through the exits, or through cracks and crevices in the walls and ceiling which act as exits, and the incoming air does not, therefore, have to mix with and dilute that portion of the impurities that is so immediately removed. In other words, if 10 per cent. of the vitiation is thus directly removed, 10 per cent. less of pure air is needed to dilute the remaining contaminants to the limit of permissible impurity; but as the quantity and the consequent velocity of the incoming or of the outgoing air diminishes, less and less of the impurities are thus directly removed, and experience teaches that almost the full theoretical amount of fresh air is needed in practice to secure satisfactory results.

Provision must also be made for sufficiently diluting the impurities from other sources of vitiation whenever they are present. Although combustion products are not usually as dangerous as impurities from the human body, and though they are generally massed near the top of the room, we should provide at least 1800 cubic feet of air for each cubic foot of gas burned, and ten times as much for each pound of oil consumed.

In sick-rooms and hospitals an exception must also be taken to the equation in which 0.02 per cent. of carbonic acid is taken as the permissible respiratory impurity, for it is found that the organic matter exhaled from the sick is much more offensive than that from the healthy, and is noticeable to the senses when the respiratory CO_2 is much below 0.02 per cent. So, one-fourth or more of fresh air at least must be added to the usual amount to be supplied to the healthy, and the rule is to give the sick as much as possible, provided it be properly warmed and distributed.

The use of the following formula will often be advisable in solving problems relating to ventilation, viz.: $\frac{e}{r} = d$, where e represents the amount of carbonic acid exhaled in the given time, r the respiratory CO_2 in parts per cubic foot, and d the delivery or volume of fresh air in cubic feet. Example: What will be the respiratory impurity in the air of a room of 3000 cubic feet capacity which has been occupied by three men for two hours, supposing that there has been an ingress of 9000 cubic feet of fresh air in that time? Here $e = 0.7 \times 3 \times 2 = 4.2$, and $d = 3000 + 9000 = 12{,}000$. $\frac{4.2}{r} = 12{,}000 : \frac{4.2}{12{,}000} = r = 0.00035 = 0.035$ per cent. CO_2.

Before considering the means by which a sufficient quantity of pure air may be supplied to buildings and apartments, it will be well to note the following restrictions as to the size and height of the rooms. If a room be too small, the air therein will have to be changed often, the velocity at the inlets will be increased, uncomfortable draughts will be created, and the air will not diffuse itself so thoroughly throughout the room. Experience shows that even when the air is properly warmed it cannot be changed much oftener than three times an hour without discomfort to the occupants of the room, unless the ventilating apparatus be very perfect in its workings, and, therefore, expensive. Consequently, as we take 3000 cubic feet of fresh air to be the average amount required per person per hour, the *cubic space* per individual should be at least 1000 cubic feet, with a corresponding increase where the occupants are all adult males, are all at work, or are in hospitals.

Again, it must be remembered that the difficulty of securing equable heating and ventilation increases with the height of the room above a certain limit, and that with the sick especially a certain amount of *floor-space* is necessary, both for the separation of patients and convenience of attendance. Ten or twelve feet will usually be found to be the safe limit of height for all apartments intended for continuous rather than temporary occupation, and, consequently, there should be a minimum allowance of from 85 to 100 or more square feet of floor-space per head, and an increase even upon this in workshops, hospitals, etc. However, there is no objection to high ceilings if you are not limited as to floor-space, pure air supply, and heat; and they may even be advisable in rooms where many lights are to be burned. Again, these restrictions regarding cubic and floor-space do not necessarily apply to such buildings as churches, theatres, etc., which are occupied for only a comparatively limited time, which can be thoroughly flushed out after use, and in which it is evidently impracticable to allot to each person the above floor area. Yet pains must be taken in such assemblies to keep the atmosphere pure by whatever means are necessary; while for school-rooms and the like there must be extreme care that the pupils are not overcrowded, and that they have a full supply of properly warmed air.

Any correct system of ventilation, in addition to the above considerations, must take into account the source of the air supplied, the distribution, and the heating or cooling of the air when necessary.

The air supplied to any house should be taken from well above the level of the ground, where it is free from contamination and is constantly changing, and not from cellars or closed areas, where the atmosphere is stagnant and full of impurities. The conduits leading to the heating or ventilating apparatus should also be so arranged that they may be frequently and readily cleaned; it is well to have them covered with gratings to prevent objects being thrust into them, and, in extreme cases, it may even be advisable to filter the air through coarse cloth or fine wire gauze to free it from dust and other impurities. In the mechanical system of ventilation adopted in the chemical laboratory of University College, Dundee, the air is filtered by being passed through jute cloth (light Hessian) stretched on frames seventeen feet long by four feet wide. In this case the presence of the screen actually increased the delivery of the air by nearly 10 per cent., probably by preventing eddies. The screens collected two and one-half pounds of dirt in seven weeks. They last about a year, and the cost is about 2*d* (four cents) a yard.[1]

The air may be kept in motion and efficient ventilation produced (1) by those forces continually acting in nature, producing *natural ventilation*, and (2) by these in combination with other forces set in action by man, giving *artificial ventilation*. The three main forces of natural ventilation are diffusion, the winds, and the difference in weight of volumes of air of different temperatures.

Diffusion is constantly taking place between all the gaseous constituents and impurities of the air, and even goes

[1] Stevenson and Murphy, vol. i. p. 51.

on through brick and stone walls, but is insufficient in itself to keep the air pure, though it does much to further this. Moreover, as suspended matters are solid, not gaseous, they are not changed or removed by it.

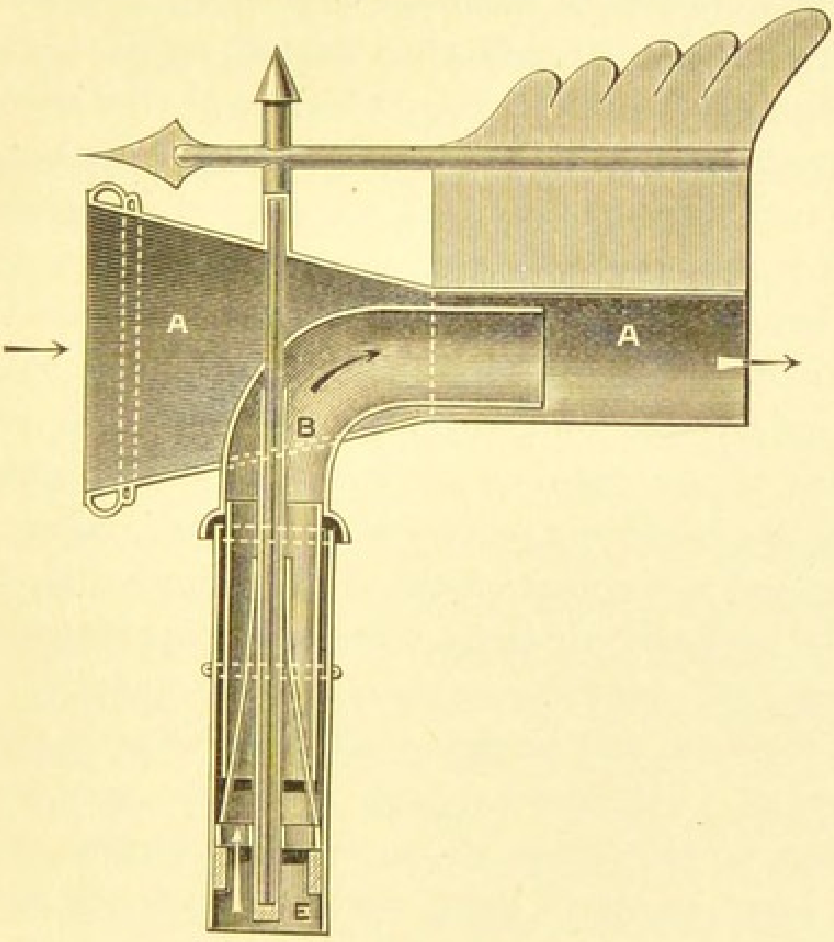
However, the action of this force should not be ignored in our calculations as being insignificant, for it is not only continuous, but it affects the whole volume of the atmosphere in maintaining its uniformity of composition. "Roscoe found that when he evolved carbon dioxide in a room the amount had decreased one-half from that cause (diffusion) in ninety minutes."[1] The rate of diffusion is inversely as the square roots of the densities of the gases concerned.

Winds are powerful agents for ventilation, and a slight breeze passing through a room changes the air therein many times in the course of an hour, and carries out by its force many of the solid impurities not affected by diffusion. Winds will pass through walls of wood, brick, or stone, although their progress is markedly arrested by much moisture in the walls and by paper or plaster. The average rate of movement of the wind is considerable, but the difficulties in the way of applying them in ventilation are the uncertainty of their direction and velocity, the difficulty of regulating them, and the fact that they may fail us at a time when we need their action most. In winter they usually have to be excluded directly from our houses, because a velocity of five or six feet per second is not to be borne unless the air be previously warmed. We may, however, take advantage of the fact that a small current with a high velocity will set in motion a large volume of air, and that wind blowing

[1] Notter and Firth, p. 194.

across the top of a tube will cause an upward movement of air in the tube. This is one reason why there is often a draught up an unusued chimney and why it acts as a good ventilating outlet. To utilize these perflating and aspirating powers of the wind, and to prevent back draughts down chimneys and ventilating pipes, we make use of *cowls*, either movable or fixed. We can so arrange these that

FIG. 13.



Cowl or ventilator for aspiration.

the force of the wind either drives air into the house (perflation), or draws air out of it (aspiration). Very good systems employing these have been put in operation, the air being warmed, if necessary, by passing it over stoves, steam coils, etc., and they are especially useful where the inner air is colder than that externally, and where artificial methods of ventilation dependent upon heat cannot be employed, as in the holds of ships, deep basements, etc.

The most important agent in natural ventilation is, however, the movement produced by variations in the specific gravity of air. Though the wind might be included under this head, being produced by the same force, the latter acts independently of the wind, especially in closed buildings. As the air expands when heated, equal volumes become lighter than they were hitherto and rise, and colder, heavier air pushes in beneath to occupy the space. But in all inhabited apartments a warming of the atmosphere is continually taking place, not only by the lights and fires, but also by the bodies of the occupants. The movement is, therefore, a continual, though not necessarily an equable one, varying as it does with the temperature of the out-door air and the number and intensity of the heating agents within. There being such a heating and movement of the air, it follows that, unless a room be perfectly air-tight, some of the apertures will act as inlets and others as outlets, and the quantity flowing out of the room will be practically equivalent to that flowing into it. Therefore, though this force may not be as powerful or efficient as strong winds at certain times, yet being more constant, more readily calculated, and more controllable, it is the one most to be considered in arranging a system of ventilation.

To determine the velocity of this influx or outgo of air, we make use of the law that a fluid passes through an opening in a partition between two volumes of the fluid with the velocity which a body would acquire in falling through a height equal to the difference in level of the fluid on the two sides of the partition. In the case of a current of air we substitute for the difference of level the difference in pressure on the two sides of the partition or opening, and this is expressed by the difference in temperature multiplied by the difference in height of the openings of entrance and exit, and divided by 491, $\frac{1}{491}$ representing the expansion of the atmosphere in volume and lessening of density for each degree (Fahrenheit) of rise in temperature. The velocity will, therefore, equal

$$8\sqrt{\frac{(\text{diff. in temp.}) \times (\text{diff. in height}).}{491}}$$

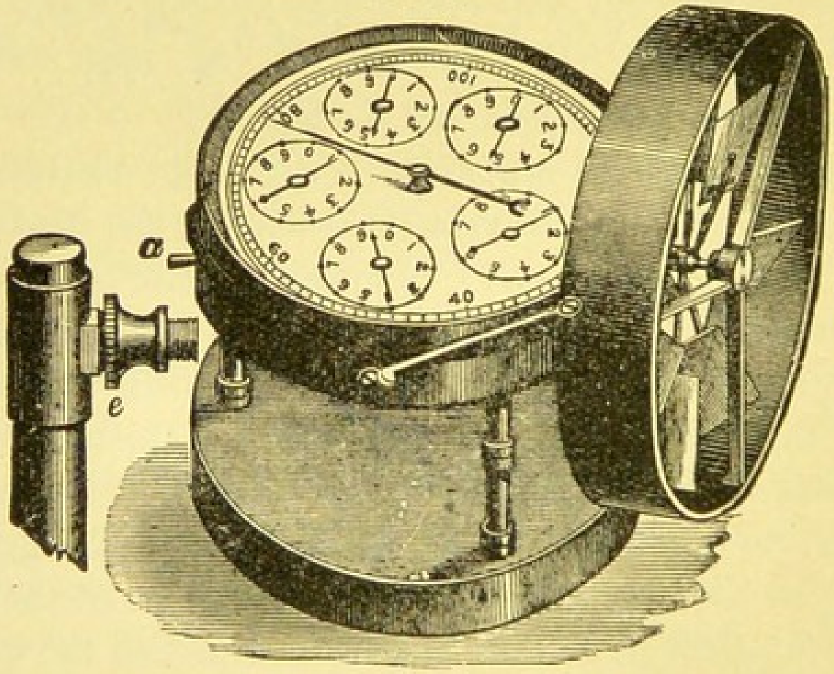
Example: What is the velocity of the current in a chimney 40 feet high, the out-door temperature being 20° F. and in-doors 70° F.? Answer: $V = 8\sqrt{\frac{50 \times 40}{491}} = 8 \times 2 +$, or about sixteen feet per second.

In actual practice use is made of a table derived from this formula, or else the velocity is determined directly by means of the *anemometer*. Allowance must be made for the friction of the air against the sides of the ducts and against itself, amounting to from one-fourth to one-half of the theoretical delivery, according to the length, size, straightness, etc., of the inlets and outlets. The friction will be inversely as the diameter of the openings and directly as the length of the tubes; the shape of the openings also affect it, and right angles diminish the current one-half. Accumulations of dust and dirt greatly lessen the velocity.

The velocity multiplied by the total area of the inlets or outlets, with a proper allowance for friction, will give the quantity of air passing through the rooms or series of rooms in any given time.

One of the most difficult problems in ventilation is to secure a uniform distribution of pure air through the rooms, and to remove the impure air as fast as the pure is supplied, thus preventing its mixing with the latter. Certain circumstances always make the question complicated: the size and number of inlets and outlets, the rate and direction of motion, and the forces acting to produce it must always be subject to constant change, and must thus constantly alter the result. In fact, it is practically impossible to devise a plan that will satisfy all conditions at all times, and the best that can be done will be to select that one which will give the greatest efficiency and most satisfactory results under all ordinary circumstances.

FIG. 14.



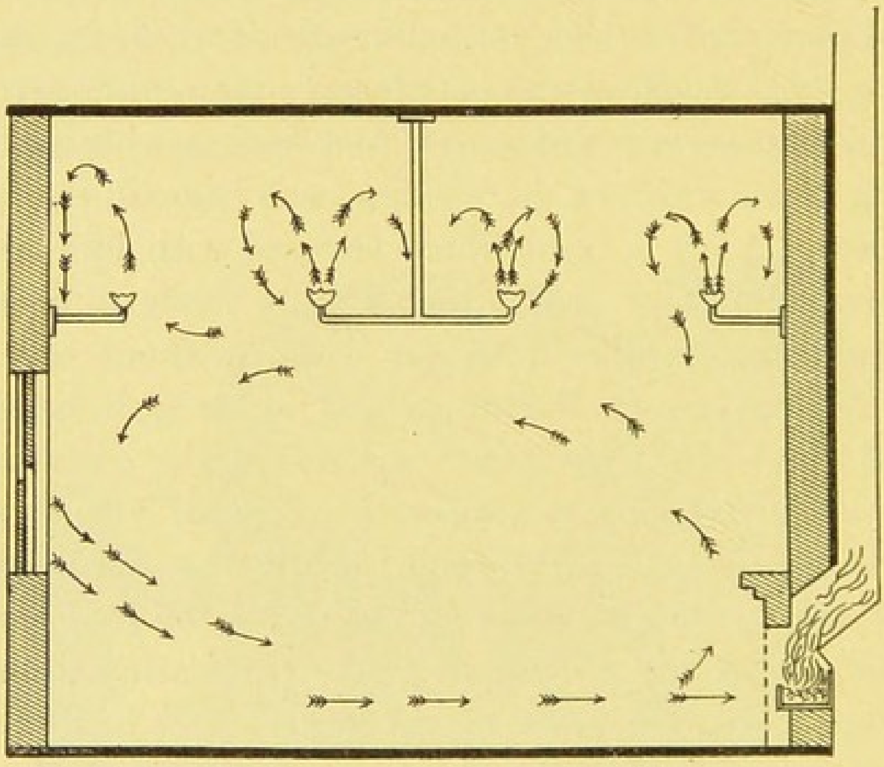
Anemometer, used for measuring the velocity of air-currents directly. *a*, slide for releasing or stopping the dial hands; *e*, support for attaching the instrument to a staff or cane.

The force of diffusion will always act as long as there is any communication between the exterior and interior, and no special attention need be given to it. We cannot use the wind continually, for reasons already given, but we should employ it whenever possible by opening doors and windows, on account of its great power for sweeping out solid impurities and thoroughly changing the air. In cold weather, currents from windows, etc., should be directed toward the ceiling, so that they may be diffused and partially warmed before reaching the inmates of the room. Numerous devices have been suggested for introducing unwarmed out-door air without discomfort, or for diffusing it through the room: among these may be mentioned perforated bricks, or double-paned windows, valves, screws, etc. A cheap and satisfactory temporary arrangement is to place a board about four inches wide and just as long as the width of the window-sash beneath the latter. Or, better, have a light frame covered with fine netting or wire-gauze, four or five inches wide made to fit above the upper sash: the fresh air from without can now enter freely between the upper and lower sash, being reflected upward by the inner surface of the glass in the upper sash, and thus mixing with warm air before reaching the occupants of the room; while the frame at the top of the window becomes an outlet for the foul air, the interference of the netting or gauze preventing too rapid an outgo and consequent loss of heat. But in a climate such as our own, and in all cold countries, special measures must be taken during the greater part of the year for warming the out-door air before introducing it into occupied rooms.

Where we intend to depend most upon the third force of natural ventilation, viz., the movement of unequal weights of air, we must provide openings for the entrance and exit of air other than the windows and doors, so that there will be a practically constant movement through the rooms in a given direction, that we may be sure the air is from a pure source, and that we may get the utmost service from our appliances.

There is considerable difference of opinion as to the best locations for inlets and outlets, and as the conditions are necessarily different in every case, and as so many factors are to be considered, it is difficult to lay down any general rules. It should be an aim, however, to have the air well

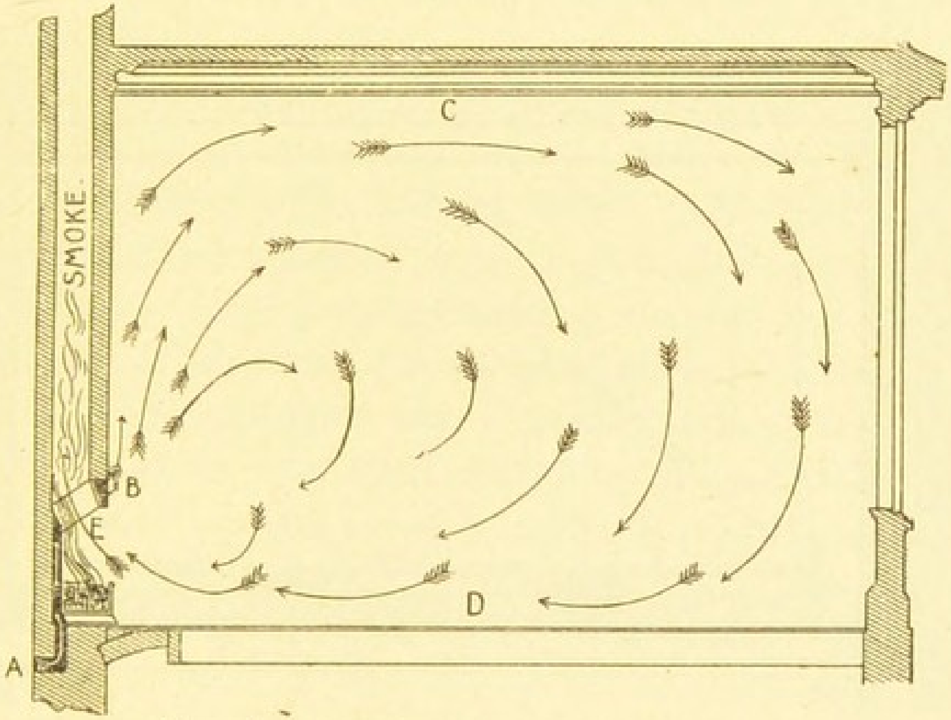
FIG. 15.



Currents in room lighted by gas and heated by open grate.

distributed throughout the room or rooms, and to have no direct draughts from the inlets either upon the occupants or to the outlets. It is the writer's opinion that, usually, the outlets should be located near the top of the room, owing to the tendency of the used air to rise, and because, in unventilated rooms, the foulest air for some time after its contamination will be found nearest the ceiling. The products of combustion from lights, etc., will also practically all be in the upper strata of air. If, however, provision is or can be made for a constant and sufficiently strong aspirating force in the outlet ducts, it will be advisable to withdraw the used air near the floor level and below, though not in too close proximity to, the inlet openings, since in this way a more thorough distribution of the incoming air and a greater dispersion of its contained heat are secured. This is aptly shown in the illustration depict-

FIG. 16.



Currents in room heated by a ventilating grate.

ing the currents in a room heated by a ventilating grate. (Fig. 16.) This principle is also involved in the well-known Smead system of ventilation and heating, which still further serves economy by carrying the foul air beneath the floor of the room from which it is taken, thus warming the floor with what heat the waste air yet contains and gaining the utmost benefit and value from the fuel. (Fig. 17).

The location of the inlets should depend on the temperature of the incoming air; if it is cold, it should be admitted near the ceiling, so that it may diffuse and be practically warmed before reaching the inmates of the room; if it is warmed, it may come in near the floor or below the middle level of the room. Where much fresh air is required, it is better to have a number of inlets and outlets than one large one of each, as the distribution is then more certain. The total area of the outlets may be the same as that of

FIG. 17.

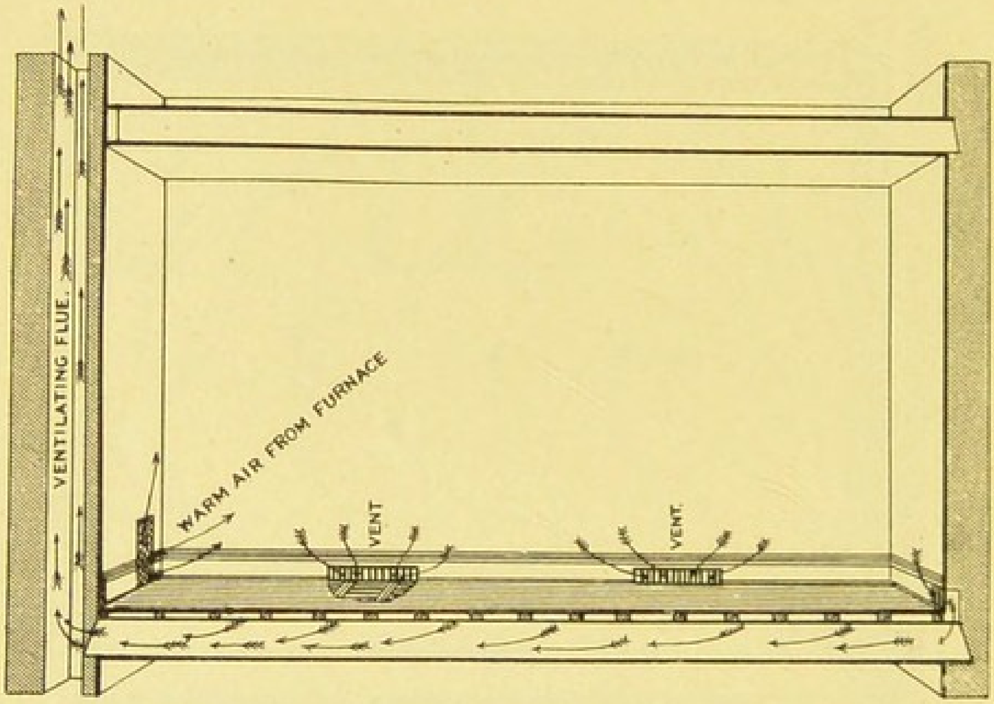


Diagram illustrating the general system of ventilation.

the inlets, as the expansion of the air is scarcely great enough to require a difference. The outlets should all be on the same level, else the highest one will be the one of greatest discharge and often the only one, the others possibly acting as inlets and drawing air from an impure source. As the temperature varies from time to time, and with it the current, some arrangement is needed for regulating the size of the openings of the inlets or outlets to suit the varying conditions. To supply 3000 cubic feet of air per head per hour at a velocity of five feet per second will require an inlet-opening of twenty-four square inches for each person; but practically it is better to have a larger opening, as the above velocity is uncomfortable unless the air be well warmed. Outlet tubes should always be protected from cold and kept as warm as possible.

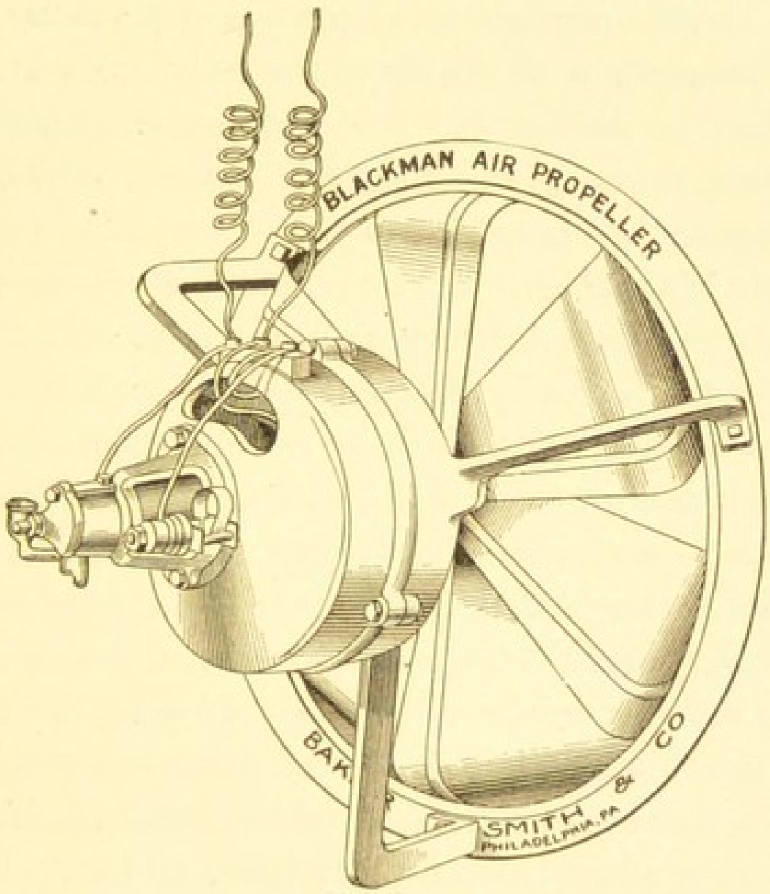
Artificial ventilation is that which is brought about by the intentional application of the above mentioned and other forces, and by means of special apparatus and devices, in contradistinction to natural ventilation, which may act independently of human cognizance and intention. It may consist in either extracting air from or forcing air into a room or building, or in both together. In the first method the object may be attained by heating the air in the outlet or the outlet itself, or by the use of a fan, a screw, or a steam or water-jet. Of the first of these the common house-chimney is as good an example as any. As long as there is a fire in a grate or stove connected with the chimney there will be a constant upward current; and the area of the chimney's cross section being known, and the velocity determined, as already indicated, by the anemometer or by calculation, the amount of air passing out of the room in this way may readily be determined. In this connection it may be stated that a chimney may thus act as the only outlet, and all other openings into the room serve as inlets, especially when the fire is strong, and that the upward current will be practically equivalent to the amount of incoming air. Moreover, the outgoing current may be so strong as to overtax the capacity of the inlets, in which case more or less of a vacuum will be formed in the room and down draughts will probably be set up in the chimney, and smoke carried back into the room. The remedy is to enlarge the inlet area by opening a door or window, or to lessen the draught by means of a damper in the chimney. On the other hand, the inlets may be so large and the current so strong that the air in the room cannot be properly warmed, in which case the size of the outlet should be lessened by a damper, or there should be an increase in the efficiency of the heating apparatus.

When we wish to draw air from distant and non-communicating rooms, the ducts may be led into a chimney below or just above a fire, or, better, into a flue or shaft alongside or encircling the heated chimney. The draught is greater just above a fire than below it, but conduits should not enter near the top of a chimney, for there the extracting power is not so great and there is danger of high winds blowing smoke and foul air back into the rooms. Outlet flues should be alongside chimneys that are being constantly used; should be as smooth as possible interiorly, and should be as high as the adjoining chimney to avoid down draughts. The openings from the rooms into these ducts should be as near the ceiling as possible, to get the benefit of the high temperature of the upper strata of air, unless, as previously indicated, there is certainty of the extracting force being constant and sufficiently strong, when the air may be taken from a lower level.

In hospitals and other places where a constant and independent supply of heat can be afforded, extraction shafts apart from chimneys may be used. These extraction shafts may be heated by fires, steam pipes, or steam jets at the bottom, or by steam or hot-water pipes coiled around the sides. Some system like this is used in mines, where large quantities of air must be extracted. There is an entrance and an extraction shaft; large fires are constantly maintained at the bottom of the latter, the air is drawn down the former, diverted through all parts of the mine by partitions, and finally heated and carried up the extraction shaft.

We may also use a jet of steam or water in place of heat to extract air through a shaft, the openings of the foul-air ducts being back of or behind the jet. It is said that a steam jet may thus set in motion over two hundred times its

FIG. 18.



Air propeller, with electric motor attached.

own bulk of air. Lastly, fans driven by steam or water-power have been employed to extract the air, though these are usually more efficient in forcing in air. For instance, one of 36 inches diameter, at 600 revolutions per minute will extract over 18,000 cubic feet of air per minute.

In ventilation by propulsion or forcing in air, these large revolving fans are generally used. The advantages of this system of ventilating are the certainty as to the direction of current and amount of air supplied, and the ease with which the quantity can be altered or measured. The disadvantages are the high cost of power in most cases, the inconvenience or danger from prolonged stoppage from accidents to the apparatus, and some difficulty in distributing the air. For instance, if it be forced in through small openings or at too great a velocity it will not mix properly with the air of the room. The increased use of electric motors and lowered cost of running them will doubtless serve to make this system of ventilation more common in the near future.

House Warming. In cold countries there must be some resort to artificial heat in the winter season, and as this subject is more or less inseparably and closely connected with ventilation, it may be appropriately considered at this time. Cold is depressing, uncomfortable, and dangerous to the young and aged, and to women whose habits of life keep them much indoors; though well-fed, healthy, adult men may not be much affected, if accustomed to it. In this country we need a higher temperature in our houses than in Great Britain, on account of our drier climate; evaporation and consequent cooling of the body take place more rapidly here, and so, while they are accustomed to a temperature from 60° to 65° F., we find from 65° to 75° F. to be no more than comfortable.

It needs but slight investigation to determine that we practically make use of but two kinds of heat—radiant and convected—in the heating of houses, and that of these the latter is by far the most generally employed and the most economical. *Radiant* heat, although it is the most healthful and warms an object directly without raising the temperature of the intervening air, has the disadvantages of utilizing but a small proportion of the fuel value, of decreasing directly as the square of the distance of the object from the source of heat, and of being available only in comparatively small apartments. Our best example of radiant heat is that which comes from open fires, though any highly-heated object, as a stove, gives off more or less of it. Heat that is carried from one place to another by heated masses of air, water, or steam, is said to be *convected*, and because of the economy in its use and the ease of distribution, especially in large spaces, it is the kind most generally used. Conducted heat, which passes from molecule to molecule of the conducting substance, acts too slowly to be available to any extent in house-heating, and may, therefore, be omitted from this discussion.

Just here it may be remarked that, under present conditions, there are three things, any two of which we may have, but not all three together, except in rare instances: they are good ventilation, efficient heating, and cheapness. The reason for this is that any good system of ventilation necessarily and continually carries off a large quantity of air with its contained heat, which latter is lost for heating purposes and must be replaced at the expense of more fuel. A heat unit cannot be used at the same time to produce ventilation and to heat objects other than the air it keeps in motion. The principal aim, then, in establishing any system of combined ventilation and heating must be to heat, introduce, and carry off no more air than is necessary for the requirements of good ventilation and health, and to produce the heat for warming this air and the house itself as economically as possible; though care must also be had to secure evenness of distribution, absence of draughts, etc.

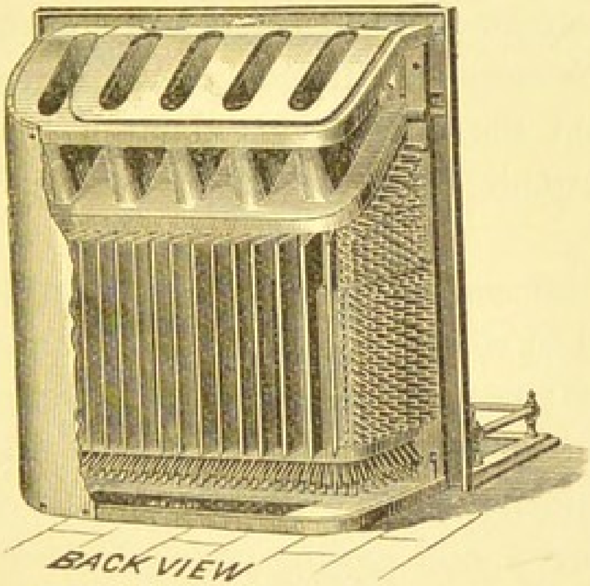
The usual appliances for house-heating are open grates or fireplaces, stoves, and hot-air, steam, and hot-water furnaces. To these may now be added electrical heaters, but the cost of maintaining them at present prevents their use by any but the wealthy.

Ordinary grates and open fireplaces give practically only radiant heat, and render available only from 7 per cent. to 12 per cent. of the fuel efficiency. They also only heat directly the surfaces of objects facing them, leaving the remainder cold; and by reason of the great current up the chimney are also apt to bring in large quantities of air from without that has not been properly warmed, and to thus cause injurious draughts. Where there is some additional means of heating the air before it enters the apartment, and where the chimney current is controlled by a damper, they are valuable, not only for the good ventilation they produce, but for the pleasing effect of the exposed fire.

To make open grates most effective for heating, the sides and top should be inclined to the back at an angle of 135°, so as to throw as many heat-rays as possible into the room; the fuel surface should be concentrated, and there should be a damper to prevent too rapid combustion and too much heat and air escaping up the chimney. It is to be understood, of course, that the objects warmed by the radiant heat of the open fire do in turn give us convected heat by warming the air surrounding them.

If, however, the back and sides of these grates be surrounded by a space through which the air can pass and be warmed by the heat that would be otherwise wasted, we shall have a much better heating apparatus, since we thus get both radiant and convected heat, and may obtain from 25 per cent. to 35 per cent. of our fuel efficiency. And if outdoor-air be let into this air-space and warmed, the ventilation will be greatly improved, other inlets will be unnecessary, uncomfortable draughts will be avoided, and there will be enough heat provided for one or more apartments of moderate size. The air-chamber at the back should not be too small, and there should be as much heated surface to warm the incoming air as possible.

Fig. 19.



Jackson's ventilating grate. The outer casing is cut away to show space and surface for warming the incoming air.

Stoves utilize a considerable percentage of the fuel—75 to 80 per cent. or more—but do not remove much air; so ventilation has to be provided for in some other way and is apt to be neglected. Stoves may also give off dangerous gases and products of combustion if not properly cared for, or if the damper in the stovepipe be entirely closed. There should be as much surface exposed as is possible without diminishing the heating capacity, so that there may be much radiant heat. It is often advisable, especially in assembly or school-rooms and the like, to surround the stove with a sheet-iron cylinder extending from the floor toward the ceiling, and to bring in between this and the stove a supply of fresh air from without.

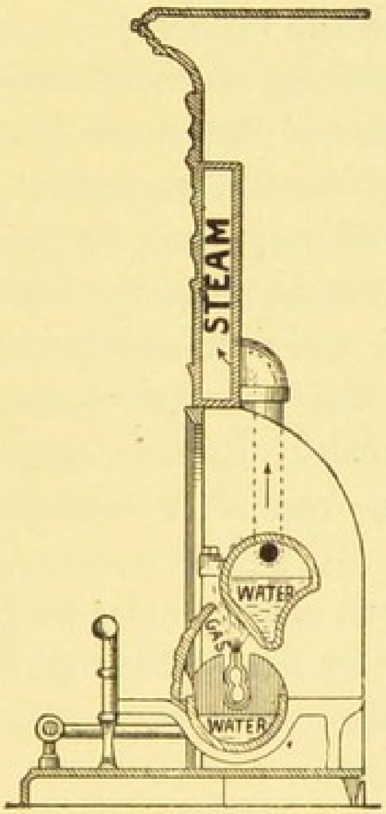
This air becomes heated and, passing out over the top of the cylinder or drum, gives a plentiful supply of convected heat, together with good ventilation. A suitable outlet must, of course, be provided. Carbon monoxide and other gases are known to leak through cast-iron when it is too highly heated, so that stoves should not be allowed to become too hot.

Other objections to stoves that are allowed to become too hot are the excessive dryness of the atmosphere which they cause, and the unpleasant odor due to the scorching of floating organic substances that come in contact with the hot iron.

The fuel most commonly used in both grates and stoves is either wood or some kind of coal (bituminous, anthracite, or cannel); but gas may often be advantageously employed instead of any of these, since the heat can be had from it practically instantaneously, can be closely regulated in quantity, and can be promptly checked when no longer desired, and since there is no production of dust or ashes in the room. The main objection to gas is that for large rooms or prolonged or continuous heating it is usually more expensive than the other fuels; but this does not hold good for small rooms, and sometimes for isolated apartments, or where the warmth is needed only temporarily; and it is very probable that before long fuel gas will be—it can be now—supplied at rates which will justify a much more extended use of such fuel.

The ordinary kinds of gas-grates and stoves, especially those which consume the gas incompletely, should all be constructed with flues to carry off the products of combustion directly, and this particularly when any large quantity of gas is used. Theoretically, when the gas is burned in a properly adjusted Bunsen or "atmospheric" burner, the only combustion products will be carbonic acid and water, the former of which is rapidly diffused into the outer air, as has been shown, and is not likely to be harmful in any quantities thus produced, while the aqueous vapor is beneficial to the atmosphere rather than otherwise. However, it seems that in practice even these Bunsen burners may sometimes give to the air a disagreeable odor (said to be due to the formation of acetylene), and so need flue connections.

FIG. 20.



Section of Backus' portable steam radiator for use with gas.

In this connection it may be interesting to describe one form of gas-heater which, so far as the writer knows, is unique. It is intended not only to consume perfectly the gas it uses, giving nothing to the air but carbonic acid and water, but also to destroy by fire the impurities of the atmosphere of the room, thus doing away with chimneys or flues and the necessity of much ventilation. By a peculiar arrangement, a continued current of air is made to pass through the flame, thus burning the impurities, whether gaseous or solid. The heat of the burning gas is also used to convert a quantity of water into steam, thus warming the containing chamber or coils of pipe, and these in turn the air surrounding them, in this way warming many times the volume of air possible to heat by the flame alone. In addition, the normal humidity is maintained in the atmosphere by the evaporation of water from an open basin beneath the fire.

The ordinary openings of any room are amply sufficient to allow the diffusion of the excess of carbonic acid—one-half escaping in this way, according to Roscoe, within ninety minutes—and to permit the ingress of enough air fully to supply all the needs of the inmates and of the fire itself. Experience and careful experiments seem to show that the claims of the inventor are well founded and that the apparatus is healthful in its operation and produces no harmful effects, even after continued use for several months.

At any rate there seems to be no reason why we may not purify the air by fire instead of by dilution and removal, the methods employed in the hitherto described systems of ventilation.

Oil-stoves are now used quite extensively and, beside being portable, have the same advantages as gas-stoves, viz., that a considerable quantity of heat may be had quickly and just as long as it is desired, and at a fairly moderate cost. The combustion products necessarily mix directly with the atmosphere of the room, and where reasonably perfect burning is had doubtless consist of little else than carbonic acid and water. One pound of oil, the hourly consumption of a rather large stove, will require about 150 cubic feet of air for its complete combustion, and will produce about twenty-five cubic feet of carbon dioxide.

"We do not think that the experience has yet been accumulated which would enable us to speak positively of the innocuousness of a considerable admixture of carbonic acid with the air we breathe, but the knowledge that in hundreds of cases oil-stoves are used for heating living rooms and even bedrooms without apparent injury to the occupants makes one feel fairly confident that the products of the complete combustion of hydrocarbons are not injurious when mixed with such an amount of air as is sufficient to dilute to a proper degree the respiratory products. . . . Experiments show that, provided the combustion of the oil is complete, and that the ventilation is sufficient for the ordinary effects of respiration, the use of oil-stoves for heating purposes may be advantageously employed in both day- and sleeping-rooms. The efficiency of oil-stoves is increased by placing over them a diffuser or radiator, so as to prevent the heated products ascending direct to the ceiling; care needs also to be taken that only the better kinds of mineral oil are used; if inferior qualities of oil are burnt perfect combustion is more difficult to obtain."[1]

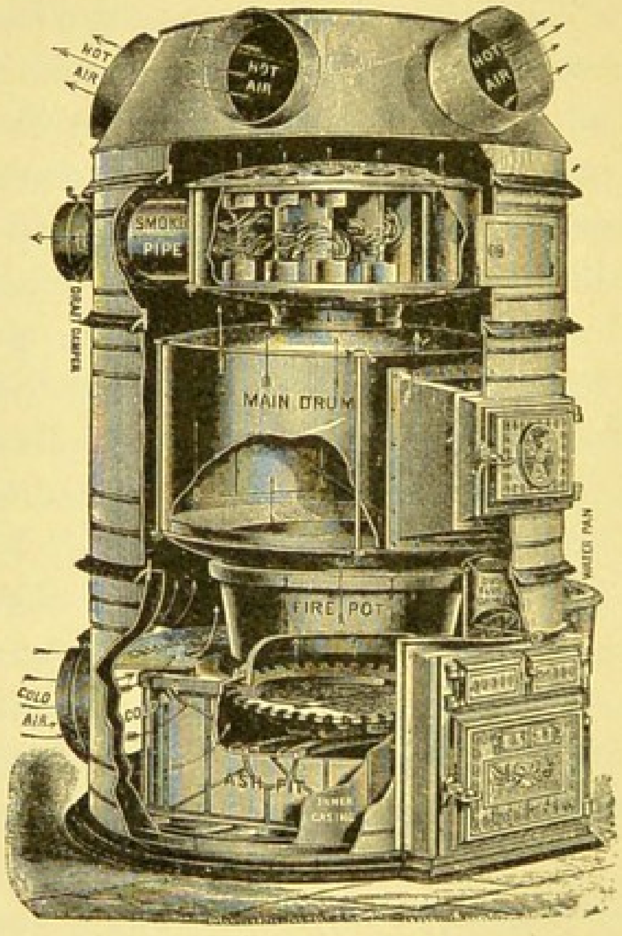
The above remarks, as far as they apply to the healthful use of the air, may probably be used with equal justice in regard to gas-stoves, provided that with such dilution, their products give no obviously harmful or disagreeable results.

The heating apparatus thus far described is such as we

[1] Notter and Firth, p. 228.

are accustomed to employ for warming the air of single or, possibly, of adjoining rooms. Where a whole dwelling or other large building is to be heated, it will usually be of advantage to do this from one point, and that not in any of the living apartments. In this way we shall have a centralization of fuel, both unburned and burning, and the

FIG. 21.



Spear's hot-air furnace.

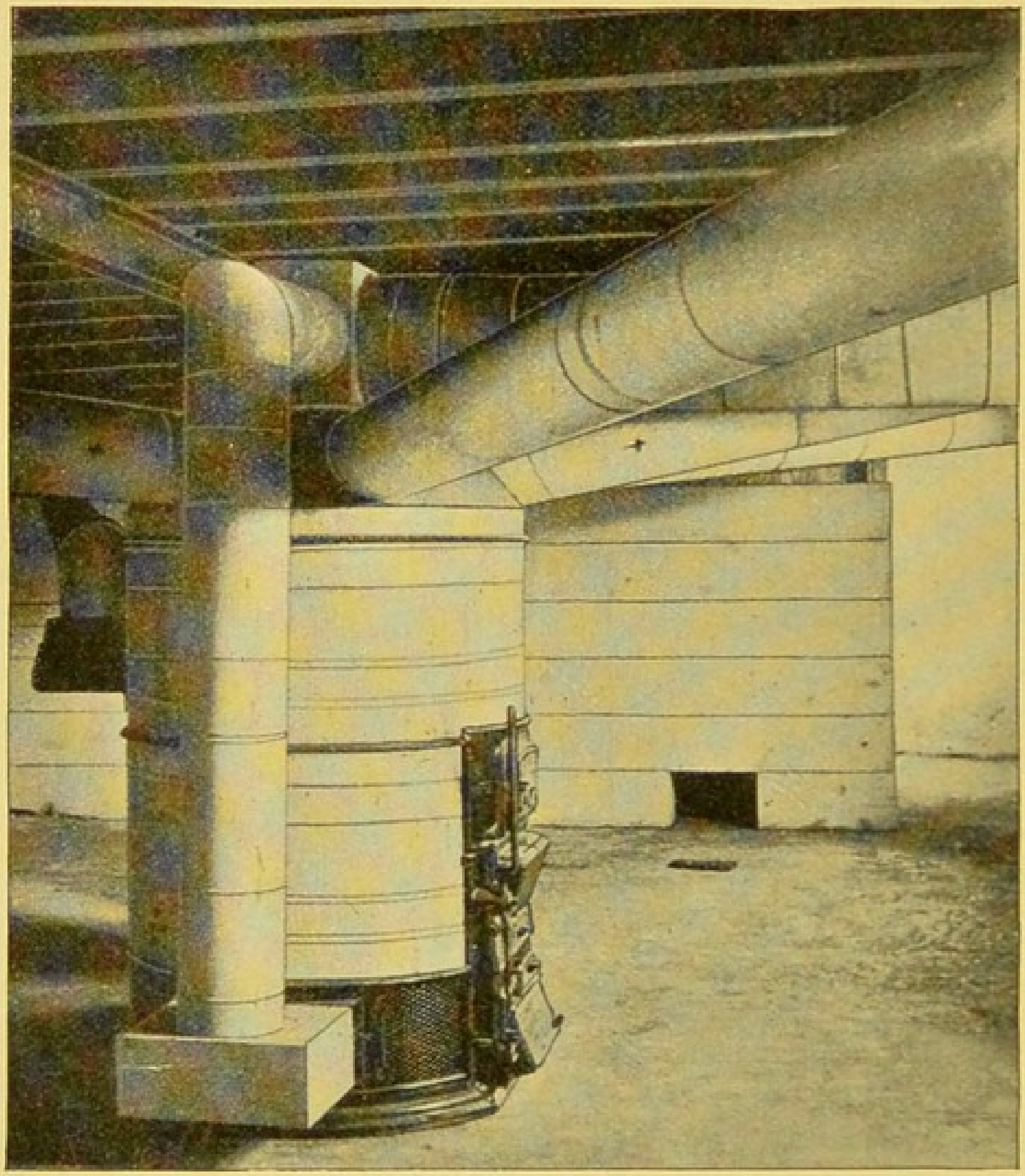
ability to derive more heat from it; a lessening of the labor and attention bestowed on the fires; the obviation of much dust, dirt, and combustion-products in living-rooms, and, presumably, a more equable and satisfactory warming of the whole building. From such a central point the heat is distributed by hot air, hot water, or steam, or by hot air in combination with either of the other two.

Hot-air furnaces supply a large amount of convected, but no radiant heat. There is a very prevalent opinion that they are not healthful and that wherever possible they should be substituted by some other means of heating; but when properly constructed and cared for a hot-air furnace of the proper size is not only a good heater, but a powerful ventilating agent; for the large supply of air passing through it into the rooms above must in time find an exit either through specially devised outlets or through the innumerable cracks and crevices around all doors and windows, and the ventilation will be accordingly.

One frequent source of trouble is too small a fire-pot, giving insufficient heating surface and necessitating too rapid and too intense combustion of fuel. There should be a considerable expanse of surface, never too highly heated, so that large volumes of air will be moderately warmed, rather than small quantities over-heated and "burned." Air too highly heated is very dry and offensive to the senses—also, by taking excessive moisture from the body through the skin and mucous membrane, it increases the liability to frequent "colds" and congestions. Moreover, a large quantity of air moderately warmed will, perforce, be carried to *all* the rooms of the house, warming them equably and driving before it the air already there: whereas, a much smaller volume, excessively heated by the same or even a greater amount of fuel, will make its way along the channels of least resistance to certain favored rooms, overheating them and keeping the rest of the house cold, beside preventing any satisfactory natural ventilation.

All joints in the furnace must be as near gas-tight as possible, to prevent the combustion products passing from the fire-box or smoke-flues into the air chambers and thence into the house.

Fig. 22.



Hot-air furnace, showing cold-air inlet and hot-air flues. Only one of the lateral branches of the main inlet above is shown.

The furnace should be located near the cold side of the house—that is, the side on which the prevailing cold winds impinge, for it is said to be as difficult to drive the air ten feet against the wind as forty or fifty feet with it. It may also be well, if the basement ceiling is low, to place the ash-pit even below the level of the basement floor, in order to give sufficient slope to the air-ducts; but in every case the space beneath the furnace should be cemented or laid in asphalt to prevent the drawing in of soil-air.

The air-supply should not be taken from the cellar, even though the latter be apparently clean and free from any contamination with soil-air, but should come from a clean source out of doors, well above the ground-level and from the direction of the prevailing winds. The cold-air duct or ducts should be screened at the entrance to prevent the admission of refuse or vermin, should be arranged to permit of regular cleaning, should have a damper to regulate the supply of air, and should have a cross-section of at least two-thirds of the combined area of the hot-air flues leading from the furnace. It may be desirable to provide for the filtration of the air through coarse cloth or fine wire gause, especially if there be much dust in the incoming air.

If possible, the hot-air flues or ducts should not be flat, but round or square, to lessen the friction, and should be as direct in their course and as nearly vertical as possible for the same reason. They should be covered from the furnace to the register openings with asbestos or other non-conducting material, to prevent the loss of heat that otherwise escapes from them into the cellar and between the partitions. Lastly, their register-openings into the rooms should not face the windows or prevailing winds, unless absolutely unavoidable, for if they do, the passage of warm air into the room will often be completely checked.

The following table, from Coplin and Bevan, will indicate the proper size for hot-air flues and registers :

FIRST FLOOR.

Size of room in cubic feet.	Size of pipe.		Size of register.	
	If round.	If square.	If round.	If square.
Less than 1500 . .	7 inches	4 x 9 inches	9 inches	7 x 10 inches
1500 to 2000 . .	8 "	4 x 12 "	10 "	8 x 10 "
2000 to 3000 . .	9 "	4 x 16 "	12 "	8 x 12 "
3000 to 4000 . .	10 "	4 x 18 "	12 "	9 x 14 "

Economy will be subserved in most cases by taking care to burn the fuel in hot-air furnaces quite slowly, since in this way larger quantities of air are warmed and more satisfactorily, and there is also less waste of heat through the smoke-flues and up the chimney. Moreover, it is the experience of the writer, that by working the furnace in this way at low pressure, so to speak, the air from it will practically never be too dry, nor need the addition of moisture, something essentially necessary and yet most often neglected where too little air is excessively heated.

When it is necessary to carry heat for a considerable distance or to warm large buildings or blocks of buildings from a central point, it will be better and more economical to employ hot water or steam as the heat-transmitting agent, on account of the high specific heat of the former and the great amount of latent heat held by the latter. "It is uneconomical to convey heated air any long distance, as the amount of heat conveyed per cubic foot of air raised to any practical temperature is so small and so easily lost in transit. On this account Morin considers the availability (of hot-air furnaces) limited to a horizontal range of forty or forty-five feet from the heating apparatus."[1]

[1] Stevenson and Murphy, vol. i. p. 117.

An equal quantity of heat, viz., one thermal unit, is required to raise one pound of water or fifty cubic feet of air 1° F., and accordingly water will carry over four (4.21) times as much heat as an equal weight of air at the same temperature. "Further, a greater effect is produced when water, in the form of steam, is made the carrier of heat, because one pound of water—vapor—at 100° C. (212° F.) will, in condensing to form boiling water, give off sufficient heat to raise the temperature of 5.36 pounds of water (or $4.21 \times 5.36 = 22.5$ pounds of air) from 0° C. to 100° C. (32° F. to 212° F.)."

Hot-water heating may be by either the low-pressure or the high-pressure system. In the former large pipes (generally four inches in diameter) are used, and, the system being open to the air at its highest point, the temperature of the water can never be much above 212° F. at any part of the system. The water circulates comparatively slowly, but, owing to the large volume, conveys much heat from the furnace to the places where it is needed. The high-presure system employs small but very strong pipes, the water being completely inclosed from the outer air, wherefore it attains a high temperature, usually about 300° F., and circulates rapidly. The necessary expansion is provided for by larger pipes partly filled with air at the top of the circuit. The maximum temperature is regulated by the proportion of pipe exposed to the fire, usually one-tenth. Either of the hot-water systems, but especially the low, require careful planning and setting to maintain evenness of circulation; but when the latter is complicated, as by many radiators at various levels, or where a number of circulations have to be supplied from the same boiler, it may be very difficult to maintain an even head and an equable distribution of heat in all. "If properly constructed and the heating planned for when the house plans are made, this hot-water system is probably the most economical, both in fuel used and repairs demanded."[1]

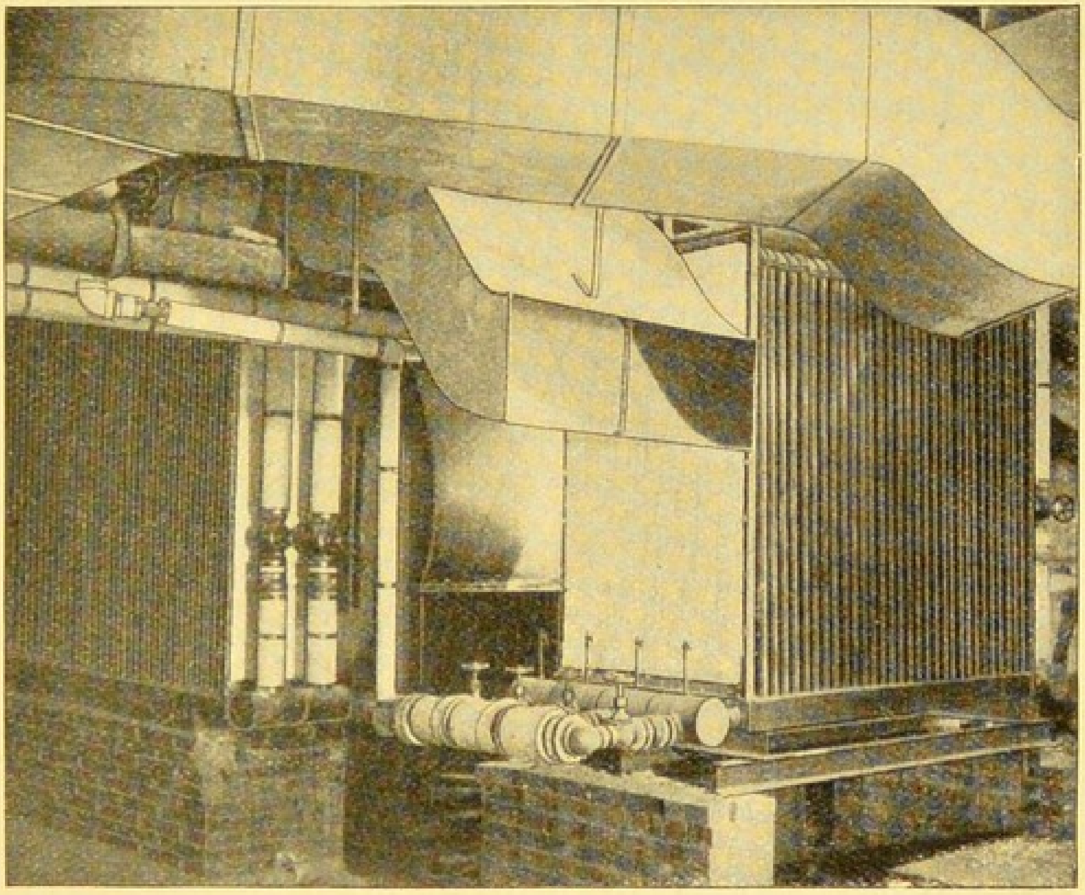
Steam-heating methods are usually quite satisfactory, not only because of the large quantity of heat carried, but also since a rapid circulation is readily maintained, even under adverse circumstances. The size of pipe used will depend on the extent of the distribution, but the calibre of the radiator should always be considerably larger than that of the supply pipes, in order to favor condensation and the consequent liberation of latent heat, and every facility should be provided for the speedy return of the condensed vapor to the boiler. Care must also be taken to prevent the condensation occurring in such a way as to cause obstruction to the flow of the steam and the disagreeable thumping and noise that result.

With either steam- or hot-water heating, the direct, the indirect, or the direct-indirect method of radiation may be used. Of these the direct method—that is, where the radiators are placed in the rooms to be warned—is most commonly employed in dwellings and other buildings of moderate size; but it is open to the objections that in itself it does not bring about a sufficient change of air, that the necessary inlets and outlets for the latter are rarely provided, and that when present they are independent of the heating system of the house. Of course, these objections are removed when the direct is combined with the indirect method, or when a plentiful supply of pure air is brought from without and is warmed by being made to pass through the radiators (either open or enclosed in boxing) before diffusing through the room, this being the

[1] Coplin and Bevan, p. 325.

direct-indirect method. In the indirect method the radiators are placed in suitable and convenient enclosures outside of the room, into which fresh air is brought from out of doors and from which the warmed air is conveyed by suitable ducts to the respective rooms above. If properly

FIG. 23.



Steam radiators and blower used in warming the clinical amphitheatre of the Medico-Chirurgical College of Philadelphia, by the indirect system. (The casing of the radiators is not yet applied.) Tempering radiator at left; warming radiator at right; casing of fan between.

arranged, both the indirect and the direct-indirect methods should furnish good and ample ventilation, the incoming warm air pushing the used air of the room ahead of it through the various openings in the walls of the room.

Safety valves on steam boilers prevent any danger from explosions, and automatic thermo-regulators make it possible to maintain a practically even temperature throughout the house or building at all times.

In the Clinical Amphitheatre of the Medico-Chirurgical College of Philadelphia, the indirect system is employed, the details being as follows: The cold air is brought from near the roof-level by a large shaft into the cold-air room, where it is moistened by a spray and whence it passes through a dust-filter, consisting of a double layer of fine wire gauze. Thence it passes through tempering radiator (to modify the temperature) into the revolving fan, driven by its own engine, whence part passes through a second and larger radiator to be further warmed, and part below the latter, the two currents again uniting and, after mixing, passing through the flues into the amphitheatre above. In this the temperature is regulated by a thermostat (which governs a damper not shown in the cut) which always permits the same volume of air to pass into the flues, but controls the respective quantities of heated and tempered air, so that the mixture practically does not vary in temperature. In this way 900,000 cubic feet of air at a fixed temperature can be supplied per hour.

For the private operating-rooms the system is the same, except that the tempered and the heated air are not mixed, but each is carried by separate flues to double registers in the operating-rooms. In this way each operator can have the temperature that he desires in his room at any time.

In very large buildings it may be advisable or necessary, as above, to drive the air heated by the indirect method into the rooms (the plenum or propulsion system), or to withdraw it through special outlets by suction (the exhaust system). Of these the former is preferable, since the source from which the air is taken and the inflow through the heating apparatus are both more certain.

To determine the amount of radiating surface needed for any room we must multiply the volume of air to be heated per hour by the difference between its temperature in degrees Fahrenheit before and after warming, and divide this product by 50, the quantity of air in cubic feet raised 1° F. by one thermal unit. This will give the number of heat units required to warm the air. Then this quotient must be divided by the difference between the temperature of the radiating surface and that of the air when finally warmed multiplied by 1.75, the number of thermal units given off per hour by one square foot of hot water or steam-pipe for each Fahrenheit degree of heat it loses. This will give the area of hot water or steam-pipe required to warm the given volume of air. Thus, to warm 6000 cubic feet of air per hour from 20° to 70° F. will require $\frac{6000 \times (70 - 20)}{50} = 6000$ heat units, and if the surface of the radiator be 200° F., $\frac{6000}{(200° - 70°) \times 1.75} = 26.37$ square feet will be the area of radiating surface needed. To this must be added at least one-half square foot for each square foot of window glass and for each square yard of outer wall exposed.

CHAPTER V.

WATER.

NEXT to air, water is the most important of all substances necessary to human life. While it has been often demonstrated that man may do without food for a considerable length of time, even for several weeks, he can probably not survive much more than ten days without water. But not only must we have enough to supply the internal wants of the body and to replace that lost by excretion, evaporation, and respiration; but from a sanitary point of view, a plentiful supply is needed to maintain cleanliness of bodies, clothing, and dwellings, and, oftentimes, to remove sewage, excreta, etc., from the vicinity of inhabited places. The care of furnishing water in abundance and of maintaining its purity is, therefore, entirely within the domain of the physician and the sanitarian.

Before inquiring into the source whence we obtain the water that we use it will be well to know what amount is required by the body for its daily needs, and how much for other necessary purposes, so that we may be able to judge not only whether a given source furnishes pure water, but also whether it gives a sufficient supply of it.

The average adult should take from seventy to one hundred fluidounces per day for nutrition and the internal needs of the body alone—about one-third of this being a component part of the food, and the rest being taken in as drink. The writer is of the opinion that the average person does not imbibe enough water for the most healthful action of his tissues and organs. Certain it is that in most cases the plentiful use of a good drinking-water not only greatly favors the body metabolism, but also materially assists in the flushing out and carrying away of the various wastes and excreta of the system.

In addition to this we must supply a sufficiency for cooking and for washing the food, body, clothing, household utensils, and parts of the house itself, and to remove the household waste and sewage through the drains and sewers provided for that purpose. Cleanliness is an essential requisite for the preservation of health, and cleanly habits should be inculcated among all classes of people, and every facility provided for removing filth of all kinds from persons, clothes, and dwellings. This, of course, cannot be done without a fair supply of water.

Experience shows that about twenty-five gallons per head per day should be furnished for the above purposes, and as the quantity used by domestic animals, manufacturing establishments, municipal needs, etc., must be added to this, fifty gallons or even more per capita should be supplied daily, wherever it is at all possible. And though a supply that permits of excessive waste may be inadvisable and expensive, both to provide and by increasing the cost of carrying it away after use, it is always better to have too much than too little, and the disadvantages of too scanty an amount are much greater than those of one too large.

It should be stated, however, that most foreign cities are supplied with much less water per capita than is apparently needed by the municipalities of this country, and yet they seem to have an abundance for all necessary purposes and the requirements of public health. For instance, London, with a population of over five millions, has an average daily supply that but slightly, if at all, exceeds that of Philadelphia, with one-fourth the number of citizens; while Berlin, which is of about the same size as Philadelphia, had in 1893 an average daily supply of filtered water of only 18.4 gallons per head, all of which was sold to the consumers by meter, but to which must be added considerably more that was from wells and was exclusively used for manufacturing purposes, running machinery, etc. It cannot be doubted that the quantity wasted in many of the cities in this country is excessive, and that the cost of supplying that part of the total quota would go a long way toward improving and rendering pure and safe the remaining part that is absolutely needed. Whether the compulsory use of water meters is the best way of bringing about an improvement in this respect remains to be determined; but it is also a question whether our larger cities, with rapidly increasing populations, can afford to use the means necessary to safely purify the enormous quantity of water now daily supplied to their respective consumers.

As only a small portion of the quantity indicated above is required for the internal needs of the body, it has been suggested that two kinds of water be furnished—one for drinking and cooking purposes and for the washing of the body, to which especial attention as to purity should be given; and another kind for all other purposes, its composition and purity being disregarded, excepting possibly as concerns the hardness. This would enable the authorities to furnish a water purer than usual for those needs where purity is of the greatest importance, and would obviate the need of furnishing pure water abundantly for *all* purposes; but the scheme would necessitate a double set of reservoirs, mains, distributing apparatus, etc., thus materially increasing the cost; and there would always be present the danger of the careless or ignorant using the impure water for bodily needs, thus increasing the risks and bad results that we wish to avoid. Therefore, wherever there can be an abundance of pure water for all personal and domestic purposes, if the authorities but take pains to furnish it, it will be best to have but one supply in dwellings, and this as pure and abundant as money and the highest sanitary skill can make it; though there may be little or no objection to using a different water for factories, stables, city uses, etc.

As to the question of supply through meters, it may be added that the suggestion has been made that the regular charge for water begin only after a certain specified amount per month per capita or per household has been furnished free or at the lowest possible cost, thus doing away with the objection that those who need the water most for personal and sanitary uses would be tempted to economize too much if they had to pay for all they consumed. Whether a city could afford to do this would have to be carefully considered, and would probably depend largely upon local circumstances.

Sources. Practically, all drinking-water has at some time or other fallen upon the earth from the air in the form of rain, hail, snow, or dew; but when we speak of its sources we have reference rather to the place or locality from which we collect it for use. The rain on reaching the earth is disposed of in three ways: part at once evaporates and goes back to the atmosphere, part flows off according to the slope of the ground and collects in pools and streams, and part sinks into the soil. The ratio which these three portions will bear to one another will depend on the time, place, character of soil, intensity of rainfall, etc. Consequently, we may classify the sources of potable waters—as Leffmann does—as follows: *Rain-water*, collected immediately as it falls from the atmosphere, in the form of rain, dew, snow, etc.; *surface-water*, collected in ponds, lakes, streams, etc., and in free contact with the atmosphere; *subsoil* or *ground water*, derived mainly from the rain or surface water of the district, but which percolates and flows through the subsoil, and is, therefore, not exposed directly to the atmosphere; *deep* or *artesian water*, which is separated from the ground water of the district by one or more practically impermeable strata, and which accumulates at a considerable depth below the surface. Springs are caused by the outcropping of water-bearing strata below the level of the water-line in them, and furnish either subsoil or artesian water, according to the kind contained in the respective strata.

Rain-water is, theoretically, the purest at our command, but in reality it takes up many impurities from the air in its fall, especially in the neighborhood of human habitations, and communities, and by the time it reaches the earth contains ammonia, nitrous and nitric acid, and in towns, sulphurous acid, soot, many bacteria, and even microscopic plants. Moreover, the collecting surface upon which it falls is apt to be covered with dust and impurities of all kinds, especially after continued dry weather, which, being taken up by the rain-water, render it unfit for use. However, if there be some arrangement for turning aside the first portion of rain that falls, it containing the most of the impurities, and if the remainder be filtered and stored in proper receptacles, the water may be of excellent quality.

The main objection, however, to the sole use of rain-water is that dependence is placed upon a very uncertain source, and one which is especially apt to fail when an increased supply is most needed. The average rainfall in Philadelphia is about thirty-nine inches per year; in very wet years it is about one-third more, and in very dry years about one-third less than the annual average. Each inch of rainfall gives 4.67 gallons per square yard of area on which it falls, equivalent to 22,617 gallons per acre. Allowing sixty square feet of collecting surface per head, and counting the loss by evaporation, etc., at 20 per cent., an annual rainfall of thirty inches would give only about two gallons per head per day, or just about enough for cooking and drinking purposes, and none for the other needs of the household.

Rain-water may be collected from roofs or from a plot of ground paved for the purpose with slate or cement, and led by proper conduits to a cistern. It should be filtered before passing into the cistern, while the cistern itself should be such as to give no unpleasant taste or injurious substance to the water, should be so situated that it will receive no rubbish or impurities and that the water may be kept cool, and should be cleaned regularly and often enough to keep the water sweet and wholesome. As rain-water contains considerable carbonic acid and other gases, its solvent powers are marked, and cisterns should not be lined with lead, copper, zinc, or iron, lest these metals be taken up by the water and produce harmful results. These remarks do not apply to the so-called rustless iron now much used, but galvanized iron should not be used, as it may give up zinc to the water.

Cement should be used in lining brick or stone cisterns instead of mortar, as the latter may give up lime to the water and render it hard. Underground cisterns for storing rain-water should be condemned, since they are liable to sewage contamination unless absolutely water-tight. The overflow pipe from a cistern should not open into a soil-pipe or sewer-pipe or drain, but always into the open air, since water is so prone to take up the various kinds of gas with which it comes in contact, and the sewer-air might readily contaminate the entire contents of the cistern.

Rain-water is especially valuable in cooking and washing, on account of its softness, water being called "hard" when it contains an excess of the salts of calcium or magnesium in solution. Hardness due to the presence of calcium bicarbonate is said to be *temporary*, because it is removed when the water is boiled, one molecule of carbonic acid being driven off by the heat, leaving the insoluble calcium carbonate behind. Hardness due to the other salts of calcium and magnesium is called *permanent*, because it is not lost by boiling. In cooking with water temporarily hard, the chalk is precipitated upon the sides and bottom of the vessel and, being a non-conductor, prevents the passage of heat, and thus wastes fuel.

Hard water may also prevent the proper softening of certain foods, such as peas and beans, in cooking. In washing and laundry work, the calcium and magnesium salts unite with the fatty acids of the soap and prevent the formation of a lather; for instance, one grain of chalk wastes about eight grains of soap. As we do not call a water hard unless it contains more than ten grains of chalk or its equivalent per gallon, and as rain-water rarely has more than one-half a grain per gallon, it is easily understood why the latter is so valuable in the kitchen and laundry.

A water-supply taken from rivers or smaller streams not polluted by the refuse and sewage from towns, factories, or cultivated farm lands higher up the stream, may be fairly pure and safe to use. The best water of this kind will be from hilly and uninhabited, uncultivated tracts, with many small streams fed by constant springs and uniting to form rapid creeks and rivers. Such water may be tinged slightly with vegetable or mineral matters, but, in general, such coloration is harmless. For storage, dams may be thrown across convenient valleys, thus impounding the water and at the same time keeping it exposed to the oxidizing and aerating influence of the atmosphere, and allowing the solid impurities to settle to the bottom. Small lakes or ponds may be used to add to supplies of this kind, provided they be not stagnant nor have much decaying matter along their banks.

On the other hand, water from a stream which has received the sewage from a village or town of any size, or the refuse of factories, or the drainage from large tracts of cultivated land, should be considered as at least suspicious. River-waters are generally hard, and may contain any of the minerals in the soils which they drain or over which they pass; but the great danger is from impurities of animal origin poured into them along their course. It is not safe to depend altogether on the self-purification of sewage-contaminated rivers, as was formerly done, though much of the sewage and filth undoubtedly is removed, part by oxidation by the air in the water, especially in streams flowing over dams, rapids, etc., part by subsidence or deposition along the banks, part by fish and animalculæ, and much by the myriads of the saprophytic bacteria which such waters contain. If no additional pollution is added, what is left unchanged by the above purifying agencies is still further diluted by the supplies of pure water that every stream receives from springs along its banks and in its bed, and from tributary streamlets, so that, though the water may never be as pure as it was originally, it may become or, by proper filtration or treatment, be made a safe and usable water. But where the proportion of filth exceeds a certain percentage, or where sewage is being constantly added, the contained oxygen is rapidly used up and oxidation ceases, fish and animalculæ cannot live in the water for lack of sufficient oxygen, and though the heavier and larger particles of the sewage sink to the bottom or stick to the sides, they are stirred up and set in motion by any increase in the velocity of the current. The only remaining agents active in the destruction of the foul matter are the bacteria, and in themselves they are often insufficient for the task, and the water thus polluted is entirely unsafe for use.

The greatest danger from sewage contamination, however, is that it may at any time add the germs of contagious disease to the water, which, multiplying rapidly, and not being surely removed or destroyed by the ordinary methods of water-purification, greatly increase the risks to health from its use. It often, fortunately, happens that, owing to the hostility of the saprophytic bacteria of the water, or to the presence of certain chemical substances, or to other fortunate conditions, as of temperature and the like, these pathogenic organisms do not multiply as rapidly as they otherwise would, and are, therefore, not as plentiful as one might suppose; but as it never can be certainly told when a water so contaminated becomes safe for use again, and as the population of most towns and their consequent sewage production is constantly increasing, while the quantity of water in the receiving stream remains about the same, or is diminishing from year to year, the use of such water should be avoided if possible.

Water from large fresh-water lakes will be of the best quality, provided it be taken from a point sufficiently distant from the shore to escape all danger of sewage contamination. Chicago has apparently lowered the mortality percentage from typhoid fever from 7.2 in 1891 to 2.1 in 1895, and 3.2 in 1896, by preventing as far as possible the discharge of sewage into Lake Michigan, and by taking the water-supply from the lake at a minimum distance of one mile instead of 1400 feet from shore as formerly. Water from small lakes or ponds, and even from storage reservoirs, may become offensive to taste and smell through the growth in them of minute vegetable organisms, such as the algæ, though it is not known that these are prejudicial to health.

Ordinarily, water loses much organic matter as it percolates through the soil, but takes up considerable carbonic acid from the soil-air, which increases its solvent powers so that it may take up some of the mineral constituents of the soil through which it passes. When these mineral substances become so great in amount as to give the water a decided taste or medicinal properties, we call it a mineral water; but when the inorganic matter does not render it objectionable to the taste or too hard, the water, whether subsoil or artesian, will usually be considered to be quite pure.

Attention has already been called to the pollution of the soil. How then can the water in passing through it lose its organic contents and become pure? Partly by mechanical filtration, but mainly through the combined action of the saprophytic bacteria and the oxygen of the soil-air, which rapidly convert the organic impurities, both suspended and dissolved, into simpler and harmless end-products. The substances of vegetable nature are ultimately resolved by these agencies into carbonic acid, water, etc., while those of animal origin and containing nitrogen, give rise to the various ammonia compounds, or may be further oxidized into nitrous and nitric acids and their salts, all entirely harmless in the proportions in which they are found in the percolating ground-water.

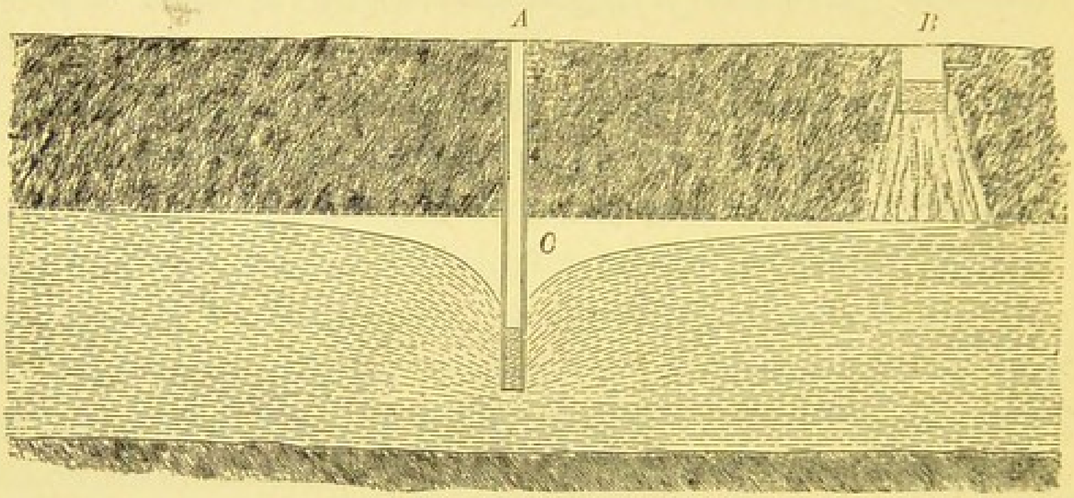
The subsoil-water sinks through the ground till at some level or other it reaches an impermeable stratum, where it is retained in natural basins or escapes at some outcropping of the stratum below the water-level, thus forming a spring. The level of the water in these underground reservoirs is constantly changing, according to the season, rainfall, discharge from springs, etc., though the variation for any given place is usually regular, and differs little from year to year. It is from wells sunk to these water-bearing strata and from springs that the majority of people who do not live in towns or cities supplied by water-works obtain their supply. These underground bodies of water are constantly moving toward outlets at some point or another, but the current is not rapid, owing to the friction and capillary force of the particles of soil through which it passes. For the same reason the surface of the water is not horizontal, but curved, the curve being sharpest near the outlet; and the difference in level between high and low water will be least near the outlet; also, the higher the level the greater the fall to the outlet, and the greater the discharge.

The above remarks regarding the purity of this underground water do not hold good for water from ordinary shallow wells, under fifty feet in depth, and which do not pass through an impermeable stratum, nor where the water passes almost directly from surface to outlet, for in both cases the complete filtering action of the soil and the removal of organic matter by the prolonged action of the saprophytic bacteria are wanting. Owing to the lessening of lateral resistance the surface-water passes almost directly into the well (unless the wall of the latter be made water-tight to almost the full depth), and may carry with it solutions of all the impurities polluting the soil about the well; and as wells drain a very considerable area—Parke says one, in ordinary soils, whose radius is equal to four times the depth of the well—there are few wells about which such an area is not subject to dangerous pollution. Moreover, the influence of pumping or other sudden withdrawal of water from the well is even more important, since it extends a distance from fifteen to one hundred and sixty times the temporary depression of the water-level, and impurities may thus be drawn into the well which would ordinarily tend to flow away from it.

Especially about human dwellings, where wells are commonly located, is filth apt to be carried into the well, for sewage and dirt of almost every kind is constantly increasing in quantity in the soil about a house, with the ever-present danger of it also receiving the specific germs of disease.

Only such parts of this pollution as can be dissolved may reach the water in the well, together with the bacteria which pass freely through almost all soils when resistance to the water current is so markedly diminished ; and it is a strange fact that many waters thus polluted are sparkling and clear, with a pleasant taste and no bad odor, so that all suspicion as to their true character may be wanting. Moreover, there is always danger that this contamination may become so concentrated as to produce very serious results, even though specific disease germs be absent, and this may occur in various ways: (*a*) The well may be so deep or the character of the soil such that in ordinary weather the liquid passing through the soil is so purified that it gives no bad properties to the water; but if the soil is being continually infiltrated with dangerous impurities, and if at last heavy rains or continued wet weather supervene, there may be more and more of these

FIG. 24.



Depression of water in shallow well by pumping. *A*, well; *B*, cesspool; *C*, underground water curve. (After FIELD and PEGGS.)

impurities dissolved and carried into the well until the proportion of harmful matter in the water passes the safety line, and we have marked illness or increased predisposition to disease among those using the water as a result; or (*b*) in continued dry weather the ground-water may be lowered to such an extent that the impurities that were formerly well diluted become concentrated and dangerous enough to cause sickness, even though there be no unusual pollution of the soil about the well; or (*c*) the water-level in the well being suddenly or persistently lowered, a greater area is drained and additional collections of sewage may empty into the well. (Fig. 24.)

Deep wells are those over fifty feet in depth, or which go through an impermeable stratum, and do not get their supply from the subsoil-water. Artesian wells are very deep wells, piercing one or more impermeable strata.

Sometimes the water rises and flows out of the mouth, in which case the well draws its supply from a water-bearing stratum between two impermeable ones, and which has its only outcroppings higher than the top of the well. The water accumulates in this natural reservoir above the level of the well-mouth, and is forced out as soon as the opening pierces the uppermost impermeable stratum. It is apt to be of much better quality than that from shallow wells, since it usually represents the total percolation through an extent of ground surface in comparison to which the combined areas of pollution within its limits are insignificant, the percentage of impurities in the water being consequently reduced by dilution to much below the danger point. It is for the same reason that there is such a difference in the quality of spring-water and that from most shallow wells. Though they seem to have a common source, one is the composite water of a large district, of which the average impurity or contamination per unit of surface may be infinitesimal; the other is the special percolate from a limited area which is, for the reasons given, particularly liable to be highly and dangerously polluted.

Artesian or deep-well water will also likely be very free from organic matters, but possibly heavily charged with mineral salts. Should these latter not be present, the water will probably be of excellent quality, though if the well be very deep, it may be too warm for immediate use as a potable water.

Frequently well-water, and that most often from shallow wells, is the only kind available, especially in country districts. In such cases care must be taken that impurities are kept out of the well by all possible means, and if this be done, water may often be had of safe and excellent quality. The area about all wells should be kept clean and the sources of all possible contamination removed. Wells should be walled or cased, shallow wells to the water-level, and deep wells to the first impermeable stratum if possible, in order to cause the water to percolate through as much soil as possible before entering the well. Wells should also have a good curb to keep out splashings and drippings of muddy or dirty water.

The well should be as far as possible from any source of contamination, especially if the latter be a constant one. We must not forget that wells drain a large area. As the ground-water has a constant movement in the direction of natural outlets, the well should be so located that the current flows *from* it toward any near-by cesspool or other source of pollution. The direction of the underground current can generally be determined by noting the location of the nearest spring or water-course, by observing the dip of the underlying strata, or by digging holes about the well and dissolving salt or an aniline dye in them in turn and testing the water from the well after a time for the salt or color. If a well be much deeper than a neighboring cesspool, it may drain from the latter, even against the ground-water current, especially if the water in the well be suddenly lowered. Again, dangerous impurities have sometimes been carried into wells from long distances through fissures or crevices in the rock.

The water from the well should be frequently tested for chlorides and nitrates, these indicating sewage contamination, and this should be done especially after heavy rains and also when the water in the well becomes low. The taste and odor of the water should also be noted after standing or being heated. Some other source should be sought whenever the tests show contamination, or when there are cases of infectious disease near at hand. Boiling the water and filtration are always to be recommended.

Wells in thickly settled towns should not be used to supply drinking- or cooking-water, as the soil is always more or less saturated with filth and sewage, and it is practically impossible in such places to locate a well which will not be in constant danger of receiving harmful impurities.

The decision as to the quality of any water must in each case be determined by all the circumstances available which relate to it, and these should all be thoroughly investigated before rendering an opinion, as some of them may counteract the others. However, other things being equal, the value of a water will probably be in accord with the following table:

Wholesome	1. Spring-water,	Very palatable.
	2. Deep well-water,	
	3. Water from unpolluted streams,	Moderately palatable.
Suspicious	4. Stored rain-water,	
	5. Surface-water from cultivated land,	palatable.
Dangerous	6. Sewage-polluted river-water,	
	7. Shallow well-water.	

A good potable water should be perfectly clear, free from odor or taste, cool, well aerated, and, if possible, soft, or with only a mild degree of hardness. Circumstances must determine the amount of dissolved matters permissible; what is an excess in one case might not be so in another.

We may also classify waters as follows: 1. Pure and wholesome water. 2. Usable water. 3. Suspicious water. 4. Dangerous water. (See table on page 179.) Pure waters and usable waters may be used without filtration; those of the third class should be filtered before distribution, and also at the house before use, if possible, and a purer source sought out or all sewage-pollution prevented. Those of the fourth class should not be used at all except when it is absolutely unavoidable, and then only after purification by all the means at command.

Inasmuch as most large cities must from necessity furnish a water of the second or third, and occasionally even of the fourth class, such water should be purified as much as possible before distribution, by storage for a time in settling reservoirs and by some effective system of filtration, combined with chemical treatment, if necessary. As much of the organic matter is oxidized, and many of the pathogenic bacteria are destroyed by saprophytes and other causes while the water is standing in the settling-reservoirs, a water originally suspicious or worse may often be made quite usable by the above means properly employed. Not only must the storage reservoirs and filtering apparatus be kept clean, but care must be had that the distributing apparatus does not allow soil- or sewer-air or sewage to be drawn in through leaks in the mains at times when the flow is intermittent, and that lead pipes are not used in the houses if the character of the water is such that it acts on that metal.

Diseases Caused by Impure Drinking-water. A polluted water may carry the organisms of infectious diseases, or it may produce or favor the development of diseases which are not due to specific germs. In addition to this, and of at least equal importance from a sanitary point of view, is the depressed state of the system that the habitual use of impure drinking-water causes, and the predisposition to disease that ensues. By the power of accommodation and through long habit, a community may become so protected against an impure water as to manifest no striking symptoms, while strangers may be seriously affected by it; but even in such a case, the condition of those habitually using the water will be apt to be depressed and far from good.

The non-infectious diseases likely to be caused by impurities in the drinking-water are primarily those affecting the alimentary tract, as dyspepsias, diarrhœas, and other disturbances having their origin in severe gastric or intestinal irritation. So, also, impure water, even though it do not contain the actual germs, may have much to do in bringing on an attack of specific dysentery by so irritating the lower intestine as to make it especially receptive to the cause of the disease when introduced from another source.

Large quantities of the sulphates of calcium and magnesium are thought to have special influence in causing dyspepsias, with loss of appetite, pain at epigastrium, etc. An excess of iron in water is also prone to produce constipation, headache, loss of appetite, and malaise. Goitre and the formation of vesical calculi are each supposed to be due to mineral or inorganic impurities, though the true relation of impure drinking-water to these diseases is still unsettled. "It has long been a popular opinion that drinking lime-waters gives rise to calculi of the oxalate and phosphate of calcium," and the "opinion that impure water is the cause of goitre is as old as Hippocrates and Aristotle." Further study of the principles underlying the new treatment of goitre with glandular extracts may make it easier to determine whether bad water has or has not a causative influence in the production of the disease.

Diarrhœa may be produced by any of the following impurities in water: Suspended substances of any kind, but especially those of fecal origin; dissolved animal, vegetable, or mineral matters, and fetid gases. The diarrhœa produced by any of these contaminants may be so severe as to simulate true dysentery and cause doubt as to the diagnosis.

Certain metals may be taken up from the earth's strata, or from the lining of cisterns, and may produce their characteristic and poisonous symptoms in the system. Lead is one of these metals, and it will be well to note here the waters that are especially apt to take up this metal. Pure waters and those containing much oxygen act most powerfully on lead, as do those containing organic nitrates and nitrites, especially ammonium nitrate. Waters containing carbonic acid and the salts of lime and magnesia and those free of absorbed gases act least on lead, and carbonic acid seems even to protect lead by forming an insoluble carbonate on its surface. Lead is more easily dissolved if other metals are in contact with it, probably owing to electrolytic action. Lead should not be used for pipes nor to line cisterns unless suitable tests show that the water does not affect them, nor should any water be used in which the tests show more than one-twentieth of a grain of lead per gallon. Even water containing carbonic acid may take up lead for a time from new pipes until the insoluble carbonate is formed within them.

Of the infectious diseases, germs of typhoid fever, cholera, dysentery, and malaria are usually carried into the system by the drinking-water, while the same is often true of yellow fever, scarlet fever, diphtheria, and kindred diseases. But, as with the impurities causing non-infectious diseases, water containing disease germs may sometimes be used for a long time by those accustomed to it without the development of the specific malady, and it may only be after the system is weakened by excesses or other predisposing conditions that the diesase manifests itself; or it may happen that only strangers and non-acclimated inhabitants incur the disease. It has been suggested that this immunity is probably brought about by the very gradual introduction into the body of the disease germs and their poisons, so that old residents are not susceptible to the quantities of either of these which are sufficient to give rise to the particular diseases in new-comers.

Many instances have been recorded which practically prove the transmissibility of infectious diseases by means of drinking-water, and of these reference may be made to the epidemics of typhoid fever at Lausen,[1] in Switzerland, and at Plymouth, Pa.;[2] of malaria on board the transport ship "Argo";[3] and of cholera in London.[4] The writer himself had an opportunity of investigating an epidemic of typhoid fever in a small village in North Carolina.[5] In this there were only four or five in about sixty cases which were not undoubtedly due to the contamination of the subsoil-water by the infected excreta from the first case; and of four exceptions, which were all in one family, the first was in all probability infected while in attendance upon sick neighbors. It was also shown that with the exception of these four, the cases all developed directly along the lines of natural drainage leading from the residence of the original case—a boy, who came to the village sick with the disease—and that the latest cases to develop were those most remote from the starting point of the infection.

Moreover, in most large cities of this country the

[1] Pepper's System of Medicine, vol. i. p. 250.
[2] Rohé's Text-book of Hygiene, 2d edition, p. 63.
[3] Parke's Hygiene, 8th edition, p. 64, and Rohé, p. 60.
[4] Rohé, p. 64. [5] University Medical Magazine, May, 1892.

typhoid fever death-rate is accepted as the direct index of the character of the water-supply; and it seems to be a fact almost without exception, that any marked improvement in the latter will be followed by an immediate and positive reduction in the former. The same may also be said to hold good in regard to diarrhœal diseases, while in eastern North Carolina there has been a very marked reduction in the prevalence of malarial fevers as a result of the efforts of the State Board of Health to persuade the people to substitute rain- or deep well-water for the subsoil-water, which was almost universally used a few years ago.

The ova of certain parasites, such as tape- or roundworms, may often be taken into the system with the drinking-water, and these upon developing may cause disturbances more serious than the slight attention usually given to them would seem to indicate. Any attack of convulsions in a child or other manifestation of severe reflex action should lead to the inquiry as to whether these parasites may not be present and whether the water-supply has not been a source of invasion.

Regarding the foregoing remarks, Parkes makes the following statements: "1. An epidemic of diarrhœa in a community is almost always owing to either impure air, impure water, or bad food. If it affects a number of persons suddenly, it is probably owing to one of the last two causes, and if it extends over many families, almost certainly to water. But as the cause of the impurity may be transient, it is not easy to find experimental proof. 2. Diarrhœa or dysentery constantly affecting a community, or returning periodically at certain times of the year, is far more likely to be produced by bad water than by any other cause. 3. A very sudden and localized outbreak of typhoid fever or cholera is almost certainly owing to the introduction of the poison by water. 4. The same fact holds good in malarial fevers, and, especially if the cases are very grave, a possible introduction by water should be inquired into. 5. The introduction of the ova of certain entozoa by means of water is proved in some places, probable in others. 6. Although it is not at present possible to assign to every impurity in water its exact share in the production of disease, or to prove the precise influence on public health of water which is not extremely impure, it appears certain that the health of a community always improves when an abundant and pure water-supply is given; and, apart from this actual evidence, we are entitled to conclude from other considerations that abundant and good water is a prime sanitary necessity." The statistics already given and those to come in later pages are confirmatory of the correctness of this last assertion; and sanitary authorities now realize that the main cause of an increase in the death-rate of diarrhœal diseases is more often to be fairly attributed to a bad water-supply than to improper food or untoward temperatures. Even with respect to cholera infantum (which is generally supposed to be principally due to the influence of excessive heat upon the infant and its food), a number of epidemics show a closer relation to impure water-supply than to temperature changes.

The Purification of Water. Impurities in water may be either solid matters in suspension, or dissolved substances, and may be organic or inorganic. Any turbidity is due to solid particles, and water free from these is clear, though it may have a color more or less deep from dissolved matters. Moreover, a clear water may contain such solid bodies as bacteria, ova of parasites, etc., which are too minute to be seen with the naked eye. Whether harmful or not, all impurities should be removed in so far as is possible from all supplies of drinking-water. This may be done to a considerable extent with large volumes of water before it is distributed to consumers, and should always be attended to by the latter if the water is not already clean and within the limits of safety when they receive it. In fact, a large city at the present time can scarcely have a more important subject for consideration than that of obtaining the purest possible water-supply for its people. There is always a tendency among many to allow matters to continue as they are, or as they have been in the past; and a decided objection by others to incurring additional expense for what may seem to them only æsthetic reasons; but, no matter what may be the cost of providing a reasonable supply of pure water for any large city's personal and domestic uses, a very little consideration will show that such expenditure is true economy from solely a financial point of view, even though we ignore the misery and sorrow of the sickness and deaths that are due to the use of a polluted water.

As has been stated by the excellent authority quoted above, "the health of a community always improves when an abundant and pure water-supply is given." "The death of 3400 persons from cholera followed the temporary supply of unfiltered water by the East London Water Company in 1866, while the rest of London remained nearly free from the disease," and in 1892 "Hamburg lost 8605 citizens from the same disease alone," regarding which "the health authorities found that the principal cause of this epidemic was the polluted water-supply."[1]

[1] Hazen: The Filtration of Public Water Supplies, 1895.

Again, after the scourge of typhoid fever in Plymouth, Pennsylvania, in 1885, when there were 1104 cases and 114 deaths within a few weeks in a population of 8000, as a result of the pollution of the water-supply by a single person, great care was taken to determine the exact cost of the "visitation," as some would term it. It was found that the actual expenditure for the care of the sick was $67,100.17; for loss of wages by those recovering, $30,-020.08; a total of $97,120.25, to which should be added a number of times the $18,419.52 that those who died were earning per annum when taken sick. How much cheaper in comparison would a protecting filter-plant have been! But overlooking special epidemics, and considering the *average* annual typhoid death-rates of our cities, we find that experience both here and abroad shows that with a pure water-supply a fair death-rate from this disease is 25 per 100,000, and that any city may reasonably expect to secure such a rate by observing proper precautions. And yet only eight cities of over 50,000 population whose mortality returns were given in the United States Census Reports of 1890 had so low a figure. On the other hand, there were five cities of over (and two of less than) 50,000 that had 100 or more deaths per 100,000, all using unfiltered river-water. The remaining forty-one of those above 50,000 had rates varying from 26 to 98. Counting each death as a loss to the community of $5000—not an excessive estimate according to the finding of courts, and since most typhoid cases occur during the working age of from fifteen to fifty years—"the saving due to filtration" on the unnecessary deaths from typhoid fever "would have paid for the entire cost of filters in the first year they were in use" in the first seven of these cities; "in sixteen others, with an aggregate population of 3,717,560, filtration would have paid for itself in two years or less," and in "eighteen others with an aggregate of 3,238,617, filtration would have saved seven or more lives per 100,000 annually, and would have more than paid for the interest and cost of operating the filters."

Lawrence, Mass., with a population of 44,654 in 1890, built a filter at a cost of $67,000, and saved enough lives, at $5000 per head, to pay for it within the first four months that it was in use. In Chicago, when the similarly estimated loss from typhoid deaths in the city and suburbs amounted to over $10,000,000 in 1891, the abandoning of a shore inlet near the mouth of the sewage polluted Chicago river in 1892 resulted in a reduction of 60 per cent. in the typhoid mortality during the following year. Philadelphia also had a typhoid-fever mortality rate of 40 per 100,000 in 1895, and of about 32 in 1896 and 1897, representing a preventable death-loss, as above calculated, of from $400,000 to $850,000; whereas an extremely competent authority has estimated (September, 1896) that the first cost of installing filters with all necessary accessories capable of giving an average daily supply of 100 gallons and a maximum of 150 gallons per capita for the whole population would be only about $3,000,000, and that the annual expense for operating these filters would only be $166,000, the total annual outlay on the whole capitalization thus being actually less than the death-loss from one disease for one year. Nor must it be forgotten that these figures do not include the cost of medical attention and nursing, nor the loss of time and employment by those that recovered, nor do they consider the financial loss due to sickness and deaths from other diseases than typhoid fever that may be fairly credited to polluted water-supplies. Can any one doubt where true municipal economy lies, and is there not abundant opportunity for sanitary education and work in this direction alone for many years to come?

Purification before distribution may be by either or all of three methods: subsidence, chemical treatment, and filtration.

The first method consists in allowing the water to stand in large reservoirs till the greater part of the suspended matters have fallen to the bottom. If sufficient time be given, much of the organic matter, whether solid or dissolved, will be decomposed or reduced to simpler compounds by the action of the sunlight, oxygen, animalculæ, saprophytes, etc. Most of the bacteria, also, especially the pathogenic species, will disappear either by sedimentation or by death from lack of favorable conditions. Consequently, a water originally quite impure may be much improved by this method alone, while if it is used in conjunction with and preliminary to filtration, it will be additionally advantageous, in that it reduces the cost of the latter by lessening the frequency and cost of cleaning the filters.

What the capacity of the reservoirs and the time of storage should be depends on circumstances. If it is the only method of purification employed, and especially if the water is very foul, the longer the time of storage the better. Again, if the source of supply is variable in output, or if it is liable to excessive pollution for limited periods, the capacity should be such, if possible, that water need not be collected during the emergency. On the other hand, if the water is to be subsequently filtered, the capacity of the reservoirs and time of storage need not be so great. Most German authorities on filtration hold that sedimentation for twenty-four hours or even less is sufficient, most of the solid matters being precipitated within that time, if at all, and the filters being relied upon to remove the remainder, especially the finer particles and the bacteria. The English practice is to store the water for a longer time, though local causes related to the source of supply are the reason for this. Thus the Lea and Thames, from which the London companies take much of their water, are subject to extra pollution in times of flood, which are usually of short duration, and a sufficient reserve for such periods is of obvious value.

All storage reservoirs should, of course, be kept free from extraneous contamination and should be cleaned from time to time. Weeds should be destroyed, as they sometimes give a bad taste to the water. The water may also have a bad taste or odor from algæ and other species of minute plants, which especially favor a pure water exposed to sunshine. They are not known to be harmful, but it may be necessary to cover the reservoirs to get rid of them and their unpleasant properties.

Where a water is very hard or contains an excess of mineral matter, it is frequently of advantage to treat it chemically. If the hardness is due to the bicarbonate of calcium in excess, it may be removed by the addition of a solution of calcium hydrate to the water, the *insoluble* carbonate of calcium being formed and precipitated. The change is represented by the equation: $CaOCO_2CO_2 + Ca(HO)_2 = 2CaCO_3 + H_2O$. Clark's process, based on this reaction, is as follows: About fourteen or fifteen hundredweight of lime is allowed to each million gallons of water, the actual quantity of lime depending on the amount of carbonate in the water. The lime is slaked in a tank into which the water to be treated flows; the mixture is well stirred and then allowed to stand for twelve hours, when the supernatant water is drawn off, the tank cleaned and the process repeated. The water is not only softened in this way, but the precipitate usually carries down with it much of the solid impurities and organic matters in the water. This process is extensively used in England, where much of the available water is derived from the underlying chalk beds, and thus has a superabundance of the bicarbonate; but the writer is unaware that it finds any general application in this country, though it might be an advisable method of treatment in certain of our limestone districts.

If alum (sulphate of alumina) be added to an impure water, a decomposition of the salt occurs, the acid portion combining with the bases in the water and forming a flocculent precipitate of insoluble basic sulphates and aluminum hydrate, which entangles in it and carries down the suspended impurities in the water, besides removing much of the dissolved organic and coloring matters. Moreover, careful experiments have shown that the addition of only about one grain of alum per gallon, followed by thorough agitation and subsequent settling for twenty-four hours, will almost invariably give a water free from germs and one that will tend to remain sterile for a considerable time; this possibly being due to the removal of the food-supply of the bacteria.[1]

The use of alum is especially advantageous when a water contains a very fine silt or the like in suspension, and which is not removed by subsidence even after a considerable time. It is also to be used in conjunction with or preliminary to mechanical filtration, which latter, at the usual rate of operation, is oftentimes practically de-

[1] V. and A. Babes: Centralblatt für Bakteriologie und Parasitenkunde, 1892, vol. xii., No. 45.

pendent upon alum for the furnishing of a safe water. Comparatively little alum is needed, usually not more than one, or at most two, grains per gallon, even with a very dirty water, and if the supply is practically adjusted to the condition of the water, as it should be, the extremely minute quantity of free alum that may sometimes pass through the filters is harmless and unimportant.

Should the water be lacking in sufficient bases, which, however, is extremely improbable, it might contain when filtered a very little free acid, which would be readily neutralized by the addition of a correspondingly small quantity of soda, the resulting salt affecting neither the healthfulness nor the palatability of the water. It has been suggested that the alum be first decomposed by the addition of soda, then washed free from the resulting sodium sulphate, and the flocculent hydrate of alumina added to the water, thus avoiding the danger of either free alum or acid in the cleared water; but experiments show that the results are not as good as when alum alone is used.

Regarding the danger from the use of waters purified by the addition of alum, Hazen says: "Although alum in large quantities is undoubtedly injurious to health, it is neither a violent nor a cumulative poison; and the proposition that one part of alumina in a million parts of water is injurious to health must be regarded as conjecture rather than as a matter of proof, or even of probability."

The Anderson process, which consists in the agitation of the water with metallic iron before filtration, is employed at Antwerp and elsewhere; but it is not clear that, with large quantities of water, better results are obtained than by simple filtration. The idea is that some of the iron is converted into soluble ferrous carbonate, which then oxidizes to insoluble ferric hydrate and carries down with it the suspended and many dissolved impurities, and thus facilitates their removal by sedimentation and filtration. The difficulty in using this process on a large scale seems to be that the carbonate is not formed quickly enough, and also that too much of the iron may remain in solution even after filtration.

Filtration. For the purification of large quantities of water, such as are needed for great cities, there can be no question that sand filtration is, in the majority of cases, the most available, satisfactory, and efficient method, though it may often be advantageously preceded by sedimentation or by chemical treatment, as already described. The former especially, by removing much of the suspended matters, will prolong the use of the filters between cleanings, and thus materially lessen the cost of maintenance; while the latter may greatly improve the chemical quality of the filtered water.

Municipal filters of the type to be described are as yet not widely known in this country, but they have been used abroad with increasingly good results for upward of half a century, and they now furnish the daily supply of water to more than twenty millions of people. However, we may take credit in the knowledge that the most thorough and scientific investigation of their action and efficiency has been made on this side of the Atlantic under the auspices of the Massachusetts State Board of Health, and that it is to this body that we are indebted for much of the positive information that we now have concerning them.

The limitations of this work do not permit a full discussion of the principles or merits of such filters; but the following details are given that the reader may appreciate the simplicity of their construction and the efficiency of their work. Those desiring more extended information are referred to the Massachusetts reports that discuss this subject, and to the excellent work of Dr. Hazen, already mentioned,[1] from which many of the accompanying statements and the illustrations have been taken.

Almost without exception these filters now consist of a layer of clean sand of a certain degree of fineness spread upon a layer of gravel in a carefully prepared basin, the whole being underdrained and proper arrangements made for the controlling of the depth of water upon the surface, rate of flow of the filtrate, cleaning of filters, etc.

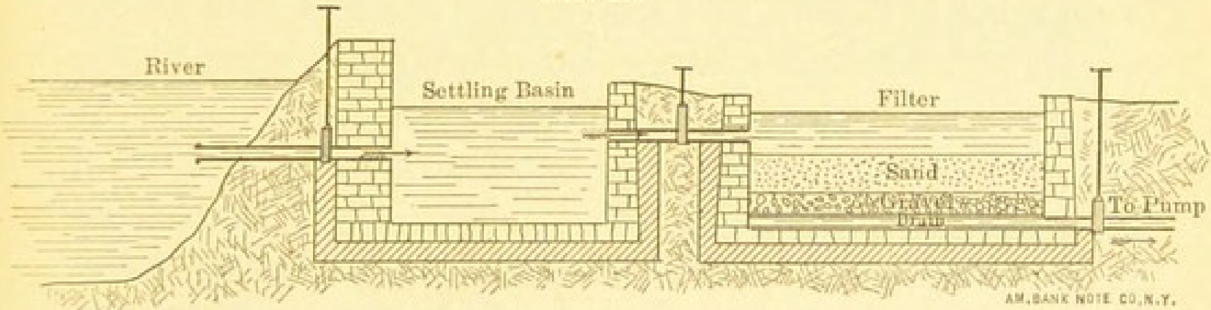
Such filters act primarily as strainers to remove the solid impurities from the water, but their efficiency is much increased by the sediment itself that is retained upon the surface of the sand, and which forms a filter much finer than the latter and is capable of mechanically preventing the passage of most of the bacteria always present in a surface-water. It was supposed until comparatively recently that this removal of the bacteria was largely due to the organisms themselves in the sediment layer, and that by forming a felt-like growth they not only increased the fineness of the strainer, but that by acting as saprophytes they decomposed much of the organic matter, and even killed the pathogenic bacteria. However, it now seems probable that for continuous filters the action is mainly mechanical, removing suspended matters and bacteria, and but slightly affecting the dissolved organic matters. On the other hand, in intermittent filtration, where the conditions more nearly resemble those taking place in the soil, and where the

[1] Filtration of Public Water Supplies.

filters are periodically aerated, the straining action is less perfect on account of the greater rate of filtration necessary, but the nitrification and destruction of organic matter due to the action of the saprophytes and oxygen are greater. Intermittent filters might, therefore, prove to be the better for the purification of sewage or a very impure water, though usually their efficiency in removing bacteria seems to be inferior to that of continuous filters.

The location of the filter beds with respect to the source of supply and the storage reservoirs will depend largely on local conditions, economy in cost of pumping, etc. Settling tanks are almost essential where the water to be filtered is very turbid, even at intervals. Reference has

FIG. 25.

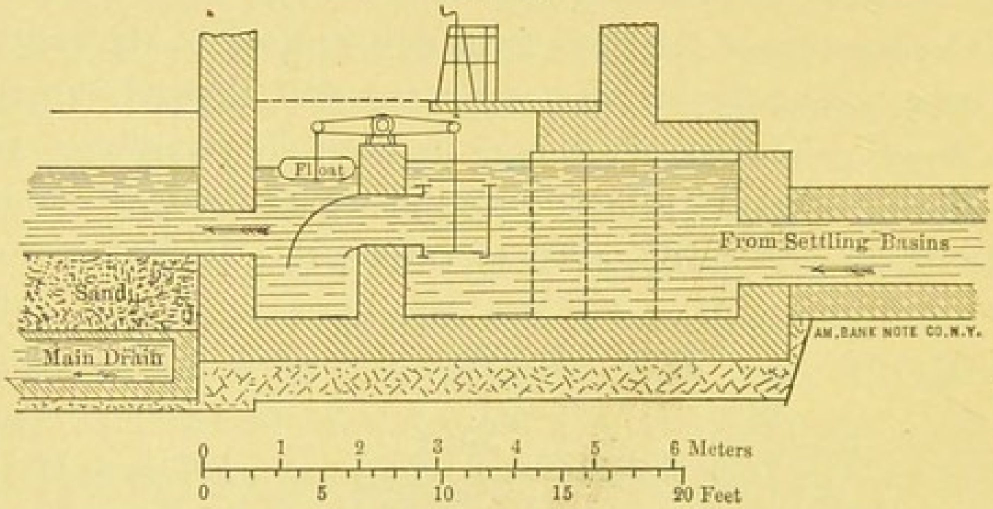


General arrangement of filter plant.

already been made to the difference of opinion between English and Continental authorities regarding the size of these settling basins. As the filtration does not remove hardness due to dissolved matters, it may also be advisable to use the Clark process previous to sedimentation and filtration. Part of the color due to peat or vegetable matters is removed by ordinary filtration, and still more may sometimes be taken away by the previous addition of alum, but such preliminary treatment is unusual. Where the water comes from a lake or from a river with a slow current, settling basins are, of course, unnecessary.

Inasmuch as it is needful to govern the depth of the water upon the filter-beds, and to prevent the disturbance of the sand and sediment layer by the force of the entering current, some method of regulating the inflow is necessary. The accompanying illustration shows a comparatively simple arrangement for this purpose.

FIG. 26.



Regulation of inflow used at Hamburg.

The total area of the filter-beds will depend upon the amount of water needed, the rate of filtration, and the percentage of area out of use while being cleaned. The total area is to be divided into beds varying in number according to circumstances, so that one or more of these beds may be cleaned while the rest are in use. Large beds decrease the cost per acre, on account of less masonry, etc., being needed, but it may be more difficult to maintain an even action over the larger areas. This latter point is, however, largely governed by the size and arrangement of the underdrains.

The walls and bottoms of filter-beds should be made water-tight, that there may be no waste of the filtered water on the one hand, nor any ingress of foul soil-water on the other. The form of the filter-bed is immaterial, provided evenness of work over the whole area is not impaired. Where the mean January temperature is below the freezing point the beds should be covered, as the formation of ice upon them seriously impairs their efficiency, and as, moreover, a number of epidemics of typhoid fever and certain intestinal diseases seem to be directly traceable to ice-formation. This may have been on account of the overtaxing of the filters through increased difficulty in working, or because the sedimentation layer and the sand were disturbed in the removal of the ice.

As already stated, the materials used practically everywhere are clean sand and gravel, and the sharper the sand-grains the better. At the Lawrence Experiment Station of the Massachusetts State Board of Health "the size of a sand-grain is uniformly taken as the diameter of a sphere of equal volume, regardless of its shape." Moreover, as it is "the finest portion which mainly determines the character of sand for filtration," the *effective size* is taken to be "the size of a grain such that 10 per cent. by weight of the particles are smaller and 90 per cent. are larger than itself." As uniformity of grain is also important, the *uniformity coefficient* is "the ratio of the size of grain which has 60 per cent. of the sample finer than itself to the size which has 10 per cent. finer than itself." Obviously, the velocity of water through a layer of sand will depend upon the effective size of the sand, the thickness of the layer through which the water passes, and the loss of head or frictional resistance of the sand. A rise of temperature also causes a progressive increase in velocity.

The effective sizes of sand-grain in use in most of the foreign filters average from 0.31 to 0.40 mm. In general, it may be said that the finer the sand, the better is the quality of the normal filtrate and the less the danger of an unsafe effluent in case the sediment layer is broken; but, on the other hand, cost of filtration increases with the smallness of sand-grain, since the filters must be cleaned oftener and fine sands are harder to wash, as well as because the velocity of flow is slower through fine sands. All things considered, the best results will probably be obtained with a sand having an effective size of from 0.20 to 0.35 mm. and a uniformity coefficient of not more than 3, the lower the latter the better, and the selection of the former depending largely upon the character and clearness of the water to be filtered.

The thickness of the sand layer should be such that it may be scraped a number of times before becoming so thin as to require refilling. The German Imperial Board of Health requires a thickness of at least twelve inches after the last scraping; while the original thickness should be from twenty-four to forty-eight inches, the thicker the better, provided the cost of the filter be not made too great and the rate of filtration be not too much diminished. The sand should be of the same degree of fineness throughout.

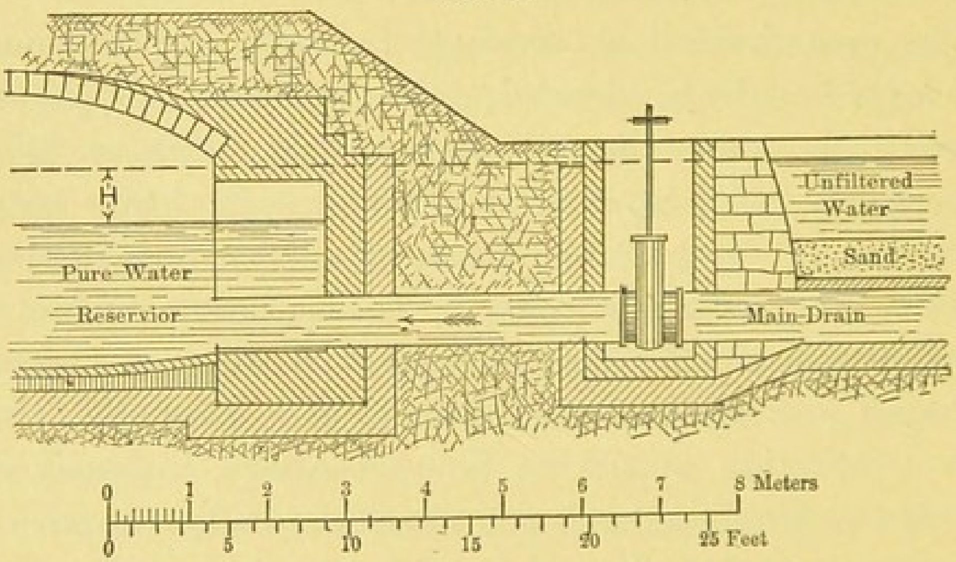
As for the gravel beneath the sand, there is no reason why it should be of excessive thickness. A depth of one foot is probably sufficient, provided the stones are of varying size, so arranged that the sand above will not work into and through the interstices, and that the water may freely enter the underdrains at low velocity. The loss of head in water flowing through a thin layer of gravel properly placed is comparatively slight. Foreign filters do have a gravel layer of two feet or more in thickness, as a rule, but careful experiments at Lawrence, Mass., show that this depth is entirely unnecessary, provided that the gravel is properly laid as indicated, and that the underdrains are not too far apart.

The underdrains should be of such size and so constructed that the frictional resistance which they offer to the flow of the water is only a small percentage of that of the clean sand, and that the rate of filtration is the same over the whole area of the filter. There is usually a main drain along the middle of the filter floor with smaller parallel lateral drains leading into it at regular intervals. The drains may be made of brick with open joints, or, for the laterals, of tile, which is usually cheaper. Care must always be had that the openings are sufficient in number and size freely to admit the water.

The area drained should vary from about 300 square feet for a four-inch lateral drain to 4400 square feet for a twelve-inch main, the velocity of flow in these being respectively 0.30 and 0.51 foot per second; while larger drains should have a cross-section of at least one-six-thousandths of the drained area. The European custom of ventilating drains by means of pipes passing up through the sand and water above is not to be commended, since such ventilation apparatus is unnecessary, increases the cost of the filters and, what is worse, may allow impurities to contaminate the filtered water in the drain. Recently it has been suggested that the filter-beds be constructed directly over the storage reservoirs for the filtered water, the beds being supported on suitable steel columns resting on concrete foundations in the bottom of the reservoirs. The bottom layer of gravel or broken stone would rest on steel tubes or bars several feet above the level of the water in the reservoir, thus allowing the filtrate to be aerated as it falls through the intervening space. Theoretically it would seem that the plan is a good one, and actual results indicate that it practically is so. Some of the advantages are the absence of underdrains and loss of the resistance factor due to them, the aeration of the filtrate as indicated, and also the practically continuous aeration of the filter-bed itself, thus enabling the saprophytic bacteria in the upper layers to carry on their work of oxidizing and nitrifying the organic impurities of the water.

The depth of water upon the filter-beds must be regulated according to the rate of flow desired, the thickness and resistance of the sand, etc. Although it has been the

FIG. 27.



Simplest form of regulation. Stralau filters at Berlin.

custom to keep the depth in excess of the loss of head, this is not essential. On foreign filters the usual depth is from thirty-six to fifty-two inches, though less than this might suffice in many instances. The necessity of regulating the inflow and of maintaining a constant level must not be overlooked if uniform results are desired.

Summarizing the preceding statements, the rate of filtration and loss of head will depend upon the depth of water on the filters, the thickness of the sand-layer, size of sand-grains, resistance of underdrains, temperature, etc., and all these will likewise affect both the cost and the efficiency of the filtration.

Two million gallons per acre per day will probably be a safe rate of filtration to maintain continuously, though with a clear water or in emergencies a rate one-half greater will very likely not materially alter the quality of the filtered water or increase the risk. But in general, as the rate increases the efficiency decreases. Where the filters are constructed above the storage reservoirs in the manner described, it is claimed that much larger quantities of water may be filtered in the given time with equally good results. If this be so, it is probably due to the increased saprophytic and oxidizing action resulting from the continuous aeration of the filter.

As the sediment accumulates and deepens upon the surface of the sand, the rate of flow necessarily diminishes, and it becomes necessary after a time to remove the deposit. This is done by carefully scraping off the top layer of the sand to the depth of from one-half to one and one-half inches, repeating the scraping as often as may be necessary until the thickness of sand above the underlying gravel is near the permissible minimum. Then the sand which has been removed, and which has meanwhile been thoroughly washed by a stream of the filtered water, driven, if necessary, by a force-pump is carefully replaced, packed, and levelled upon the beds. However, these do not attain their greatest efficiency until a certain amount of sediment from the water has collected upon them, and it is, therefore, not wise to use the filtered water for some time after the cleaning and until bacteriological tests show that the maximum purification is being attained.

Domestic Purification of Water. Boiling destroys living organisms and disease germs; it also drives off the carbonic acid and other gases of the water, and causes the precipitation of many mineral substances held in solution by these gases. This is especially the case, as has been stated, where the water is hard from the presence of calcium bicarbonate in excess, but iron is also often thrown down by boiling. If the water contains a very fine sediment, not removed by settling or filtration, it may be advantageous to add a little alum and chalk to produce the flocculent precipitate already described. Potassium permanganate has little effect in purifying a foul water. Agitation with iron filings may do a little good by favoring oxidation of organic matters. Tannin is thought to destroy micro-organisms, and a harmful water may sometimes be made usable by boiling with tea leaves or other astringents. Citric acid is said to destroy algæ. Aeration and agitation improve a water after distillation or boiling by restoring oxygen and also by oxidizing organic matters. Remember that boiled water is prone to take up gases of any kind, whether impure and offensive or otherwise. Organic matters are got rid of by boiling, exposure to air, agitation, addition of alum, astringents, charcoal, etc.; bicarbonate of lime, by boiling or by adding caustic or slaked lime; iron, by boiling and by adding lime-water. Calcium and magnesium sulphate and chloride cannot readily be removed. Some plants help to purify by means of the oxygen which they give to the water.

House filters are dangerous unless properly cared for, and may give more and worse impurities to the water than they take from it. What a filter takes from a water is left in the filter, unless otherwise removed, and an accumulation of such impurities cannot improve the water passing through them. The organic matters will undergo decomposition and putrefaction, and will furnish a good culture medium for bacteria, and these together with the putrefaction products will, in most cases, be carried through the filter with and by the filtered water. A filter has no miraculous power to annihilate filth, and, moreover, the size of a filter must always limit the work it can do, whatever the materials used.

According to Parkes, the requisites of a good filter are: 1. That every part shall be easily accessible for cleansing or renewing the medium. 2. That the filtering medium have a sufficient purifying power and be present in sufficient quantity. 3. That the medium give nothing to the water favoring the growth of low forms of life. 4. That the purifying power be reasonably lasting. 5. That there be nothing in the construction of the filter itself capable of undergoing putrefaction or of yielding metallic or other impurities to the water. 6. That the filtering material

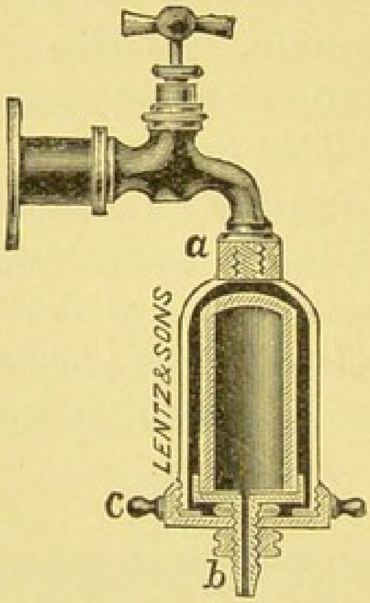
FIG. 28.

Tubes of unglazed porcelain for Pasteur filter.

shall not clog, and that the flow of water be reasonably rapid; to which may be added: 7. That the filtering medium be such that it can be readily cleansed and sterilized, or else so cheap that the removal and replenishing may not be neglected when necessary on account of the expense.

House filters may be divided into three classes: (*a*) Those entirely disconnected from the water-supply pipes of the house; (*b*) those connected with the water-pipes, but intended to filter only a limited quantity, as for drinking, cooking, etc.; (*c*) those connected with the house service-pipe and intended to filter all the water used in the house. The same filtering media may be used in all three classes, but it will be found best in the first two to employ substances through which the water passes slowly, while the latter class must necessarily filter the water more rapidly in order to yield a sufficient supply.

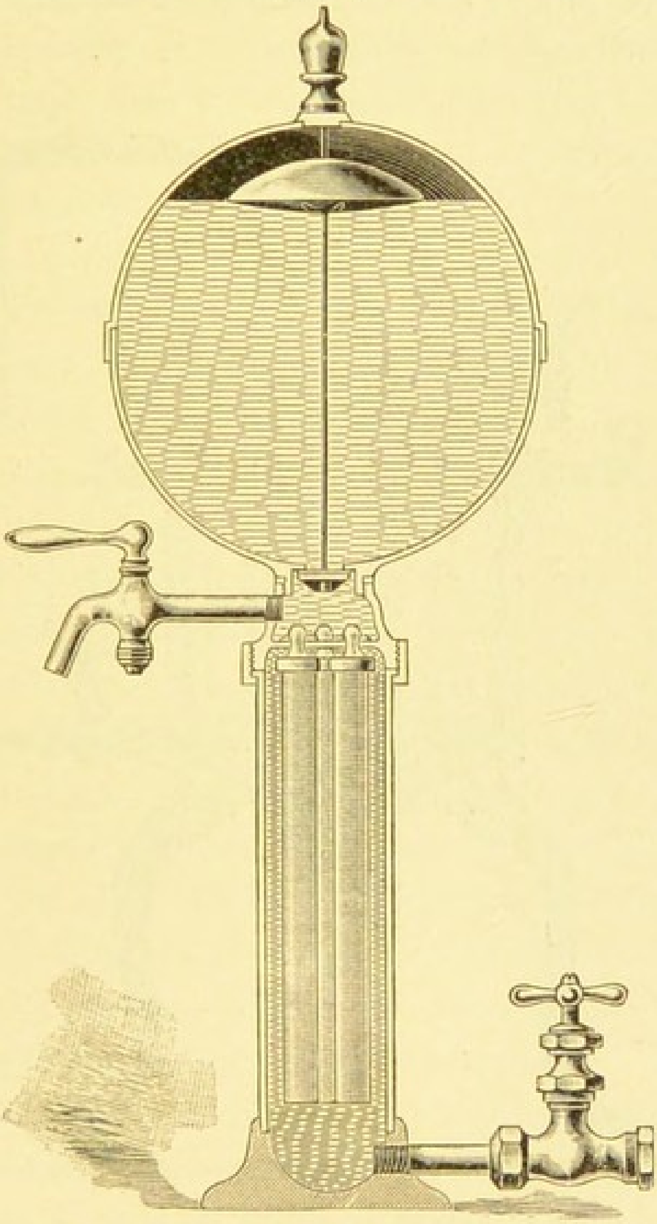
Fig. 29.



Berkfeldt filter attached to tap.

It will often be advantageous to have a settling tank con-connected with those of the first class, to prolong the safe use of the filter as long as possible; while the same object is gained in some of the second class by bringing the water in at the bottom, in which case there should be a space below the filtering medium to allow the suspended matters to fall away from the latter. Those intended to filter the whole supply of the house are generally cleansed by reversing the current and washing the collected dirt out of the filter into a drain or sewer, the first water passing through the filter after this is done being also discarded. In such filters the quantity of filtering material should be sufficient thoroughly to purify the water passing through

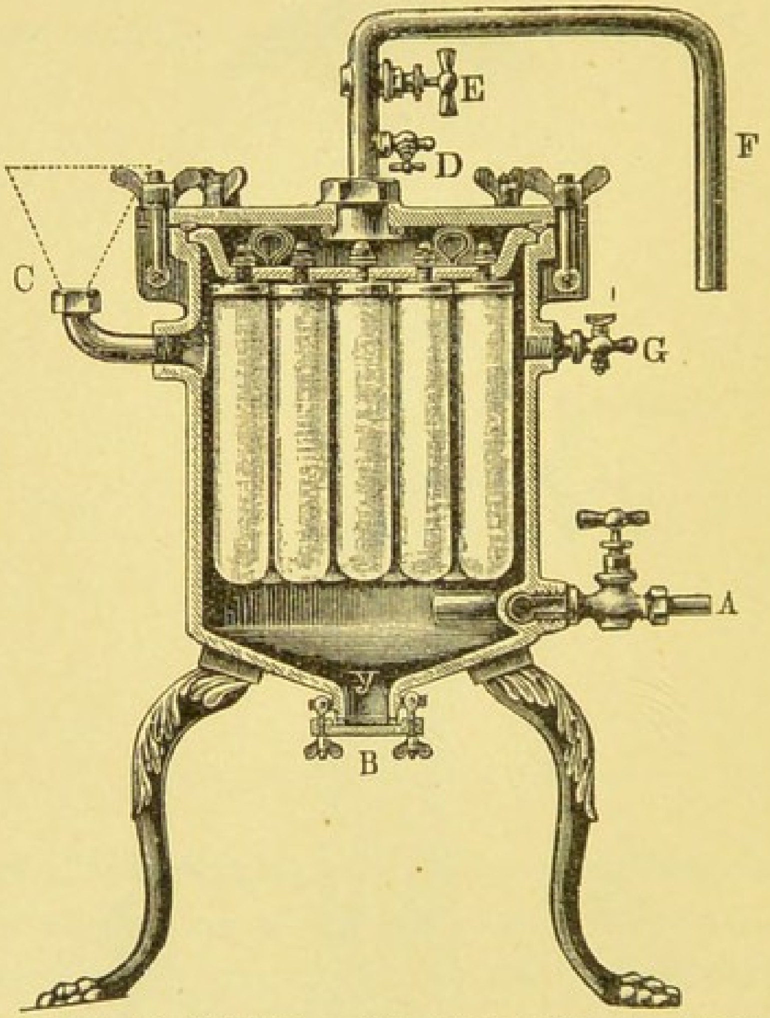
Fig. 30.



Pasteur filter with reservoir for filtered water.

it, and yet should not be so heavy that the reverse or washing current cannot lift it and separate the particles so that by their scouring action upon one another they may be cleansed and all the dirt washed out. These filters, also, may be so arranged that a small quantity of a coagulant, like alum, is automatically added to the water before filtration. If this be done, care must be had to supply no more of the coagulant than suitable tests show to be necessary, else the excess may be carried through the filter in solution.

FIG. 31.



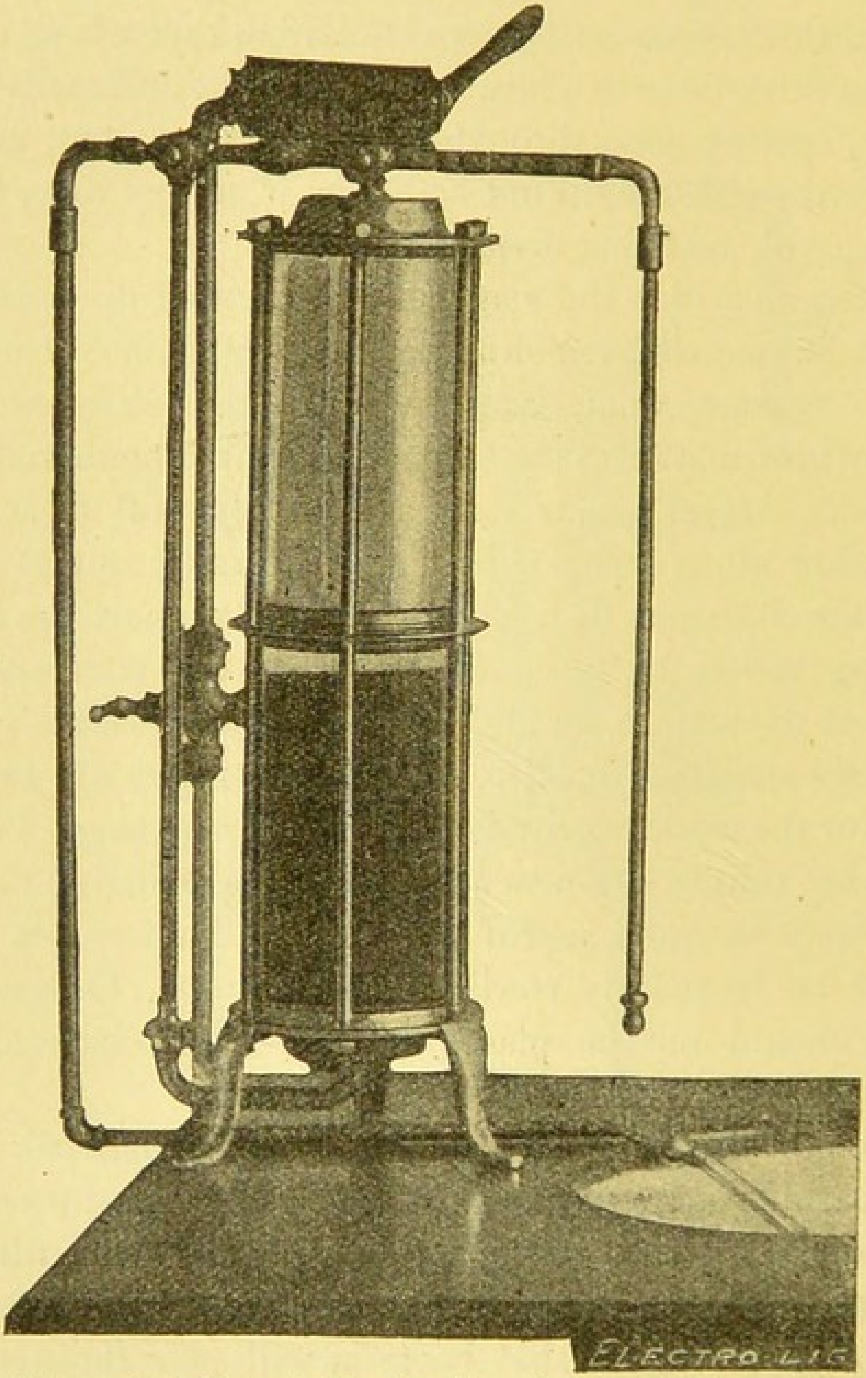
Multiple Berkfeldt filter with self-cleansing attachment.

No matter what kind of filter is used, the drinking-water should always be boiled in times of epidemics, or when the water before filtration is especially impure; for, though the Berkfeldt or the Pasteur-Chamberland filter, and possibly a few others, are practically bacteria proof, there always remains a possibility that disease germs may by some means pass through the medium or gain access to the water after it is filtered. The writer's own opinion is that with most good filters that are regularly and frequently cleaned there is an action very similar to that which takes place in filter-beds on a large scale, and that ordinarily few, if any, bacteria pass through with the water; but, nevertheless, the risk should not be taken, if, at any time, there is danger of incurring disease.

Filters in which the material is cemented up so that it cannot be removed for cleaning or renewal should not be used. Sponge, wool, etc., are liable to decompose and give organic matter to the water, and cannot be thoroughly cleaned. Asbestos acts only as a mechanical filter, and may allow albuminous matter and disease germs to pass. Asbestos-cloth may be used, however, to support the other filtering media in those filters where the water-supply enters at the bottom, and it has the advantage that it can be perfectly sterilized by fire. Small tap filters are insufficient for the work required of them, and soon clog. Pocket filters are simply strainers and have little oxidizing power. They may be quite useful for tourists, hunters, etc., but should be frequently sterilized by boiling. Ordinarily, filters should not be placed in rain-water cisterns, but outside where they may be easily cleaned.

The best filtering media are sand, animal charcoal, magnetic carbide of iron, spongy iron, etc. Unglazed porcelain or bisque, as is used in the Pasteur-Chamberland filter, is an excellent medium, and is practically germ proof, though some observers state that bacteria will pass through uncleaned filters of this material after five or six days. Others claim that these are not bacteria, but only the mycelia of certain budding fungi with no power of reproduction. Stone filters may be good and resemble the porcelain ones in action, but are apt to be slow, and must be cleansed often.

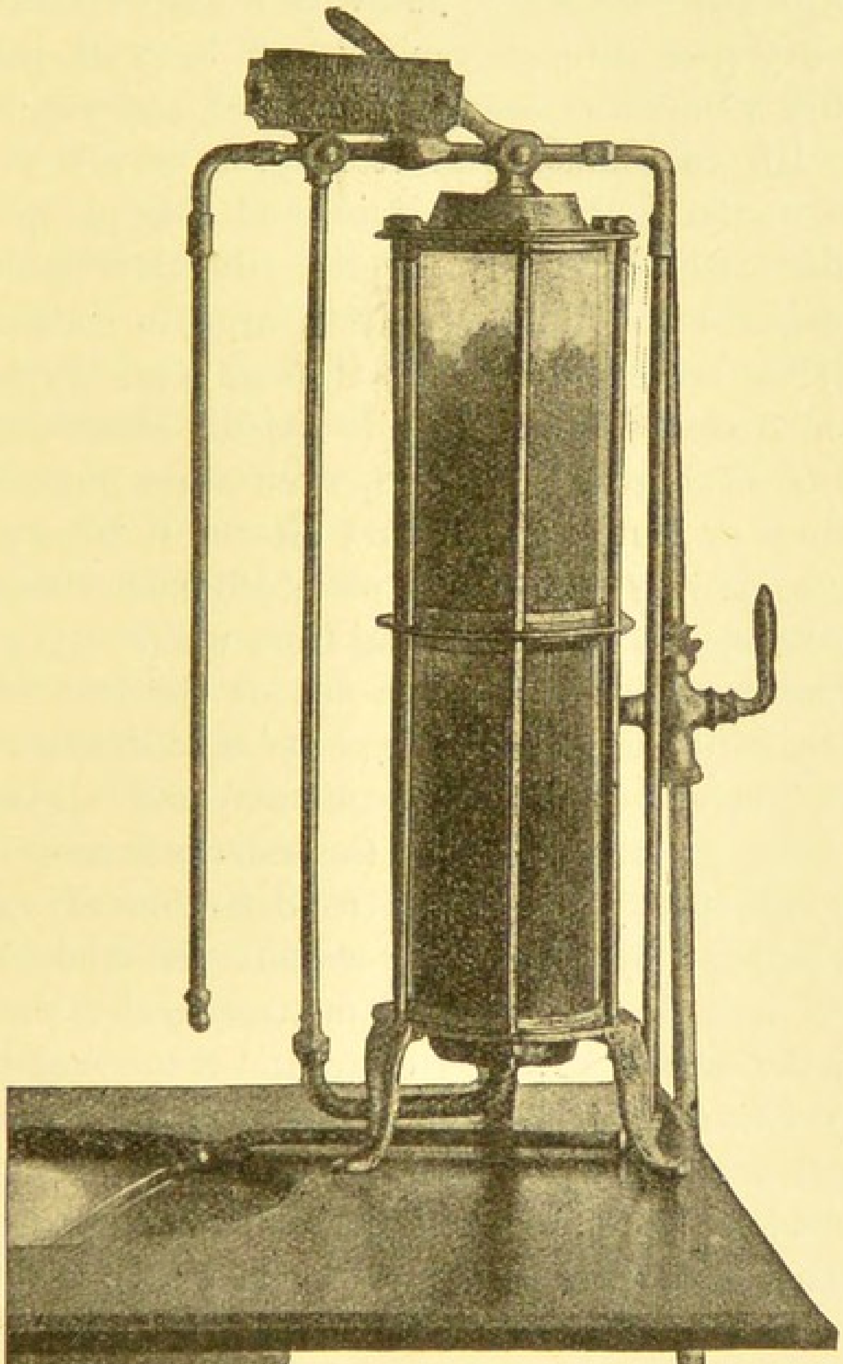
FIG. 32.



Glass model of Loomis-Manning filter, showing filter in action.

Sharp, clean sand, not too fine, has fair filtering properties, as it stops most of the suspended matters and bacteria, beside oxidizing somewhat the dissolved organic matters. It makes a good first layer for a filter, because it is cheap

FIG. 33.



Glass model of Loomis-Manning filter, showing material during cleansing.

and can be easily renewed or cleaned and sterilized by boiling. Crushed quartz is of practically the same nature.

Animal charcoal is, when fresh, an excellent material, as it removes both suspended and dissolved matters, organic and inorganic, and even color. It acts both mechanically and chemically, and with a good volume of it water may pass through rapidly and be well purified. But after a time it ceases to be effective, and water must not be left in contact with it long, as it will give up organic matter to the water again, and also phosphate of lime, the latter especially favoring the development of micro-organisms. Moreover, fresh organic matters, and possibly bacteria are said to pass through it readily, though dead or decomposing matter is rapidly destroyed. It should be changed or cleansed, even when in sufficient bulk, three or four times a year; oftener if the water to be filtered is very bad. It is more efficacious than any other substance in removing lead from water.

Magnetic carbide of iron is one of the best filtering materials, as it has considerable power in oxidizing organic matters, converting them into nitrates and nitrites, the action being greater the longer the water is in contact with it. It acts partly by surface condensation of oxygen; partly, perhaps, by electrolytic action. If sand be used as a first layer to remove solid matters, so that the water reaches the carbide perfectly clear, and if the sand be frequently renewed or cleansed, the carbide need never be changed; but the filtration must be intermittent, so that the carbide may be frequently aerated. Spongy iron has an action very similar to that of the magnetic carbide on organic matter, and, like it, the action is the greater the longer the contact. It must be kept covered with water to prevent rusting and caking, and should be renewed about once a year. The small amount of iron that the magnetic carbide and spongy iron give to the water may be removed by passing it through a layer of pyrolusite, a crude oxide of manganese. A mixture of pyrolusite and sand, or crushed quartz, makes an excellent filtering material.

Ice should not be added to filtered or drinking-water, as freezing, even for a long time, may not kill certain disease germs. Prudden has kept typhoid bacilli frozen in ice for over three months without destroying their power of growth and reproduction when brought to a suitable temperature. The same objections do not, of course, pertain to artificial ice carefully made from distilled-water as to that from polluted ponds or rivers; but it is well to cool the water by placing it in stoppered bottles upon ice or in vessels surrounded by ice, rather than by adding ice to the water directly.

The examination of a drinking-water should have regard to its physical, bacteriological, and chemical properties, as well as to a consideration of all the circumstances affecting its source, storage, and distribution. Consequently, a decision on the purity of a water should be governed by all the circumstances available: whether it is well-, spring-, rain-, or river-water; whether it has been at any time exposed to pollution; in what kind of a cistern or reservoir it has been stored, etc.

A physical examination of water considers the color, clearness, sediment, lustre, taste, and smell. Pure water has a bluish tint, but most waters are grayish, greenish, yellow, or brown. Yellow or brown waters are suspicious, as the color may be due to animal matter or sewage, though vegetable matters or iron may give the same color. Green waters are usually harmless, the color being due to vegetable matters. The color is judged by allowing the sediment to settle and pouring off the supernatant water into a tall glass vessel or tube to the depth of about twenty-four inches; the color is then compared with a similar depth of distilled water, looking down through both upon a white surface, or, after sealing the tops of the tubes with glass plates, by looking through each in turn at a white light.

The clearness of a water is to be estimated in the same way as above, except that the sediment is to be shaken up with the water. The depth needed to obscure print may be used as an index. Where the solid matter will not settle, owing to the minuteness and lightness of the particles, one should determine whether the use of a coagulant and filtration is indicated, or whether boiling will tend to precipitate the sediment. The sediment may be roughly judged by the eye as to whether it is mineral or otherwise; it should also be examined microscopically, for which purpose it may be collected by using a centrifugal apparatus or by allowing it to settle from the water in a conical glass, and then removing it to the slide with a pipette. Mineral matters are recognized by their crystalline or amorphous structure or by micro-chemical tests; vegetable cells, portions of leaves, etc., by their structure and the presence of chlorophyll; animal substances, as hair, wool, epithelial and other cells, by their peculiar characteristics. Dark brown, globular masses may come from sewage. Anything indicating that water has come from human habitation renders it suspicious, as it may contain sewage or other polluting substances. Some of the larger animalculæ and sometimes iron may be detected with the naked eye.[1]

The lustre is supposed to indicate the amount of aeration; it may be *nil*, dull, vitreous, or adamantine. It should not be forgotten that a very impure water may be clear, bright, and sparkling.

[1] See J. C. MacDonald's Guide to Microscopic Examination of Drinking-water.

Any badly tasting water should be considered suspicious. Dissolved animal matters may be tasteless, but suspended substances give a peculiar taste, whether animal or vegetable. Iron is about the only ordinary mineral that can be tasted in small quantities. Good water depends for its taste mainly upon its gases, and water free from gas tastes flat.

The smell of a water, if it has any, may be brought out by heating gently to about 110° F., or by boiling it. This may make evident a fecal odor, although sulphuretted hydrogen may mask this latter; in such a case the sulphuretted hydrogen may be removed by adding a little copper sulphate to the water. The odor may also be developed by allowing the water to stand in a corked bottle in a warm place for a few days.

A bacteriological analysis is almost as necessary as a chemical one, for purity in the one respect does not necessarily indicate purity in the other. The presence of the *bacterium coli communis* in a water, irrespective of any pathogenic organisms, would create a suspicion of contamination by fecal matter, as this microbe is practically a constant occupant of the human intestinal tract.

Water may be collected for bacteriological analysis in sterilized, closed bulbs blown from glass tubing. The heat used in sealing the ends creates a partial vacuum within the bulb, so that if the tip of one end be broken off beneath the surface of the water, the latter is drawn up into the bulb, which can then be resealed and conveyed to the laboratory. But it is always best, if possible, to inoculate the culture-media at the place where the supply for examination is obtained, as the bacteria multiply rapidly in transportation, and some species may even destroy others. This can be done by adding a small quantity of water to melted nutrient gelatine and making plate cultures in the manner already described. The number of colonies resulting therefrom will indicate practically the number of bacteria in the quantity of water added to the gelatine.

The details of the tests and methods employed in the chemical analysis of drinking-water will be given in another chapter. Here we need only consider the influence that the substances sought for in the analysis have in affecting potability and within what limits we may consider them as being permissible in drinking-water. The water should be filtered or free from sediment for all the tests, except in the estimation of nitrogen as ammonia compounds and as organic matter, and of the oxygen-consuming power of the water.

The amount of total solids will vary with the source of the water, and much more might be present in some cases than would be safe in others; but usually the proportion should not exceed 50 or 60 parts in 100,000. Only a small portion should be volatile, and there should be little charring or ignition, except in the case of waters from peaty soils; nor should there be any odor on ignition, especially of ammonia compounds, as that would indicate an excess of animal organic matter. Deep well-water will probably have much more total solids than rain- or river-water, the excess being mainly mineral substances dissolved from the strata through which the water passes.

Even the purest waters contain a little chlorine, usually in the form of sodium chloride; but as the latter is a constant constituent of household slops and sewage in general, any excess of chlorine above the amount common to the water of the district, unless otherwise accounted for, will be decidedly suspicious, and sewage contamination should be looked for. So, also, any sudden increase in the proportion of chlorine would very likely indicate the accession of some new supply of contamination to the water. Unless accounted for by the strata traversed, more than three parts of chlorine in 100,000 of water is very suspicious.

The presence of considerable "free ammonia" in rain-water is not a bad sign, as it has probably been absorbed from the air; but the same amount in subsoil-water, especially if with an excess of chlorine, would indicate probable contamination with urine, as this latter rapidly undergoes ammoniacal putrefaction. In such a case there will probably also be considerable "albuminoid ammonia," but much albuminoid ammonia with little free ammonia and chlorine generally indicates vegetable contamination. The writer is acquainted with a case in which the albuminoid ammonia and chlorine are in marked excess, the former being altogether of vegetable origin—from a peaty soil—and the latter characteristic of the whole district. The free ammonia is, however, slight in amount. An excess of free ammonia, chlorine, nitrates and nitrites indicate animal contamination, though, if the pollution be by effluvia alone, there may be no excess of chlorine.[1] The total ammonia in a usable water should not be over 0.13 or 0.15 parts per 1,000,000. If there is almost no "free" ammonia, the "albuminoid" may amount to 0.10 parts per 1,000,000 without giving cause for suspicion; likewise, if there is but little "albuminoid," there may be considerable "free" ammonia; but if the "albuminoid" exceeds 0.5 parts per 1,000,000, the "free" must not be greater than this proportion. The simplest test for ammonia is by means of Nessler's reagent, a solution of a double iodide of potassium and mercury. It gives a yellow or yellowish-brown coloration when ammonia is present.

[1] Kenwood's Hygienic Laboratory, p. 49.

Organic matters of animal origin, and, therefore, nitrogenous, are, during oxidation, converted partially into ammonium compounds, and these, by the action of certain bacteria, may be further oxidized into nitrites and nitrates. "Nitrification takes place under the influence of microbes, the habitat of which does not extend more than a few yards below the surface of the soil. The nitrifying action is probably exerted only upon the ammonium which is formed from the organic matter. The presence of some substance capable of neutralizing acids is necessary to continuous action. Calcium and magnesium carbonates fulfil this function. Nitrates are the final result of this action; nitrites are present at any given time, only in small quantity."[1] Deep water may, of course, also contain nitrates taken up from strata rich in these salts.

Although nitrites and nitrates are not at all harmful in the quantities usually found in water, and though the water containing them may have been thoroughly purified by long filtration, their presence, as will be seen from the above remarks, is important in determining the character of the water. The presence of the slightest trace of nitrites is always suspicious, and any marked amount of nitrates, excepting possibly in a deep water, should require close investigation; the nitrates and nitrites together measured in terms of nitrogen should not exceed one part per million.

The hardness should not be greater than that indicated by 20 or 30 parts of chalk in 100,000, and the more "temporary" in proportion to the "permanent" hardness the better.

Phosphates, not from phosphatic strata, help to indicate sewage contamination. So, also, do sulphates, though these by themselves may come from harmless sources.

[1] Leffmann and Bevam: "Examination of Water," 2d edition, p. 13.

It will be seen from the above that the opinion regarding any water must be based on a broad consideration of all the circumstances in connection with it, and not from the presence or absence in it of any one or two substances, which are not in themselves harmful. The presence of poisonous metals above the limits of safety would, however, alone contraindicate the use of a water. For instance, there should not be more than one-twentieth of a grain of lead or copper, one-fourth grain of zinc, or one-half grain of iron in any water, and the faintest trace of arsenic condemns it.

The following table has been adapted from Parkes :

PROPERTIES.

Class.	Physical.	Microscopical.	Chemical (Parts per 100,000).
I. Pure water.	Colorless or bluish tint; transparent, sparkling, and well aerated; no sediment visible; no smell; taste palatable.	Mineral matter; vegetable endochrome; large animal forms; no organic *débris*.	Chlorine under 1.4 Total solids under 7.14 Ammonia under 0.007 Nitrogen, as nitrites & nitrates, under 0.023 Total hardness 8.5
II. Usable water.	Colorless or slight greenish tint; transparent, sparkling, and well aerated; no suspended matter, or easily separated by coarse filtration or subsidence; no smell; taste palatable.	Same as for pure water.	Chlorine under 4.3 Total solids " 42.8 Ammonia under 0.015 Nitrogen, as nitrites & nitrates under 0.125 Total hardness 17.3
III. Suspicious water.	Yellow or strong green color; turbid; considerable suspended matter; no smell; but any marked taste.	Vegetable and animal forms, more or less pale or colorless; organic *débris;* fibres of clothing or other house refuse.	Chlorine 4 to 7 Total solids 43 to 71 Ammonia 0.015 to 0.023 Nitrogen, as nitrites and nitrates 0.125 to 2.47 Total hardness, above 17
IV. Dangerous water.	Yellow or brown color; turbid, and not easily purified by coarse filtration; large amount of suspended matter; any marked smell or taste.	Bacteria of any kind; fungi; numerous vegetable or animal forms of low types; epithelia or other animal structures; evidence of sewage or ova of parasites, etc.	Chlorine above 7.14 Total solids " 71.4 Ammonia above 0.0225 Nitrogen, as nitrites & nitrates, above 0.026 Total hardness, above 28.5

CHAPTER VI.

FOOD.

The use of food is necessary to build up the body structure, to repair waste, and to furnish force and energy for the proper action of all the organs, tissues, and parts of the body. In addition, certain substances are needed, not so much because they become a part of the tissue framework or yield kinetic energy directly, as that they are essential factors in the multitudinous chemical reactions and changes that are continually occurring within the living person. We may, accordingly, define a food as anything that tends to fulfil any one of these functions, provided it is not at the same time by nature harmful to the economy and that it does not produce physiological effects out of all proportion to its nutritive or metabolic activities.

Strictly speaking, this definition might include air and water, as the former is necessary to supply oxygen for union with other foods or with the tissues themselves, in order to produce the heat and vital energy of the body, and the latter is needed to assist in the solution and assimilation of food-stuffs, to maintain the fluidity of the body juices and keep the tissues effectively moistened, to preserve roundness of form, and to flush out and remove from all parts of the system those waste matters and excrementitious substances whose retention gives rise to the symptoms of certain autogenetic diseases. But they are not usually included in the category of foods, and, as we have already considered them at length, they may be passed over in this connection with but incidental reference here and there.

If we classify foods according to their chemical composition, we may separate them into the followng main divisions:

1. Proteids and albuminoids. 2. Carbohydrates. 3. Hydrocarbons or fats, and 4. Salts, extractives, etc. Each group is subject to different digestive and metabolic processes, and each has usually a different office within the body; for experience and careful experiments both show that all forms of these different classes of food are needed to sustain life and maintain health for any considerable length of time, and that with them nothing else is absolutely necessary; although what are sometimes called the accessory food-stuffs and many pleasant volatile odors and flavors are desirable and advisable adjuncts to the food proper, since they greatly favor its reception, digestion, and assimilation. But, though each class of food has its own special function in the economy of nutrition, in times of need or deprivation any one of the first three divisions may, in a way, supply the place of either of the other two.

Fothergill[1] epitomizes the use of the food-principles in this way: "The carbohydrates are the body-fuel, the surplusage being stored as fat; the albuminoids (proteids) serve to repair the tissues as they wear out; the salts form the blood-salts; the fat helps to build up normal health tissues, the excess being burnt as body-fuel. That is the real object of food."

While in the main correct, this is a broad statement of facts, and it needs some qualification. For instance, just

[1] Manual of Dietetics, p. 5.

as there is some wear and tear in any mechanical machine while in use, which must eventually be provided for; so in the human body with its manifold activities there must be some destructive effect upon the body structure and tissue framework, and it is to renew and replace this inevitable loss of material that a part—perhaps the great part—of the proteid food is taken. But we now also know that in addition to this simple repair and replacement of tissue, "the presence of nitrogenized structure, and its participation in the action going on there, is a necessary condition for the manifestation of any vital energy or any chemical change," and we must feel that, entirely apart from the idea of repair, proteid food is essential to the maintenance of this chemical and vital activity of nitrogenized tissue.

Confirming this, Pettenkofer and Voigt have shown that the absorption of oxygen is largely determined by the nitrogenous substances composing the tissues of the body, and that it is proportional to their size and vigor. Moreover, it is known that proteids may be, in part, converted into fat and possibly into other oxidizable substances, and thus become a source of body heat and energy.

So also with the fats and carbohydrates. While they are not immediately nor entirely interconvertible, and while neither class may be permanently excluded from the diet, yet in emergency either may apparently fully supplant and substitute the other for a time, and we cannot yet say exactly how similar or dissimilar their service within the body is.

However, while Fothergill's epitome needs this emendation, known facts make it comparatively easy to gain a fair idea of the differences and functions of the proximate food principles, to which end some help will probably be given by the following table:

	EXAMPLES.	FUNCTIONS.
NITROGENOUS SUBSTANCES. **1. Proteids.** All substances containing nitrogen of a composition identical with, or nearly that of albumin; proportion of N to C being nearly as 2 to 7, or 4 to 14.	Animal: Albumin, Fibrin, Syntonin, Myosin, Globulin, Casein. Vegetable: Glutin, Legumin.	Formation and repair of tissues and fluids of the body. Regulation of the absorption and utilization of oxygen. May also form fat and yield energy under special conditions. In most foods the above, both animal and vegetable, are partially converted into peptones.
1 (*a*). Substances containing a larger proportion of nitrogen are apparently less nutritious. Proportion of N to C, about 2 to 5½, or 4 to 11.	Gelatin, Ossein, Chondrin, Keratin,	These perform the above functions less perfectly, or only under particular circumstances.
(*b*). Extractive matters, such as are contained in the juice of the flesh.	....	These substances appear essential as regulators of digestion and assimilation, especially with reference to the gelatin group.
NON-NITROGENOUS SUBSTANCES. **2. Fats** (*or Hydrocarbons*). Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the proportion of oxygen being *less* than sufficient to convert all the hydrogens into water. Proportion of unoxidized H to C, about 1 to 7.	Olein, Stearin, Margarin,	Supply of fatty tissues; nutrition of nervous system? Supply of energy, and animal heat by oxidation.
3. Carbohydrates. Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being exactly sufficient to convert all the hydrogen into water. Proportion of water to carbon, about 3 to 2.	Starch, Dextrin, Cane sugar, Grape " Lactin (or milk sugar)	Productive of energy and animal heat by oxidation. Conversion into fat by deoxidation.
3 (*a*). *Vegetable acids and pectous substances.* Substances containing no hydrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being generally in greater amount than is sufficient to convert all the hydrogen into water.	(More O than is sufficient to convert all H into H_2O). Oxalic acid, Tartaric " Citric " Malic " (No excess of O). Acetic acid, Lactic "	Preserving the alkalinity of the blood by conversion into carbonates; furnish a small amount of energy or animal heat by oxidation.
4. Salts (*mineral*).	Sodium chloride, Potassium chloride, Calcium phosphate, Magnesium phosphate. Iron, etc.	Various; support of bony skeleton, supply for HCl for digestion, etc. Regulators of energy and nutrition.

Dietetics means "a systematic regulation of the diet for hygienic or therapeutic purposes." It considers all the factors that affect the proper digestion and assimilation of food. For instance, it is not alone necessary to determine just what substances, in a chemical sense, the body needs to sustain life and maintain health. Nor is it sufficient to say that a man must have just so much of this and so much of that food, for there must always be a variation in both kind and quantity to meet the changing demands of the system. With a few exceptions, no matter how toothsome or healthful a certain food may be, it soon palls upon the appetite if necessity compels its continued use for a prolonged period, and this disgust may be so impressed upon the memory of the senses as to cause them to prevent the use of that food forever after.

The æsthetic factors in the preparation and serving of food must also be taken into account, and the question of pleasing the appetite has much to do with the progress and completeness of digestion. Other things being equal, palatable and agreeable foods are disposed of much more satisfactorily than others not so, and physicians and others should learn that especially in sickness the appearance and palatability of a food have much to do with its acceptance, not only by the patient, but by his stomach as well. Cleanness and neatness in food, china, and napery are of greater value than expense or show, and a little attention and tact in such matters will often enable a patient to take, enjoy, and retain food and nourishment, even when he or she asserts and believes this to be impossible.

Another factor of much importance in the digestion of food, but one too often too lightly considered, is the mood or state of mind when the food is taken and while it remains in the alimentary canal. There is more than moral philosophy in maintaining a cheerful and a tranquil disposition during the daily meals and for a time thereafter; while there are numerous instances of most serious results occurring from the giving way to anger or other intense emotion at such times, the digestive functions being either completely checked or, what is frequently worse, so altered that the products are actually toxic in their character. And is not a dyspeptic often so because of his pessimism, rather than a misanthrope because of his indigestion?

Before proceeding further it will be well to consider briefly the physiology of digestion in so far as it concerns the chemical changes occurring in the food while it is in the digestive tract. These changes are brought about by the action of certain bodies secreted or made by the digestive organs and glands, which we have been in the habit of calling unorganized ferments, but which would, perhaps, better be known hereafter as *enzymes.* Unorganized ferments were so called because they have not the definite cell-formation, life, and power of reproduction which belong to the yeasts, mould-fungi, and bacteria which bring about the fermentative changes in organic substances so commonly within the knowledge of every one, such as the conversion of saccharine solutions into alcohol, of alcohol into acetic acid, etc.

The enzymes likewise act upon organic matter, viz., upon the food which we eat, and—like the other ferments—apparently simply by their presence rather than by entering into actual combination with the matter acted upon, as do ordinary chemical reagents. They are undoubtedly the products of glandular protoplasm, probably proteid in nature, and some, at least, very likely belonging to the group of nucleo-albumins, which latter form a component part of every organic cell.

The knowledge of the digestive functions will be greatly simplified for the student if he remembers that "with the possible exception of the coagulating enzymes, the action of the enzymes is that of hydrating agents: they produce their effect by what is known as *hydrolysis*—that is, they cause the molecules of the substance upon which they act to take up one or more molecules of water; the resulting molecule then splits or is dissociated, with the formation of two or more simpler bodies."[1]

Thus the insoluble proteids and carbohydrates become respectively the soluble peptones and sugars of their allies, capable of absorption into the myriad capillaries that are distributed throughout the lining membrane of the alimentary tract; and even the change that takes place in the fat digested is one that involves the taking up of some water.

There are four characteristics of the enzymes worthy of note: 1. That they are all soluble in water and glycerin, the latter being specially useful in making stable preparations of them from the organs producing them. 2. "That very low temperatures (0° C.) retard or suspend entirely their action, without, however, destroying the enzyme; that for each enzyme there is a temperature at which its action is greater," and that "in a moist condition they are all destroyed by temperatures below the boiling-point; 60° to 80° C. are the limits actually observed."[2] 3. "That they never completely destroy the substance upon which they act," probably being retarded by their products when the latter reach a certain percentage. "When these are removed the action of the enzymes begins again."

[1] American Text-Book of Physiology, first edition, p. 219. [2] Ibid.

4. " Except for very small quantities, it may be said that the amount of change caused is independent of the amount of enzyme present," or rather, " with increasing amounts of enzymes the extent of action also increases, reaching a maximum with a certain percentage of enzyme; increase of enzyme beyond this has no effect." The amount of change capable of being produced by a small amount of an enzyme is enormous, good pepsin, for instance, having the power of converting 2500 times its own weight of proteid; but we must remember that this power is not infinite, and that after a time all of the enzymes will cease to act.

There are five groups or classes of enzymes to be found in the animal body concerned with the proper digestion of food, and it is interesting to note that examples of each of these classes are also to be found in various members of the vegetable world. The two principal remaining classes, being neither of animal origin nor digestive agents, need only be mentioned here: They are the *glucoside-splitting* and *urea-splitting* enzymes, the latter being produced by certain bacteria and converting urea into ammonium carbonate.

Considering the digestive processes in their order as the food proceeds from the mouth through the alimentary canal, we find that the first active secretion or fluid is the saliva, and that its enzyme is *ptyalin*, belonging to that group which converts the insoluble carbohydrates (starches) into soluble sugars, maltose, dextrin, etc. Pytalin acts best in neutral or slightly alkaline media, at about the body temperature (40° C.), and upon cooked rather than raw starch. Its action is retarded or totally checked by a low temperature or by strongly alkaline or very slightly acid solutions, and the enzyme itself is actually destroyed by a slight increase in acidity or by a temperature of 65° or 70° C. The reason it converts cooked starch so much more quickly is probably because the heating process breaks up the cellulose envelopes that protect the starch granules within from its action, and upon which the pytalin has almost no effect.

In addition to its digestive function, the saliva also serves to moisten dry food so that it may be swallowed, and to dissolve sapid and savory substances that they may be duly appreciated by the organs of taste.

Our first hygienic lesson in regard to the digestive functions is, therefore, that in order to get the full benefit of the salivary secretions, all food, and especially that of a starchy nature, should be well masticated and retained in the mouth for some little time, instead of its being "bolted" at once or after a hasty bite or two. Nor should very cold nor very hot beverages be taken at the same time with the food, for not only will the action of the pytalin be thus retarded or destroyed, but that also, as we shall see, of the gastric juice within the stomach.

The food, having passed from the mouth to the stomach, may still be acted upon for a few moments by the pytalin until the latter is checked by the acid of the gastric juice. The energy of digestive action is then transferred from the starches to the proteid constituents of the food, the chief enzyme now being *pepsin,* though we also find in the gastric juice a coagulating ferment—*rennin,* which acts upon soluble proteids like the casein of milk, to form insoluble clots or curds.

Pepsin acts only in an acid medium (the acidity being supplied normally by the free hydrochloric acid of the gastric juice), and best at the body temperature. As stated, extremes of temperature are adverse to its activity, and may check it altogether, and, likewise, too much or too little acid may have the same effect, from 0.2 to 0.3 per cent. of HCl being the normal amount and giving the best results. Rennin seems in the normal stomach to act only on the casein of milk, and curdles this probably because it is then more easily digested by the pepsin and by the trypsin of the pancreatic juice.

The action of the pepsin plus the acid upon the proteids of the food is a hydrolytic one, and the end products are practically hydrated proteids, substances especially diffusible and capable of absorption. The gastric digestion, therefore, after the ptyalin has been checked by the acid gastric juice, practically has to do only with the albuminous or nitrogenous part of the food, the remainder, or at least that part of it not yet capable of absorption, remaining unchanged until it passes on further into the intestines. Soluble salts, sugars, and part, at least, of the peptones as they are formed, may, however, be taken up by the stomach capillaries, while the rest of the food-mass, kept ever in motion by the muscular movements of the stomach-walls, is being thoroughly mixed and converted by the peptic action into the semi-liquid substance called chyme, which is passed at intervals and in small quantities through the pyloric opening into the duodenum. Long before the stomach has entirely emptied itself, which may only be after several hours of activity, intestinal digestion is well under way, and in some respects this is the most important as well as the most comprehensive process of all. The three secretions to whose combined action the chyme is now subject are the pancreatic juice, the bile, and the intestinal juice. All are alkaline and quickly neutralize the gastric acid; it scarcely need be noted, then, that the remaining enzymes act best or only in alkaline media, though one of them, trypsin, may act in solutions not too strongly acid.

In the pancreatic juice we find three enzymes, practically the only remaining ones of much importance; although in the rather scanty intestinal juice two others have been found, one capable of converting starch into sugar, and the other inverting cane-sugar into levulose and dextrose. The bile contains no enzymes. The pancreatic ferments are *trypsin*, which acts upon proteids and albuminoids even more powerfully than pepsin, and likewise converts them into peptones; *amylopsin*, which is practically identical in its properties with ptyalin; and *steapsin*, which causes neutral fats to take up water and split into free fatty acids and glycerin.

Under the action of the trypsin all that portion of the proteid foods which has not been completely digested in the stomach reaches that stage in the upper intestines and is absorbed therefrom. In fact, it is very probable that the tryptic digestion is often the more important of the two. As the action of the saliva upon the carbohydrates, which form the greater bulk of our food, must of necessity be very limited, it is evident that practically almost all of the starch digestion is performed by the amylopsin, aided in slight measure by the similar enzyme of the intestinal juice. The salts and other soluble elements of the food have already been absorbed, and there remain only the fats or hydrocarbons.

Under the influence of the steapsin comparatively a small portion of these is, as stated, separated into glycerin and free fatty acids, and this action for some reason takes place much more rapidly when aided by the bile than with the pancreatic juice alone. Then, these fatty acids unite with the alkalies and alkaline salts of the above secretions, but especially of the bile and intestinal juice, to form *soaps*, and these soaps aid in emulsifying the remainder of the fats and thus making them ready for absorption, which latter process is also facilitated by the direct action of the bile upon the intestinal epithelium.

The digestive processes having been thus outlined, it will be well to learn how they may be maintained as complete and perfect as possible. In the first place, the cooking of food is usually an essential preliminary. We cook meats not only to make them more agreeable to the palate, but also to facilitate digestion. The effect of cooking upon muscle (flesh) is "to loosen the bundles of fibrillæ from each other, so that they are readily torn asunder or crushed by the teeth," while the various connective tissues are softened and gelatinized, not only thus becoming more digestible and nutritious, but allowing the histologic elements which they bind together to separate and be more freely acted upon by the solvent fluids. So with the vegetables, the heat and steam soften and rupture the cellulose envelopes of the various cells that the ferments may the more readily act upon their contents; and at the same time they bring about subtle chemical changes that greatly increase the palatability of the food-stuffs.

Thorough mastication of the food is important for the reasons already stated, and the cause of most dyspepsias may be found in faulty habits of eating. Foster says that in the stomach "the natural bundles of meat and vegetables fall asunder, the muscular fibres split up into disks, and the protoplasm is dissolved from the vegetable cells;" but, "if the meat be not chewed properly, but 'bolted,' the solvent gastric juice can only act on the exterior of the mass, while 'lumps' offend the stomach and arrest the gastric secretion." The importance of abstaining at meal-time from beverages or other substances of too low or too high a temperature has already been stated, and, as all the enzymes act best at the body temperature, care should always be had to avoid the chilling of the abdominal organs while digestion is under way.

Again, as the formation and action of the enzymes begin with the ingestion of food and depend largely upon a sufficient blood-supply to the organs concerned as long as digestion continues, it is essential that the blood-current shall not be diverted from these organs during this period by excessive mental or physical demands, and that a condition of cheerfulness, repose, and rest should wisely follow every meal. Regularity as to the time of meals and the avoidance of too great a tax upon any of the organs by over-indulgence or intemperance in eating are likewise both important matters and ones too often neglected.

It is interesting to note that in certain members of the vegetable kingdom are to be found enzymes very similar to those just considered, and that where the latter appear to be deficient in quantity or action, these kindred ones may be used with advantage. Thus, in the pineapple and in the papaw are ferments akin to pepsin or trypsin, and in the former another with the same action as rennin. All are familiar with the diastase of germinating seeds and its use in the making of beer, but not so common is the knowledge that other seeds contain fat-splitting enzymes much like steapsin.

The Amount of Food Necessary to Life and Health. Considerable work has been done to determine just what amount of the proximate food principles the average person requires daily, and in this respect Moleschott's tables are quite generally accepted, having been constructed from data gained by actual experiment and also by the continued observation of the effects of a number of dietaries. According to these tables, a man weighing 160 pounds and doing work equivalent to 300 foot-tons per diem will need about 4.6 ounces of proteids, 3 ounces of fats, 14.25 ounces of carbohydrates, and a little more than 1 ounce of salts. Prof. Vaughan believes that the average working man in America requires daily, in round numbers, not less than *four* ounces of proteids, *two* ounces of fats, and *eighteen* ounces of carbohydrates.

It is essential that the proper proportion between the ingested nitrogen and carbon should be maintained, and this should be as *one* of the former to *fifteen* of the latter.

In addition, the individual needs from 70 to 100 fluid-ounces of water daily, a good part of which, however, is normally taken with the food. It must be remembered that the above figures only represent average amounts, and that climate, amount of exercise, the size and activity of functional and excretory organs, and personal peculiarities all serve to modify them in the case of any special individual.

Other conditions not interfering too greatly, any combination of foods giving the above amounts of the proximate principles at a reasonable cost will be an economical and healthy diet, provided such food is acceptable to the palate, is digestible, and contains nothing harmful to the system.[1]

Fothergill thinks that, as a rule, we take too much proteid food, especially in the form of meat, and that, though this goes in the main for tissue repair, the latter requires

[1] For such combinations, see Vaughan's Healthy Homes and Foods for the Working Classes, and Mrs. Abel's Practical, Sanitary, and Economic Cooking. Both are essays published by the American Public Health Association.

much less of such food than we ordinarily suppose, and that the system does not need so very much of albumin or its equivalents. In this he may be correct to a certain degree, particularly as regards his fellow-Englishmen, who are notorious meat eaters, and as to the facts that tissue waste is comparatively slight, and that the body framework rusts out rather than burns out. But in addition to the statements already made—that part of our nitrogenous food regulates the demand for oxygen and that part is doubtless a source of energy and may be converted into fat—we should also remember that animal food is a concentrated food, that much energy has been expended in converting and storing it up from the vegetable world, that it is stimulating, and that our digestive organs resemble more closely, at least as far as comparative weight is concerned, those of the carnivora rather than of the herbivora. These reasons, as well as the fact that proteids make up a considerable part of the only typically complete food that we have and which nature gives to the mammalian infant, indicate that we should be as careful not to use too little as too much nitrogenous food.

The proteid portion of our food is obtained from the albumin of meat and fish, from milk and eggs, and from the gluten of cereals and the vegetable casein (albumin) of the leguminous plants, such as peas, beans, etc. The proportion and properties of the albuminous matter vary, of course, in each of these, and even in the same substances under different circumstances; but all should be taken into consideration and used interchangeably, if we wish to obtain the greatest variety and benefit in feeding, together with due economy of expense.

In this connection attention may be directed to the peculiar fact that the leguminous plants, through the aid of certain species of bacteria, are able to absorb and store up in the form of proteids a considerable quantity of nitrogen from the surrounding atmosphere.

The carbohydrates that furnish food to the body and are one of the sources of the heat and energy upon which muscular motion and vital activity depend, are practically all derived, with the exception of milk sugar, from the starches, sugars, and gums of the vegetable kingdom.

It has already been shown that much the greater part of the digestion of carbohydrate food is due to the action of the pancreatic enzyme—amylopsin, but we should not forget the action of the saliva, nor that thorough mastication greatly assists the subsequent digestion by breaking up the starch granules and exposing them more freely to the action of the digestive juices. The latter object is also obtained by crushing the cereals, and by cooking the starch-bearing foods, for "grinding and cooking lessen the labor of the jaws and salivary (and pancreatic) glands."

After the end-products (dextrose, levulose, etc.) of carbohydrate digestion have been absorbed from the alimentary canal, part of them, at least, are reconverted in the liver into animal starch or glycogen, and this portion becomes a part of the body-store of fuel. Fothergill says: "The liver stores up from each meal so much glycogen and gives it off as required; otherwise life would only be one dreary meal." Another and perhaps greater moiety of the digested carbohydrates is converted into fat and stored away as adipose tissue in various parts of the body, a further reserve of fuel for any emergency. "Many authorities state that fat is formed *directly* from carbohydrates, and the weight of evidence appears to favor this view; but whether it is so formed directly, or indirectly by retarding the metabolism of the fatty and proteid constituents of the food, there is no doubt that the consumption of carbohydrates results in the formation of fat within the body."[1] Moreover, "whatever the mixture of fats taken in as food, the fat of the body always has the same composition; this fact agrees with the conclusion that the metabolism and deposition of fat in the body is due to cell activity, and that the fat comes in part from the proteid and part from the carbohydrate foods."[2]

Another important function of the carbohydrate foods is the formation by their metabolism in the body of lactic and other acids, which are of the greatest value in nutrition and in maintaining the normal reactions of the body-fluids. This is perhaps one of the chief reasons why fats and carbohydrates are not interconvertible in any prolonged dietary.

Fat is essentially a compound of glycerin with one or more fatty acids, usually stearic, palmitic, and oleic. The digestibility of a fat largely depends upon its being fluid at the body temperature; therefore, the more stearine, whose melting-point is higher than this, a fat contains, the less digestible it will be. For this reason butter is more digestible than suet, lard than mutton fat, etc., and the more easily assimilable cod-liver oil is that from which the stearine has been removed.

Fat for food is derived from vegetable as well as animal sources, many seeds and nuts and some cereals, as oats and corn (maize), containing much fat. By improved methods it is becoming possible to supply fats in purer, cheaper, and more agreeable forms, so that they can now be freely used even by the poor, the very class that needs them most.

Under normal conditions it is probable that the body-fat

[1] Notter and Firth: Treatise on Hygiene, p. 254. [2] Ibid., p. 253.

or adipose tissue is almost never derived from the fat in food, but rather, as stated, from the proteids and carbohydrates. But fat is also an essential part of tissue-structure, making up more than one-fifth of the solid matter of the brain and one-sixth of muscle, and possibly serving as fuel when the tissue is oxidized; and it is not impossible that this tissue fat may come in part from that ingested as food. The writer has already hinted at the possibility of a combination of the newly absorbed fat with the argon of the atmosphere in the lungs, and the consequent formation of new cells or vital material. In any case, however, fat is a very necessary part of a man's diet, for not only is a small quantity necessary to the digestion of proteids, causing the formation in the body of larger amounts of fat than the quantity ingested and greatly improving the physical condition; but it may be, and undoubtedly often is, used directly as fuel when occasion requires without first being stored up in the tissues. As it is a concentrated fuel-food, it is to be used freely when we want to keep the body warm or when we need extra force for any increased exertion.

"On a diet rich in fat great muscular effort can be undergone with but little destruction of muscular tissue, and without increased urea discharge." The object of fat in the diet, then, may be said to be as fuel to give heat and energy, and, when necessary, to aid in the repair or building up of active tissue.

The constructive property of fat is especially valuable in the treatment of all wasting diseases, especially phthisis. Fothergill emphatically declares that "the great food for the strumous is fat," and also says: "Whenever there is any tendency to tubercle the individual should learn to eat fat, just as a seafaring man learns to swim. As a physician to a chest hospital I have learned to dread the announcement that fat is no longer taken, especially if the individual is of strumous build, with a small, narrow chest. In my opinion, the existence of a considerable area of affected lung where the digestive powers keep up is less fraught with evil and less prognostically significant than intractable wasting with very little disease in the lung." In this connection, note that an excess of proteids in the diet causes a more rapid oxidation of fat, and that an excess of fat or of carbohydrates lessens the absorption of oxygen and the oxidation of both fats and proteids. Also, that the free use of fluids is thought to favor an increase in the quantity of fat deposited in the body.

Fat is practically indigestible in the stomach, and some stomachs cannot tolerate it, especially when taken with other food; although usually a little fat assists in the digestion of proteids by stimulating the secretion of the gastric juice. Cases occur not rarely in which it is necessary that comparatively large quantities of fat should be ingested and yet in which there is apparently decided gastric intolerance of it. In such event success is often to be attained by giving the fat some little time after the regular meals, when the gastric digestion is approaching completion and the chyme is being passed out of the stomach to be further subjected to the action of the intestinal digestants. It may also be well to emulsify it partially or wholly, especially if there be faulty secretion of bile and pancreatic juice, and sometimes to disguise its taste with agreeable flavors. In this way there is generally but little trouble in administering fats, even such as those which, like cod-liver oil, have a disagreeable taste and odor. Failing in this, we may still resort to inunctions, preferably of predigested or emulsified fats, and often with considerable advantage, since it has been experimentally shown that after passing through the skin fat may be taken up by the subcutaneous lymphatics and later be oxidized or metabolized almost as completely as if it had entered the system by way of the intestinal canal and thoracic duct.

Certain salts in certain proportions are necessary for the maintenance of health in the body. "Lime, chiefly in the form of phosphate, is absent from no tissue, and there is reason to think that no cell-growth can go on without it." Even the bacteria must have earthy phosphates for the purposes of growth. Chlorine, derived largely from the sodium chloride of food, is necessary to form the hydrochloric acid of the gastric juice, the chlorides also keeping in solution the globulins of the blood and body fluids and helping to dissolve the albumin. Phosphorus is necessary in the formation of the lecithin of nerve tissues, as well as for the phosphates above mentioned, and those of potassium, magnesium, etc., which go to form bone. Potash salts maintain the alkalinity of the solid tissues, and soda salts that of the body fluids. Iron is essential for the construction and nutrition of the blood-corpuscles, though small quantities of it are to be found in almost every other tissue.

But not only must the above inorganic salts be given in proper supply, but also certain ones of organic nature, in order to prevent conditions of malnutrition or disease. Those especially which are changed to form carbonates, as the lactates, tartrates, etc., or their respective acids, help to maintain the alkalinity of the system and appear to be most essential, as a scorbutic condition seems to be inevitably created or fostered by their absence. There is also some evidence that certain gouty conditions may be due to the removal of the natural vegetable salts by unwise methods of cooking. The fact of the carbohydrates being an important source of these organic acids and salts has already been mentioned.

Lastly, with many of our foods we require the addition of certain flavors, condiments, etc., which, though they have little or no real food value in themselves in the sense of repairing tissue or furnishing energy, do much good, when not abused, by making the food more palatable, by stimulating the secretion of the digestive fluids, and by acting as carminatives. These condiments should not be omitted from the food of the sick or convalescent, for they have a value of their own, and are "agreeable to the palate and, in moderation, good for the digestive organs."

As a review of the preceding statements, the following quotation, from Notter and Firth,[1] may be of value:

"With regard to the necessity for all four classes of aliments, it can be affirmed with certainty that (putting scurvy out of the question) men can live for some time and can be healthy with a diet of proteids, fats, salts, and water. But special conditions of life, such as great exercise or exposure to very low temperature, appear to be necessary, and under usual conditions of life health is not very perfectly maintained on such a diet. It has not yet been shown that men can live in good health on proteids, carbohydrates, salts, and water, etc., without fat.

"The exact effect produced by the deprivation of any one of these classes is not yet known. An excess of the proteids causes a more rapid oxidation of fat, while an excess of fat lessens the absorption of oxygen, and hinders the metamorphosis of both fat and albuminous tissues. The carbohydrates have the same effect when in excess, and appear to lessen the oxidation of the two other classes.

[1] Treatise on Hygiene, p. 256.

"It is generally admitted that the success of Banting's treatment of obesity is owing to two actions: the increased oxidizing effect on fat consequent on the increase of meat (especially if exercise be combined), and the lessened interference with the oxidation of fat consequent on the deprivation of starches.

"Health cannot be maintained on proteids, salts, and water alone; but, on the other hand, it cannot be maintained without them."

It will be impossible to go into details concerning all the articles commonly used as foods, but there are certain facts that should be well known and which cannot properly be omitted from a work of this kind.

Milk is a typical food-stuff, complete in itself, in that it contains all the food principles, and these in nearly the proper proportion, at least for infant life. The casein and albumin represent the proteids; the cream, the fats; and the lactose or milk-sugar is a concentrated carbohydrate—all being in combination with sufficient salts and water.

It should constitute almost the sole food of infants during the earlier months of life; and that it is capable of sustaining adult life almost indefinitely, especially where there is little demand for heat or the expenditure of force, has been shown in numerous instances. Coplin and Bevan mention the case of a patient who lived and thrived on milk alone for over thirteen months, and of another who lived for three years on the same diet. But, of course, the limited proportion of carbohydrates, even though concentrated, is not all-sufficient for the maintenance of great vital activity, and for persons in ordinary life some addition to the diet is necessary.

The albumin of milk is coagulated by heat, but the casein, which constitutes the greater part of the proteid element, is clotted by an acid or by an enzyme, such as rennin; and as both of these are present in normal gastric juice, it would seem that the preliminary coagulation of casein was essential to its proper digestion. It should be remembered, however, that the casein of cow's milk forms a much harder and firmer clot than does that of human milk, and that the former should, therefore, never be introduced into the stomach in large volumes, but should rather be taken slowly and preferably with other food which will help to divide the curd mechanically. In the feeding of children an alkali, such as lime-water, mixed with the milk is thought to soften the curd and possibly facilitate digestion.

Outside of the body, fermentative changes due to certain bacteria may convert the milk-sugar into lactic acid, which coagulates the casein and "sours" the milk. Another peculiarity of casein is the tenacity with which it holds large quantities of phosphate of lime, one of the most valuable of food-salts.

Sometimes it is advantageous or necessary to predigest milk for infants or sick persons, but if the digestion be carried beyond a certain point, the consequent peptones and albumoses will give the milk a bitter and disagreeable taste. In the feeding of infants it must not be forgotten that the percentage composition of human milk is different from that of cow's milk, and that the latter will need dilution to decrease the proteid proportion, but an increase of fat and carbohydrates. As a child grows older and more active, it becomes necessary to add to the milk additional carbohydrates. These should be easy of digestion and soluble, milk-sugar and predigested starches in the form of maltose and its allies being preferable.

Milk should always be kept as cool as possible and in closed vessels, not only to prevent the absorption of disagreeable odors and harmful gases, to which it is very prone, but to exclude dirt and bacteria. As it is an excellent culture medium, and as it is commonly liable to be exposed to contamination by organisms from many sources before it reaches the consumer, fermentative or other harmful chemical changes are almost certain to occur in it if the temperature conditions are at all favorable. For this reason, it is necessary that the greatest care should be used in the handling of the milk from the time it leaves the cow until it is used, and for the feeding of children and whenever there is any possibility of it being the carrier of disease germs of any kind, it should be properly sterilized and then kept sterile until used. In fact, sterilized milk, modified to resemble the human secretion, will usually be superior to any other artificial food for infants, but the sterilization should always be done before fermentation has begun and harmful products have been developed in the milk. The sterilization may slightly alter the taste and other properties of the milk by coagulating the albumin, but it is doubtful whether it makes any real change in its digestibility.

The cream of milk is fat in its most digestible and acceptable form, and should not be removed from milk if the latter is to be used as food. If the milk seems to be too rich, it may be advisable to skim it, giving it in some form or other with the regular meal and reserving the cream until a couple of hours or so later, when gastric digestion is approaching completion. One may also often escape the use of cod-liver oil and similar fats by taking cream in this way—either plain or flavored and whipped—some little time after the meals.

Skimmed milk and buttermilk may be used freely as beverages, as both are refreshing and healthful, with some food value; buttermilk is also very acceptable to many persons on account of its lactic acid. "Koumiss" and "kefir" are both prepared from milk through the action of certain fermentative organisms, which also bring about a partial digestion of the casein. Each contains carbonic and lactic acids, though in different proportions, some peptones or albumoses, and a little alcohol. They are agreeable to most palates and are usually retained and utilized by stomachs rebellious to almost all other foods.

Milk may be a factor in the causation of disease in a number of ways. The products of the fermentative action already referred to are a frequent source of serious intestinal disorders in infants and even in adults; while if further decomposition occurs, a very poisonous ptomaïne, called tyrotoxicon, is apt to be developed and to cause even fatal results to those using the milk. This same substance is also liable to occur in any milk-product, such as cheese or ice-cream, and is usually the cause or agent in the cases of poisoning by such products that are so frequently reported.

Again, the active principles of plants which the cow has eaten may be transmitted by the milk and produce their physiological effects. But a graver question is whether disease may be transmitted directly from the animals to man by this almost universal food-stuff. Every one knows that the milk from sick cows may cause marked disturbance of health, and there now seems to be fair evidence that cattle are subject to certain diseases identical with or very similar to human maladies, the milk serving as a carrier for the contagium.

Scarlet fever and diphtheria may be mentioned as diseases suspected of being transmitted in this way, and there is no longer any doubt in regard to tuberculosis. Though some authorities still question whether this disease can be thus transmitted unless the milk-glands themselves are affected, the great prevalence of the disease among cattle and experimental evidence both make it certain that milk is often tuberculous, and many believe that by far the larger number of the many cases of infantile tuberculosis have origin from this source.

Milk may also become a disease carrier through carelessness in handling by infected persons or by the admixture with it of water containing disease germs. Epidemics of diphtheria, scarlet fever, typhoid fever, and cholera have all been traced to a contaminated milk-supply, and it is a question whether many of the more or less local outbreaks in cities are not of this character. The writer is personally cognizant of five cases of undoubted scarlet fever that occurred almost simultaneously in one locality and in which, apparently, the only common source was the milk-supply. He was unable to discover that there had been any illness either among the cattle or in the family of the milkman in question, but he has always felt that there was considerable evasion in replying to the inquiries made.

The possibility of milk as a source of danger to health having been shown, the lessons to be had are these: that not only must there be the greatest care in the handling and keeping of milk until it is consumed, but there must also be frequent and careful inspection of the animals from which it comes and of their environment; that no milk from any diseased cow should ever be used as food; that wherever there is the suspicion or possibility of the milk being contaminated with disease germs, it must be thoroughly sterilized, and that any change from its normal condition should also forbid its use.

Fortunately, good milk can almost always be had so cheaply and readily that no serious hardship inures in the strict observance of these rules, and the public should be educated to demand as well as fairly to pay for pure milk from healthy animals, these matters being even more important than that the quality, as shown by analysis, should always be up to a certain standard.

Good milk in bulk should be opaque, of clean ivory-white color, should have no peculiar smell or taste nor any deposit on standing. Nor should it show any change in taste or appearance upon boiling, excepting the formation of the slight skin of coagulated albumin due to the heating. Details regarding the composition of milk and the methods for its examination will be found in the final chapter of this volume.

Cheese is a most valuable food-stuff, and, as a milk product, should be considered at this time. Good cheese usually contains twice as much nitrogen and three times as much fat as the same weight of meat, but many persons apparently find it difficult of digestion and can eat but little of it. This is perhaps because the nutriment is so concentrated and because, as usually eaten, it forms a pasty, solid mass in the stomach into which the gastric secretion cannot penetrate. Mattieu Williams has remarked that we habitually use cheese in the conditions in which it is most indigestible—either in its raw state or cooked into a leathery mass; and he asserts that if the cooking is such that it is thoroughly mixed with other articles of food, or if we will masticate it with other food, so that this commingling of particles takes place, it will be found to be quite digestible by almost every one. He also advises the addition of a small amount of potassium carbonate in the cooking, as this favors the solution of the casein and replaces that salt removed in the whey. It goes without saying that, as a food, only cheese made from whole milk, or from that to which extra cream has been added, satisfies all requirements, and that skim-milk cheeses are decidedly less nutritious than those having the full proportion of fat.

Butter, consisting as it does largely of the fat of milk, is a highly nutritious article of food and one of the most digestible of its class. It should be pure, sweet, and free from rancidity, and while some of the substitutes offered in its stead are entirely wholesome, they should never be sold as butter or used to adulterate it. Neither should butter contain an excess of water, nor of casein, as its food value is thereby accordingly lessened.

Eggs yield almost their full weight of food in a concentrated and very digestible condition, and are valuable on this account, as well as for their palatability and their value in the preparation of many dishes. Containing practically no carbohydrates, they have sufficient food material in themselves for the complete development of the living chick with the aid of nothing external except the oxygen which passes through the shell: the lack of the carbohydrate element, one of the essential food principles ordinarily, is supplied by the heat from the mother hen or incubator, which is sufficient for the development and maintenance of the vital processes, since the unhatched creature wastes almost no energy in physical activity.

The white of egg is almost pure albumin with a little water and some salts; the yolk contains about 30 per cent. of fat and some albumin. The albumin coagulates at about 170° F., but if it is exposed to a higher temperature for any but a very short period of time, it becomes hard and difficult of digestion. A so-called "soft-boiled" egg is scarcely more difficult of digestion than an uncooked one, and is certainly more palatable to almost every one.

Eggs, milk, and cheese may be made into many nutritious combinations which furnish food especially agreeable to the sick, as well as to those whose appetite and digestive functions have not been impaired.

Good meat, when deprived of its contained water, is a concentrated food, and is used not only on account of the large amount of nutriment it contains, but for its rich and agreeable flavor. It represents much vegetable matter converted into its present palatable and more digestible form by the metabolic activity of the animals from which it came. It contains all the essential food principles, the carbohydrates, however, being present as muscle sugar or inosite and, as in milk, in very small proportion. In all fresh meat there is much water, but more in lean meat than in fat; fat bacon contains 60 per cent.; lean beef, from 75 to 78 per cent. of water. As the proportion of fat increases the quantity of albuminoids or proteids decreases: thus, lean beef may have only 2 per cent. of fat to from 20 to 24 per cent. of proteids; while bacon has about 24 per cent. of fat to 15 per cent. of proteids.

Of the varieties of meat commonly used, beef is the most nutritious. Good beef should not be too pale nor too dark, should show no blood clots, have almost no odor, be elastic and not soggy to the touch, be well marbled with clean, white fat, and have compact flesh. Dark beef indicates that the animal was not properly bled, or has had some febrile disease; wet and flabby meat, that it is approaching decomposition. The flesh of young animals is more tender than that of older ones, but not as digestible, partly because the young flesh cannot be so thoroughly masticated and the fibres so well separated. Therefore, veal is not as digestible as beef, nor lamb as mutton. "Young flesh is less stimulating and nutritious and more gelatinous than that of the adult." (Vaughan.) Veal should not be too pale, as that indicates ante-mortem bleeding or too young an animal. The calf should be at least one month old before the killing.

Mutton is more digestible than beef, but not so nutritious. Its flavor is objectionable to some. Pork is an economical food for the poor man, as good pigs store up three times as much of the food they eat as does the ox. The flesh is also easily preserved by drying or smoking, and ham and bacon are exceptions to the rule that dried meats are more indigestible than fresh ones. Again, pork fat furnishes much heat for cold weather by its oxidation and combustion in the body. But it must be remembered that it requires good digestive apparatus to dispose of it, and that much pork is not to be advised for those of sedentary habits.

The flesh of poultry is acceptable to most palates, if not too old and tough. White meat is more digestible than the dark, but not so nutritious or rich in flavor, since the latter is more highly nitrogenous. Chicken broth is more nutritious and more laxative than that made from mutton.

Fish is not sufficiently stimulating to constitute the chief flesh diet of a people, but it furnishes variety, and undoubtedly should be used largely by those subject to neurosal affections, on account of its contained phosphorus. White-meated fish are more delicate in flavor and more easily digested, but not so stimulating as those of red flesh. Some fish are poisonous, either by nature or from inhabiting foul waters; while any fish may become so if undergoing decomposition. Shell-fish are particularly liable to develop poisonous ptomaïnes in the process of decomposition, and, consequently, only such as are absolutely fresh should be used. Oysters and clams which have been taken from a water contaminated by sewage may also convey the germs of infectious diseases, such as typhoid fever; an instance of this having been proven in the case of a recent epidemic of the latter disease in Connecticut, which was investigated and reported by Prof. Conn, of Wesleyan University.

"The following meats should not be eaten: 1. The flesh of all animals dead of internal diseases, or which have been killed while suffering from such diseases, or animals killed by overdriving. 2. The flesh of animals with contagious diseases that may be transmitted to man. 3. The flesh of animals that have been poisoned. 4. The flesh of animals with severe infectious diseases, as pyæmia, etc. 5. Flesh that contains parasites that may be transmitted to man. 6. All putrid flesh." (Gerlach.)

Competent inspectors should be and are appointed by Government and State authorities to examine the various meats offered for sale in the large cities, and undoubtedly do much good in preventing the sale of meat that is unfit for use. Unfortunately, from false ideas of economy, they are too few in number in many communities to be able to attend to all the work that is required of them.

Coplin and Bevan give the following as diseases which are to be specially guarded against, and also discuss the symptoms of these maladies and the appearances they produce in the flesh and viscera of animals killed while suffering from them: In cattle, epidemic pleuro-pneumonia, foot- and mouth-disease, contagious typhus, anthrax, tuberculosis, actinomycosis, Texas fever, dropsical affections, and indigestion. In sheep, braxy, variola ovina, black quarter, phthisis, fluke disease, and gid. In swine, anthrax, hog cholera, measles, and trichiniasis.[1] It should also be remembered that the intestinal parasites, such as tape-worms and round worms, often, if not usually, gain entrance into the system through the ingestion of meat containing them in their embryonal or larval stages.

Therefore, in cooking meat, every part should be heated to at least 160° F. to destroy any disease germs or parasites it may contain, as very rare meat may still contain these organisms in a living state. Tuberculosis, for instance, may be incurred by eating flesh imperfectly cooked, since its germs are hard to kill; though it must be said that this disease is not so likely to affect the muscular tissues of an animal as others of the maladies mentioned. The development of ptomaïnes in flesh may also make it very poisonous, and this is especially likely to occur in meats that have been kept a long time after killing or in those preserved in cans or other packages that have been imperfectly heated or sealed.

Meat is cooked to improve it in appearance and to make it more agreeable to the palate and digestion. The effect of cooking upon muscle tissue is "to loosen the bundles of fibrillæ from each other so that they are readily torn asunder or crushed by the teeth." Perfectly cooked flesh is more savory than when it is either underdone or overdone. Foster says that in the stomach "the natural bundles of meat and vegetables fall asunder, the muscular fibres split up into disks, and the protoplasm is dissolved from vegetable cells." However, "if the meat be not chewed properly but 'bolted,' the solvent gastric juice can

[1] Manual of Practical Hygiene, 1st edition, p. 132, et seq.

only act on the exterior of the mass; while 'lumps' offend the stomach and arrest the gastric secretion."

Meat cooked before *rigor mortis* sets in may be tender; cooked during the *rigor*, it is tough, and is masticated with difficulty; after the *rigor* is past the meat becomes tender again when cooked, provided it was so originally.

In cooking meat, the ultimate condition in which we wish it to be should always be kept in mind, and pains should also be taken not to overcook or use too high a temperature. The processes pursued in making a good soup or broth, and in cooking so that it may retain all its juices, salts and flavors, are radically different. In the first case, it is desired to extract as much of soluble constituent of the flesh as possible, and to do this the meat should be cut into small pieces and allowed to remain for a time in cold water, this afterward being very gradually raised to a temperature of about 160° F. In this way the juices exude and the salts and soluble parts of the meat are dissolved before the pores are closed by the coagulation of the albumin.

On the other hand, if it is desired to retain the juices and savor in the meat, the piece should be large as possible, that the surface exposed will be small in proportion to the volume. The piece is then to be first subjected to a temperature as high as possible, that the surface may be cooked at once and the albumin coagulated, the juices being thus prevented from escaping by the sealing of the pores. In boiling this end is attained by plunging the meat at once into boiling water; in roasting, by having the fire or oven very hot. After this first heating it is best to diminish the degree of heat somewhat, that the subsequent cooking of the interior may go on more slowly and the temperature within may not rise above the coagulating point to make the fibres hard and stringy. Meat cooked in this way should be tender, juicy, and full of flavor. Broiling or grilling is, of course, but a modified roasting.

Soups and broths made of meat juices alone and without the addition of other substances are stimulating rather than nutritious, as they contain little albumin, carbohydrates, or fat. However, if certain vegetables be added to the soup, the latter will gain sufficient of these food-principles and be highly nutritious, and such vegetable soups are of great value in all schemes of economic cooking. Bones are also of value on account of the salts, gelatine, and other soluble organic matter which they contain, and with vegetables they make especially nutritious and easily digested soups.

The meat from which soup is made, on the other hand, is not all that is desirable, for though it still contains albumin and fat, it has lost its salts and savoriness, and is unpalatable and, therefore, not easily digested. It needs something—a sauce or condiment, or preferably, a meat extract, for meat extracts are nothing but thin soups evaporated to dryness or condensed. Or, if both soup and the meat be taken at the same meal, the things lacking in each are supplied in the other, and the needs of digestion and nutrition are supplied.

Frying meat, as is commonly practised, should not be condoned or tolerated, as it renders the albumin of the flesh extremely tough, beside soaking it with fat or grease, and thus greatly increasing the difficulty of its digestion. But frying by total immersion in boiling fat is an excellent way of cooking meats containing much water, and especially fish, for the boiling point of fat or oil is very high, and the meat is instantly cooked on the outside, while the water in the interior, being converted into steam, prevents the ingress of fat by its expansion, cooks the albumin, and leaves the flesh in a light, flaky condition. But the fat must be boiling hot when the meat is immersed, and the latter must not be allowed to remain in the former longer than just suffices for the perfect cooking.

Beef-tea, as ordinarily made, is only a thin extract of beef, the stimulating properties of which will be considered hereafter. To make a beef-tea containing any considerable amount of nutriment, the meat from which the juices have been extracted should be dried, pounded fine, and all fibrous and tendinous portions should be removed. This pounded beef should then be added to the liquid extract, which then only is really a food. However, the mixture should always be seasoned, even for the sick, that it may be thoroughly acceptable to both palate and stomach. In making the extract, remember that the meat should be cut into very small pieces and added to cold water in about the proportion of one pound of lean meat to one pint of water, and that the whole should be brought to the boiling-point very slowly.

The *cereals* form one of the most valuable kinds of foods. All but rice contain considerable proteid matter—from 10 to 20 per cent.—beside carbohydrates which predominate, some fat, and a goodly proportion of phosphates. Rice has only 5 per cent. of proteids to 75 per cent. of starch, but it is easily digested, and is, therefore, a valuable food for the young and the sick; it is also well fitted for a chief food for dwellers in hot climates on account of its low heat production.

Wheat is the most nutritious cereal, and bread made from it is aptly called "the staff of life," since it is a food which, with the addition of a little extra fat and albumin, furnishes the essentials in proper proportion for the support of life. Barley closely resembles wheat in composition, and rye also is rich in nutriment, though perhaps a little more difficult of digestion than wheat. Oats are valuable on account of the large amount of fat they contain—over 5 per cent.—beside a full share of proteids, starch, and salt. Corn or maize, though not a true cereal, furnishes a valuable food with considerable fat; it also contains a vegetable fibrin. The proteid constituents of the cereals are vegetable albumin, casein, and gluten, the last of these being most abundant in wheat and, perhaps, of the highest food value.

Grinding breaks up the grain and the starch granules of the cereals, aids in separating indigestible parts, and renders the starch much more suitable for cooking. Wheat flour ground by the old method should be soft and smooth, but that made by the new roller-process is more apt to be slightly granular. It should not be too white, as that indicates a lack of the proper proportion of gluten, and should contain everything but the outer husk of the grain. The inner coats should be retained in the flour, as they hold a good part of the gluten and practically all of the grain salts. Corn-meal should be dry and powdery, or, at least, not too granular. Flour of any kind should be kept well covered in a dry place, and should contain no living organisms nor any adulterants.

Bread is practically made of flour, water, and salt; though sugar, milk, etc., may be added to improve the flavor. As flour and water alone make a tough and indigestible mass, bread is leavened to make it easier of mastication and digestion, and for this purpose either yeast, baking powder, or aeration is employed. Yeast at the proper temperature rapidly converts the starch or sugar into carbonic-acid gas and alcohol, the former of which in escaping makes the dough porous and light, the walls of the cavities it produces being kept from collapsing by the tenacity of the gluten until the heat has fixed them permanently. As the heat of baking dissipates both the gas and alcohol, from 10 to 12 per cent. of the weight of the flour used is lost by this method. Moreover, if the fermentation goes beyond a certain point, lactic and acetic acids are formed, and the bread becomes "sour." Consequently, it has been advised that the yeast method be discarded and that the leavening be done by means of baking-powders or aeration. Carbonic-acid gas is evolved from the baking-powders upon the application of heat and moisture, and the bread is made light by the gas, with no loss of food substance, and, if the powders are pure, with nothing harmful being added to the bread. There should be no alum or other adulterants in the baking-powders, any more than in the bread itself. Alum unites with the phosphates of the flour, rendering them insoluble and preventing their absorption from the alimentary tract. Bread may also be leavened on a large scale by forcing air or carbonic-acid gas under high pressure into the dough, or by mixing the flour with water heavily charged with the latter gas. In this method, also, there can be no loss of food material nor any detriment to the bread, provided cleanly precautions are observed.

Good wheat bread should be almost white, light, sweet, spongy, and with a crust easily broken and equal in bulk to about one-quarter of the loaf. As considerable of the starch has been converted into dextrine in the crust, the latter is more easily digested than the interior of the loaf. Fresh bread is not nearly so digestible as that which is a day or two old. As stated, bread needs only a little added fat and albumin to make it a perfect food, and this it gets almost if not quite sufficiently in the butter which we commonly use upon it.

The vegetables in common use are valuable articles of food, in that they give us the larger portion of our carbohydrates and also furnish an agreeable variety from day to day. In the fresh state they contain considerable water —from 75 to 90 or 95 per cent., the residue being mainly one or the other of the carbohydrates. Potatoes exemplify this well, since they contain but little proteids and fat, and practically all of their solid matter is starch. On account of their customary cheapness and ease of growth and storage they are usually considered to be a good article of food for the poor man, but it should not be forgotten that other foods which are apparently more expensive may actually at times be cheaper than potatoes, both on account of containing those principles which the latter lack and because they may require less expenditure of digestive energy. Beets contain much sugar and are nutritious, palatable, and easily digested. Cabbage, cress, spinach, and other greens, are especially valuable for the organic salts which they contain, and because they serve so well as relishes. Celery and lettuce are nerve sedatives, and asparagus acts as a diuretic and is thought to be of special benefit to the kidneys.

The seeds of the leguminous group of plants, such as peas, beans, lentils, etc., contain from 22 to 25 per cent. of proteid matter in the form of vegetable casein, and almost 50 per cent. of starch. It is on account of this abundance of food-matter that they make such a valuable addition to soups and the like, and for the same reason they should also be considered and used in any dietary where economy of expense is to be a factor. Green peas and beans are much more digestible than those that have ripened and dried, though, of course, they do not yield as much food, weight for weight, as the latter.

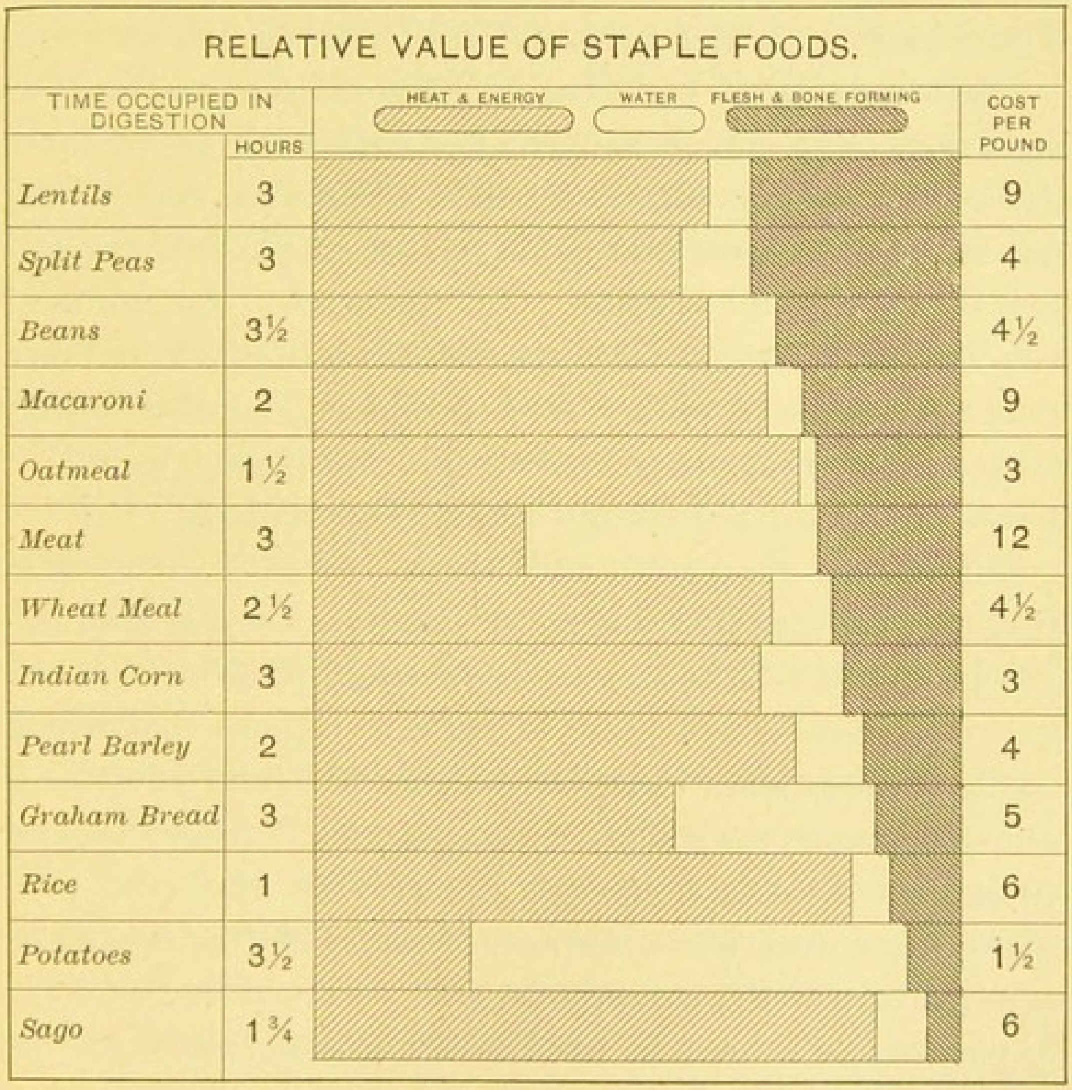
All vegetables should be cooked so as to retain their salts, or else the water in which they are cooked and which contains these salts should be used in making soup or broth, to be served at the same meal with the vegetables. This is especially advisable with regard to potatoes and sweet potatoes, as their soluble salts have much to do with their digestibility. It is for this reason that a properly roasted potato is always better than a boiled one, and that steamed vegetables are both more palatable and more digestible than those which have been cooked under water. In fact, Mattieu Williams has even suggested that possibly one reason why gout is so prevalent among Englishmen is because they habitually eat boiled vegetables and throw away the water in which these have been cooked. The salts not only help in the digestion of the starches, but they furnish bases to unite with and render soluble the irritating acids that produce the gouty symptoms. It should also be remembered that the dried legumes should always be softened by soaking before cooking, and that they as well as other vegetables should be cooked, whenever possible, in soft water.

Fruits are especially valuable on account of their flavor, acceptability to the palate, benefit to the digestion, and for their laxative action. Ripe fruits may be eaten freely, but in most cases, preferably early in the day. Fresh fruits are usually better than those dried or otherwise preserved; but where the former cannot be had, the latter should be used freely, and all should be used whenever possible throughout the year. Green fruit, or that which has begun to decay, should not be eaten, for obvious reasons.

Nuts are nutritious on account of the high percentage of fat that most of them contain, but are difficult of digestion unless carefully masticated. Recently pastes made from various nuts have been placed on the market, and are to be considered as an agreeable addition to our dietaries. Prepared starches, such as arrow-root, tapioca, sago, etc., are very digestible and, therefore, useful, especially in the preparation of food for the young or the sick.

The following diagram may be of service to some in determining the value of certain food-stuffs.

FIG. 34.



CHAPTER VII.

STIMULANTS AND BEVERAGES.

The essential function and property of stimulants is to liberate some of the latent force of the body, and they are of use and value in sudden emergencies, to tide the system over important crises, to hasten a tardy convalescence, or, perchance, to whip up a flagging digestion so that it may the better prepare food for the repair of waste or the supplying of body fuel. Those stimulants, excluding drugs, with which we are most concerned are of three classes, viz., nitrogenized vegetable stimulants, such as tea and coffee; nitrogenized animal stimulants, as beef-tea and meat-extracts; and alcohol. All these are "force-liberators," though alcohol may sometimes act the part, in more moderate measure, of a "force-producer," and it is well to remember that they scarcely give anything at all to renew or replace the energy which they set free.

This being so, care should always be taken that some food may be supplied during or shortly after the stimulation produced by the agents in question, in order that the body may have a new store of force to replace that which has been liberated. Especially is this necessary in cases of sickness, and as the soluble carbohydrates furnish fuel and consequent heat and energy to carry on the vital processes, these even more than other kinds of food are to be supplied and will generally be well received and utilized by patients or others in need of stimulation; and, just as we must not depend on stimulants alone to the exclusion of food, so also must we take care not to continue their use any longer than is necessary to attain our object, and likewise must not over-stimulate or carry the action so far that the body is left poor and weaker in force than before the use of the stimulants began.

For example, beef-tea constantly stimulates the vital and nervous functions to greater activity, this requiring that either tissue or food be oxidized to produce the necessary energy. But beef-tea, as ordinarily made, gives no food in itself, and, unless this be otherwise supplied, the body tissue must be consumed and the result must be in the end disastrous; and yet this is what occurs to many patients through the mistaken idea that beef-tea is both nourishing and stimulating. When "whole beef-tea" (the recipe for which has already been given) is used these remarks do not apply, since it contains some true food, though even here soluble carbohydrates may be wisely added.

The stimulating factors in ordinary beef-tea are the extractives, such as kreatin and kreatinine, which are products of the wear and tear of life, intermediate between living, active tissue and the final excretory matters, such as urea and uric acid; hence, they can have little, if any, real food value. Beside these the beef-tea contains only the salts of the meat, which, though valuable, are not force producers.

The active principles of the nitrogenized vegetable stimulants resemble very closely in chemical composition not only the meat extractives, but also those drugs, like strychnine, which are used in medicine as tonics and cerebro-spinal stimulants, and they act physiologically in a similar though milder manner.

As beverages tea, coffee, and cocoa supply fluid for the system and that stimulation of the assimilative functions that gives the sense of comfort after their use; cocoa and chocolate having also the advantage of supplying some food. But these beverages can all be abused in their use as readily as can beef-tea or alcohol, and "tea- or coffee-drunkards" are not uncommon in our hospitals or in private life. The teacup is not always the one that "cheers but does not inebriate." Women especially who drink much tea are apt to be nervous and dypseptic, to have the "tea-drinker's heart," and to suffer from headaches and neuralgias. They depend upon tea to take the place of food, and soon use up what little store of force they may have had, since they fail to replenish it with new fuel-food.

Men are more addicted to the use and abuse of coffee, and often manifest symptoms directly traceable to it. While caffeine increases heart action, and may be used to advantage in cases of cardiac debility, for the same reason it should be taken with caution and in moderation where the cardiac action is already too vigorous. Vogel has advised the use of strong coffee with cream as a tonic and food in debility accompanying the acute diseases of children.

It is interesting to note that among all nervous, energetic people the use of some one or the other of these stimulant beverages is common, and that "total abstainers" from alcohol seem instinctively to take to tea or coffee. And while it is probably theoretically true that the healthy person would better abstain entirely from the use of stimulants, except in emergencies or at rare intervals, yet this almost universal demand and use of them probably indicates that under our present high tension of living there is a practical physiological demand and need for them that perhaps had better be satisfied in a measure, but with moderation and judgment.

Alcohol. Liebig says "alcohol stands only second to fat as a respiratory material," but adds that "the same effect could be produced in the body by means of saccharine and farinaceous articles of food at one-fourth or one-fifth the cost." Fothergill also holds "that the chief portion of the alcohol ingested undergoes consumption in the body," but insists that "the question of 'alcohol as a food' can never be separated or divorced from that of 'alcohol as a stimulant' or as a force-liberator." Again, Liebig writes, that "the use of spirits is not the cause but the effect of poverty. It is the exception to the rule when the well-fed man becomes a spirit-drinker. On the other hand, when the laborer earns by his work less than is required to provide the amount of food which is indispensable in order to restore fully his working power, an unyielding, inexorable law or necessity compels him to have recourse to spirits. He must work; but in consequence of insufficient food, a certain portion of his working power is daily wasting. Spirits, by their action on the nerves, enable him to make up the deficient power at the expense of his body; to consume to-day that quantity which naturally ought to have been employed a day later." This may also be the case where there is an abundance of food, but where it is improperly chosen for the needs of the individual or ruined in the preparation by bad cooking. Education in the principles of the scientific and economical selection of food and its preparation may thus become a means of preventing those diseases that depend on or are aggravated by insufficient or improper food, and consequent alcoholic excesses. The effect of alcohol upon the weak and savage races is much more marked and disastrous than upon the civilized and strong; so it harms the health of the underfed and overworked much more than it does that of the well-fed man of means and leisure, and women and children more than adult men. This latter point is to be remembered in practice.

Remember also that, while alcohol is partially a respiratory stimulant, it is a force-liberator and consumes the body store, and unless given with other readily oxidizable food the risk is run of putting a patient "in a grave never dug by Nature," especially where there is already danger of the patient sinking from exhaustion. But it is just in these cases, when given with other food, that we find alcohol a most valuable therapeutic agent. Give it with foods that produce heat and force—*i. e.*, some form of the soluble carbohydrates, as maltose, malt extracts, milk, milk-whey, or even sugar. Where the assimilative powers are weak it may be advantageous or necessary to partially or wholly predigest these foods; but above all, remember to replace what alcohol takes from the body, or physiological bankruptcy will ensue. Note also that, though alcohol may be in one sense a food, it is a very costly one, and that intoxication must occur long before a man could get the equivalent of a full meal.

Alcohol is to be used in sickness practically to sustain the vital powers, to meet emergencies, and to lift the patient over obstructions in the road to health; and such use requires a thorough knowledge of its action coupled with the highest judgment.

In malt liquors there is considerable maltose left unchanged, thus combining with the alcohol a soluble carbohydrate of the highest value, and these brewed ales, etc., may often be used with benefit as tonics, especially where convalescence is prolonged. The stronger distilled liquors are diffusible cardiac stimulants, and are especially valuable in emergencies, but the continued use of them must only be advised with great caution. Fothergill gives two excellent rules for the use of alcohol by the healthy: "First, never have alcohol in the brain when it has work to do; second, a little alcohol betwixt a man and past trouble is permissible; but it is not well to put a little alcohol in front of a coming trouble." Murchison, in his work on *Fevers*, lays down these rules for practice, which it would be well for all to adopt: "What are the conditions of the animal economy in which alcohol may be of positive use? That there are such conditions, I believe cannot be denied by any one who has honestly studied the subject; but they are not the conditions of perfect health. It is especially when the circulation is weak or sluggish that a daily allowance of alcohol may do good. Thus: 1. Alcohol is useful in the course of most acute diseases, when the organs of circulation begin to fail, as they are apt to do. A moderate quantity usually suffices. The large quantity still sometimes administered may do harm by inducing congestion of internal organs. 2. In convalescence from acute diseases, or from weakening ailments, when the circulation remains feeble and the temperature is often subnormal, alcohol is useful in promoting the circulation and assisting the digestion. 3. In persons of advanced life the circulation is also often feeble, and a moderate allowance of alcohol often appears to be beneficial. All other conditions of the system marked by weakness of the muscular wall of the heart, whether permanent or transient, are usually benefited by alcohol." Alcohol is a good servant, but a bad master. King Chambers says: "Let alcohol be taken never as a stimulant or preparative for work, but as a defence against injury done by work, whether of mind or body. For example, it is best taken with the evening meal or after toil. Let the increase in the desire for and the power of digesting food be the guide and limit to the consumption of all alcoholic liquids. Let the forms be such as contain the least proportion of fusel oil. Let all with an hereditary tendency to hysteria or other functional diseases of the nervous system refrain from its use altogether, even though as yet in good health."

Beverages.

To comment individually upon the multitude of non-alcoholic and non-stimulating beverages that are now more or less generally used, is both impracticable and unnecessary, nor will an attempt to classify them be of much value. For the most part they serve only to please the palate; though if in this way they bring about a greater ingestion of fluids when these are needed, their service cannot be considered a vain one. For it has already been stated that an ample supply of drinking water or other fluids taken daily and habitually is essential to the satisfactory removal of the various waste matters from the body, and that without it the latter may readily develop conditions favoring disease.

Moreover, it is true that certain gases and salts held in solution in such beverages increase this excretory action, and may be highly beneficial in appropriate cases; but it should be a matter of caution that where such therapeutic results are thought to be necessary, competent medical advice should be the guide as to the kind and quantity of the agents used. This comment is justified by the fact that of late many substances possessing decided physiological power have been advertised and sold in the form of one beverage or another directly to the laity, who, being incompetent to judge as to whether or not such substances are actually needed in their individual cases, may actually do themselves much harm in this way.

Only such beverages, then, as are quite simple in their nature or as are advised by competent medical authority should be used. If they are artificially made and water is the solvent fluid, as it will be in most cases, there should also be certainty that it comes from a clean and safe source, lest it carry the germs of disease. There is no doubt that frequently the cheaper bottled drinks which are dispensed so generally are made from water that has been subject to more or less dangerous pollution, and there is the additional risk that arises from the imperfect cleansing of the bottles for these liquids which have been returned to be refilled. A little thought as to the dangers which do exist in relation to this matter will be convincing as to their gravity.

Many of the most popular beverages are highly charged with carbonic-acid gas under pressure, and the fact that so much of this gas can be taken into the system in this way without apparent harm, and its free elimination, would seem to be additional evidence that it in itself could not be so very harmful in the atmosphere, even when in proportions considerably greater than the normal.

In conclusion, it may be said that a free use of all such beverages as are known to be clean, safe, and wholesome will probably be found to be entirely favorable to health, unless there be some contraindicating reasons peculiar to the individual himself; and that their substitution whenever possible in place of the alkaloidal and alcoholic stimulants is to be commended on hygienic as well as other grounds.

CHAPTER VIII.

PERSONAL HYGIENE.

THE proper consideration of this subject demands an ample volume rather than the limits of a single chapter, for the ultimate aim of all sanitary work is the preservation and betterment of the health of the individual, and beside, the factors that affect the well-being of the person are so multitudinous in their number and in their phases that no brief discussion can comprehend them all.

However, much that pertains to personal hygiene and that requires no repetition for its application has already been given in the preceding pages; so that it is hoped that if the reader will exercise that virtue of common sense and reflection that is so essential in this study, the remarks to be added will be helpful in suggestion and in answering many questions, even though they may not be considered in any way as complete discussions of the respective themes.

Each age has its own requirements, and that which may be entirely satisfactory or permissible at one time may not be so at another. To attain the best results it will often be necessary to even anticipate with prophylactic measures the birth of the child; and broadly speaking, much of the welfare of future generations lies in the care of those now living.

The advances in physiological and biological science in recent years have done much for all humanity, but in no respect, perhaps, have they been of more service than in determining the great influence of environment and in establishing the fact that the presence or absence of disease is oftentimes, if not always, due as much to the predisposing conditions and physical status of the individual as to external and exciting causes. What may cause only a trifling ill in one may bring about most serious evils in another whose environment is not so fortunate.

Life has been defined as the power of an organism to continually adjust its internal conditions to its external conditions, and as long as this is done satisfactorily life persists. The secret of personal hygiene and health, then, must lie in determining the relationship between the internal and external conditions of the individual's organism.

"Know thyself" is advice good for the body as well as for the mind or soul, and knowledge of the right kind can do no harm. He who knows his personal and physical nature and acts accordingly is well equipped to fight against the ills of life, and the study of the relationship above referred to will help the thinking man so to care for himself that in all probability his days will be prolonged.

But a caution or two must be interpolated here. It is well known that "expectant attention" too persistently directed toward a certain organ may lead to decided alterations or disturbances in the functions of that organ; and again, unless one well understands the mysteries of human physiology, a little imperfect or insufficient information in this respect may lead to the assumption or pursuit of habits and practices actually dangerous to health. Too much ill-advised care and attention may be just as full of risk as too little, and physiological egotism without a sound basis may have a bitter reward.

What is needed is that each one should study carefully the phenomena of his daily life, should determine carefully and accurately the purpose and reason of each of the respective functions, and then, not forgetting their mutual interdependence upon one another and that all should work in harmony, should endeavor to do that which will best facilitate the functional activity with the least expenditure of energy.

This may be more or less readily taught to and inculcated in the young, but with much greater difficulty can we affect the mature or aged; for we are all creatures of many habits, and the impress of these may resist to the utmost any and all endeavors to modify or remove them.

To quote what has already been written: "The essence of sanitation is to secure perfect health, to increase the inherent power to resist noxious and harmful influences, and to make all the surroundings and environments of the body pure and free from depressing factors."

With this preface, the following discussions are added in the hope that they may be of some assistance in determining the way of right living and in securing the welfare and health of every individual.

Heredity.

In the broadest sense heredity is a characteristic jointly possessed by two cells, furnished by respective parents, which join and form a fused cell, which carries on its evolution under certain governing impressions indelibly stamped by the two parental lines of descent; but, in the ordinary use of the term, it may be defined as the transmission to the offspring from parent or ancestor of a trait, type, temperament, characteristic, or predisposition which has a governing or influencing effect upon the growth or nature of that offspring. This transmitted impression may be either for good or for evil. Consequently, as hygienists, we must use the influence and power that we have to further the transmission of beneficial or elevating characteristics only, and to prevent the bequest of harmful influences and hereditary diseases to the generations to come. "The germ of the unborn infant must be complete and untainted in all its nature, otherwise we cannot hope for a vigorous and perfect growth or development."

As the family is the foundation of the State, and society is a congregation of men for the purpose of acquiring greater power and more comforts through mutual co-operation, the latter, whether domestic or civil, has some right to make men understand that they must care for the health of the generations to follow, and to enact just laws looking to the prevention or obliteration of transmissible infirmities. And history seems to show that no great nation has ever been destroyed or overwhelmed until its people had first neglected or abused the laws of hygiene, heredity, and sociology.

We find that a married couple have generally, beside themselves, the welfare of five human beings within their keeping. To produce healthy children and ones not prone to disease both parents should possess good constitutions, and they should take great care not to weaken these by excesses of any kind, physical or mental, nor, as far as lies in their power, by any chronic disease. It is evident that children of parents that have been conscientious observers and followers of Nature's laws must have a better chance for health and superiority all their lives.

In this climate the proper age for marriage is considered to be about twenty-four or twenty-five for the man, and nineteen or twenty for the woman, though this must vary with the state of development of the parties concerned. Some of both sexes mature at a considerably earlier period than do others, and it would be unjust to say that they were not fit for the duties of marriage till they reached the age of slower-growing ones. Usually, however, before the ages given, development is not complete and the whole organism is in a transition state. We know that the use of any organ before it has attained its complete growth or development is very apt to cause exhaustion, or perhaps premature degeneration of that organ, and we cannot but believe that children developed in immature sexual organs must be deficient in true vital force and energy. It is often noticeable that a child apparently strong and vigorous may have but little power to resist disease, or may even be strongly predisposed to some infirmity; in such cases there will likely be some defect or taint in the parent stock.

Distinguishing characteristics are more apt to be transmitted in the early married life of parents, because their organs and forces are then more vigorous; but if a couple marry when quite young, and before their own organs are fully developed, their elder children may be more deficient, mentally and physically, than their later ones.

Late marriages are not likely to be as fruitful as earlier ones, possibly owing to the increased difficulty of parturition on the part of the mother and her consequent unwillingness to undergo the ordeal more than a few times. But healthy middle-aged persons may have even healthier children than those who have married too early.

In features, constitution, sense-organs, shape of head, etc., the child is most apt to resemble the father; while it will likely follow the mother in the shape of the trunk and in the formation of internal organs. The character and mental qualities of the child may come from either parent or both. Maternal impressions during pregnancy undoubtedly often have a marked effect upon the coming infant.

Hereditary influences are generally transmitted directly from parent to child, but we occasionally find a cessation of the trait or predisposition for one or more generations and then a recurrence. To such a peculiarity we give the term *atavism*.

A disease may be truly congenital—that is, transmitted directly from parent to offspring—as syphilis, scrofula, etc.; or there may be only an inherited predisposition to the disease, as toward tuberculosis, etc. Physicians have thus a twofold duty: first, to do all they can to guard against the transmission of such diseases; second, to combat the disease or any tendency toward it as soon as any symptoms thereof are discovered or it is suspected in the child. The first duty can be accomplished, theoretically, by preventing generation and production on the part of those unfit to produce offspring, and practically, within certain limits, by fighting the causes and their effects in the individual, especially at the ages or times when these have the greatest force or are most apt to manifest themselves. For the second, the child must be immediately placed in the most favorable hygienic surroundings, and everything possible done to prevent the further development of the disease or predisposition. In many cases such early interference will accomplish much good, and the disease may be averted entirely. Especially is this true of those inheriting the tuberculous diathesis.

The most important of the hereditary or transmissible diseases are syphilis, tuberculosis, scrofula, cancer, gout, hysteria, epilepsy, certain physical deformities, certain skin diseases, insanity, and criminal tendencies of various kinds. But what may appear to be a direct and actual inheritance of a disease may only be the production of the disease in that person by the same agents, environments and morbid conditions as caused or favored the disease in the parent. However, even here there is very possibly a transmitted predisposition to the acquirement of the disease, rendering it all the more easy for it to manifest its symptoms upon slight provocation.

There should be no marriage between persons inheriting predispositions to the same disease, especially if they be relatives, and "a person affected with hereditary or well-marked constitutional syphilis, or having a strong consumptive taint, or tendency to mental unsoundness, should not marry at all."

Defective eyesight is very apt to be transmitted to children, and the latter should be carefully examined and, if necessary, fitted with proper glasses before being placed at school or at any work requiring much use of the eyes.

Infirmities which do not prevent marriage from being fully accomplished, or which do not tend to the degeneration of the offspring, are not good reasons alone for forbidding marriage, but all that have such a tendency are. A man should not marry a woman too far advanced in life, nor one that is very feeble, delicate, or deformed, especially as to the chest or pelvis. Hysteria, convulsions and epilepsy due to organic disease should prevent a woman from marrying, though some extremely nervous and hysterical women are much benefited by marriage, and have healthy children. So with many women who have uterine congestions and displacements before marriage.

Evidence seems to indicate that marriage between relatives is reprehensible, the danger increasing with the nearness of relationship, the children of such marriage being prone to disease and to defects in the sense-organs, especially the eye and ear, or in mental qualities. This is probably because the strong or advantageous points or characteristics do not seem to be transmitted either in man or animals with the same ease or readiness as are the faults or weaknesses. However, any advice on the subject must depend upon the special circumstances in each case, but chiefly on the health and degree of relationship between the parties.

Exercise.

Exercise is generally considered to mean simply the action of the voluntary muscles, but it has a wider meaning than this. Every organ in the body is capable of being exercised in some way or other; and if not properly exercised an abnormal state is almost certain to ensue. "Life is organization in action." Each organ has its own special stimulus, and if this be normal in amount and character, we should have health. Also, the trained use of an organ makes it more effective in the performance of its functions. But deficiency in exercise favors a lack of nutrition, wasting in size and eventually degeneration of tissue; while, on the other hand, too much work may favor hypertrophy and tissue degeneration.

Proper muscular exercise is highly beneficial to health, and in the end actually necessary to the proper performance of functions in other organs; it is consistent with and necessary to health. But, to be of value, the exercise must consist of movements of sufficient force to necessitate energetic contraction of the muscles; we must do work. This necessitates resistance as an element, and we may define physical exercise as *voluntary labor*. We need the resistance to obtain the proper contraction of the muscles, the contraction for their disintegration, the disintegration for their renewal, etc.; for we know that upon the constant destruction and disintegration of tissues depends their subsequent renovation, and that the strength and vigor of all parts of the body and of the whole depends upon its *newness*.

Beside the fact that proper physical exercise makes the voluntary muscles larger, harder, stronger, and more quickly responsive to the will, and that it increases the functional capacity of the involuntary muscles employed, it largely promotes health and strength by quickening the circulation and increasing the respiratory powers. During muscular action (contraction) there is a conversion of potential energy into motion, a call for more food, an increased demand for and consumption of oxygen, and an increased production of and elimination of carbonic acid and other waste matters.

This increased demand for oxygen and elimination of carbon dioxide necessitates increased action of the respiratory organs—the lungs, and this is one of the greatest advantages of physical exercise. The respirations are increased in frequency and depth, the lungs expanded, the air vesicles flushed out and refilled with each inspiration. Doubtless many cases of pulmonary tuberculosis could be prevented or cured if only people could be taught to take proper exercise and to breathe properly, for we rarely find the lungs fully expanded except in the outdoor worker or athlete. Consequently, the movements of any given exercise should be with speed and force sufficient to quicken and deepen the respiration; and, conversely, if any severe exercise is to be undertaken or a course of training begun, especial care must be had to develop the lung capacity.

A man walking at the rate of four miles per hour inspires five times as much air as when reclining at rest, which latter amount is, for an adult, about 480 cubic inches per minute. Or, as Pettenkofer has shown, a man on a day of rest absorbs 25 ounces of oxygen and throws off 32 ounces of carbon dioxide and 29 ounces of water; on a day of work he absorbs 33.6 ounces of oxygen and throws off 45 ounces of carbon dioxide and 72 ounces of water. In other words, the elimination of pure carbon on a work-day is more than three-fourths of a pound.

Muscular exercise is necessary, therefore, for the proper elimination of waste carbon from the body, and, as the action of the muscles is checked and lessened if the carbon dioxide produced by their action is not immediately carried off by the blood and eliminated by the lungs, it follows that during exercise there should be nothing to impede the circulation or the action of the chest and lungs, and that all tightness of clothing, especially about the waist, neck, and chest, should be avoided. Moreover, inasmuch as the amount of carbon dioxide and other waste matters eliminated is so very much increased during exercise, a much larger amount of pure air is needed, and all rooms and buildings wherein exercise is to be taken should be well ventilated.

After exercise an increased amount of carbonaceous food and of water must be supplied to replenish the system for what has been eliminated. The increase of carbon is probably best given in the form of fat rather than the carbohydrates, though there is some difference of opinion on this point; and of all fluids, water is doubtless the best in ordinary cases for training. As a general rule, alcohol is harmful, because it benumbs and deadens the nerves and will, and, as every voluntary impulse must originate in the brain, anything that interferes with the communication between it and the muscles must lessen the promptness with which they respond and the consequent efficacy of their work.

The use of a small quantity of malt liquor, however, as a tonic or after the exercise is finished may not be harmful, but the decision as to its need or use should be left to the physician or trainer rather than to the one taking the exercise.

By exercise the action of the heart is increased in force and frequency, the pulse is made full and strong if the work be not too excessive or sudden, and the flow of blood and other fluids is increased throughout the whole body. As long as the heart is not overtaxed the pulse beats are regular and even, though suddenly increased exertion may make the rate very rapid. Ordinary exercise increases the rate from ten to thirty beats per minute. Excessive exercise leads to palpitation and hypertrophy of the heart (one reason why any training should be under a competent trainer); but, on the other hand, deficient exercise leads to a weakening of the heart-action, and probably to dilatation and fatty degeneration. If at the beginning of a new exercise the heart-action becomes irregular, rest should be taken, and the exercise then begun in a more gradual way. The heart stimulus is due to the increased amount of blood in its cavities, but it should be remembered that the venous circulation is largely due to the muscles. "Every muscle is a little heart," and these, by their contraction, constantly tend to drive the blood onward to the true heart and lungs.

Exercise greatly increases the amount of perspiration from the skin, this perspiration containing water, salt, and considerable waste matter. The evaporation of the water tends to keep the body cool; but there is not much danger of chilling the body during exercise, on account of the great heat production. As soon as work is stopped heat production is checked, the body cools off rapidly, and then there is danger of chilling unless more clothing be added. Flannel is best for this, because it is a non-conductor of heat, and prevents too rapid cooling of the body. Keep the skin clean so that the sweat-glands may be unobstructed in the performance of their functions.

Exercise increases the appetite, partly because of the increased demand of the muscles for food and partly on account of the increased circulation of the blood through the liver and the vessels of the alimentary tract, this causing a more perfect digestion of food.

If exercise be taken too soon before meals either the stomach, by calling the blood from the exhausted muscles, will prevent their proper repair and rest; or the muscles, calling the blood from the stomach, will prevent the proper formation of the gastric juice when food its introduced. If exercise be taken too soon after eating, it is apt to prevent the flow of blood to the stomach and the formation of gastric juice; or, by forcing the contents of the stomach into the intestines before gastric digestion is completed, and before the food has reached a condition in which the intestines can make use of it, to cause intestinal irritation and indigestion.

Proper physical exercise favors a symmetrical brain development, as exercise of the functions of the centres governing the action of the muscles must favor the growth and development of those centres. "Hand culture, apart from its value *per se*, is a means toward more perfect brain culture;" and exercise by itself alone is truly educational, although this feature of it may be more fully developed and emphasized by proper systems and methods. The great trouble is that it is extremely liable to be misapplied, misunderstood, or neglected.

The aim of training should be to increase the capacity of the lungs and the breathing power, to make the muscles more powerful, more responsive to the will, and their capacity for endurance greater, and to lessen the amount of adipose tissue. Systematic exercise helps one to resist disease, because by it waste matters are carried off, pores, glands and organs are kept active and healthy, and active tissues take the place of weak and sluggish ones.

Fatigue is due to lack of contractile material in the muscles to continue work, to the exhaustion of nerve-force and motor impulses from the brain, and to accumulation of waste products in the muscle.

Active exercise is that brought about by one's own movements; passive, that produced by something outside or collateral to one's own power.

It is hard to determine how much exercise any given person ought to take, as the personal equation varies so much. The average healthy man should do work to the equivalent of 150 foot-tons daily. The work of walking on a level at the rate of three miles per hour is said to be equal to that of raising one-twentieth of the body weight through the distance walked. According to this, a man of 150 pounds in walking one mile does work equal to 17.67 foot-tons, and he would have to do work equivalent to walking about nine miles at the above rate to get the proper amount of daily exercise.

This seems like an excessive amount, but if the work done in one's daily vocation be taken from this, it will not leave so very much for the daily health-task; and while the natural disinclination of many to exercise grows stronger by indulgence, and while urgent reminders are wanting and the evils arising from the neglect, abuse, or misuse of exercise are not so very immediate or apparent, they are still certain and not at all consistent with good and perfect health.

Bathing.

In health we make use of baths and bathing for the cleansing of the body, the stimulation of the functions of the skin, and as a tonic to the whole system. A proper bath properly taken is exhilarating and thoroughly enjoyable. Baths are also to be employed in sickness as a means of cure, but such use of them is foreign to the present discussion.

Dr. H. C. Wood says: "Cleanliness and the maintenance of the proper condition of the skin require the use of the bath at least twice a week. In some very delicate persons the general bath produces marked depression, but this can almost always be avoided by the use of very hot water. If the hot or warm bath be employed habitually, it should be preferably taken at night, and, unless under very exceptional circumstances, the hot bath should always be followed by cold sponging or the cold shower-bath, or by a plunge into cold water." The temperature of a cold bath may be from 40° to 75° or 80° F.; that of a tepid bath, 75° to 85° or 90° F.; a warm one, 85° to 100° F.; a hot one, from 100° to 110° F., or even hotter. A cold bath is taken not so much for its cleansing as its tonic and stimulating effects; the others are used mainly for their cleansing properties, though if followed by the cold sponge, shower, or dip the sense of exhilaration produced will be marked.

Cold baths taken immediately after physical exercise while the body is still warm, but after perspiration has ceased, and followed by good rubbing and friction of the skin, dispel fatigue and give a sense of buoyancy and lightness. The shock of the first contact of the water to the skin is but momentary, and can be withstood by most persons, unless there be serious organic disease; and the reaction produced certainly compensates for the momentary discomfort. If the bath be taken in the open air, there is the additional benefit of a plentiful supply of fresh air for the lungs, of the physical exercise and increased circulation induced by swimming or combating the surf, and, if in the sea, of the stimulation of the skin by the salt. In fact, sea bathing may be advantageous to a marked degree where the circulation and action of the skin are sluggish. Or a sea-bath can be imitated at home by adding about one pound of salt to the gallon of water.

Those who are subject to organic heart disease should not indulge in sea-bathing nor in deep fresh-water bathing where a sudden tax may be made upon the strength and the heart-action be disturbed or checked. Women who are menstruating or who are in the later months of pregnancy should not take cold baths.

Baths should not be taken too soon after meals, because digestion may be lessened or entirely stopped by the blood being called from the stomach to the skin and muscles, and nausea and vomiting thus induced. "There can be no doubt that many of the cases that are called 'cramps,' and which frequently result in drowning, are due to this cause."[1] In cold baths the head should be immersed first, "to avoid increasing the blood-pressure in the brain too greatly, which might result if the body were gradually immersed from the feet upward."[2]

The following rules, issued by the English Royal Humane Society, are worth noting: "Avoid bathing within two hours after a meal, or when exhausted by fatigue, or when the body is cooling after perspiration. Avoid

[1] Rohé's Text-Book on Hygiene. [2] Ibid.

bathing altogether in the open air, if, after having been a short time in the water, there is a sense of chilliness, with numbness of the hands and feet; but bathe when the body is warm, provided no time is lost in getting into the water. Avoid chilling the body by sitting or standing undressed on the banks or in boats after having been in the water. Avoid remaining too long in the water, but leave the water immediately if there is the slightest feeling of chilliness. The vigorous and strong may bathe early in the morning on an empty stomach; the young and those who are weak had better bathe two or three hours after breakfast. Those who are subject to giddiness or fainting, or suffer from palpitation or other sense of discomfort of the heart, should not bathe (out of doors) without first consulting their physician."[1]

After any kind of a bath the body should be thoroughly dried, not only to restore and accelerate the circulation of the skin by the friction and to prevent the cooling by the evaporation of the water, but also to prevent chafing and eczematous eruptions where the skin is subject to friction of clothing. Warm or hot baths should not be taken if the person is to be exposed to the cold within several hours, and the same rule applies to Turkish, Russian, and vapor baths: so these latter should not be taken away from home in cold weather, unless the bather takes pains to rest well after the bath, and then to wrap up well before going into the open air.

In all warm baths in health the principal object is to secure the cleansing effects, and to be effective their use must be systematic. The pores of the skin are self-cleansing only to a certain degree, and the free use of

[1] See also "Sea Air and Sea Bathing," by Dr. John H. Packard.

warm water is most beneficial in removing dry epithelium, sweat, dirt, and grease. If the pores of the skin are obstructed there are not only irritation and eruptions of the skin produced, but more work is thrown upon the kidneys, and these if affected will break down the quicker. Soft water is to be preferred for ordinary bathing and washing, because it often prevents or reduces cutaneous irritation, and because it saves soap.

A Turkish bath consists: 1. Of a dry, hot-air bath at a temperature of from 120° to 170° F., or even higher, from ten to thirty minutes. This causes in most persons extreme perspiration, with no sense of discomfort, but rather a very pleasant sensation. After this come: 2. A hot shower-bath to wash off the sweat. 3. Shampooing, massage, and scrubbing, to thoroughly remove all dirt, loose epithelium, and perspiration from the skin. This is in moist air at from 100° to 110° F. 4. A warm shower-bath gradually changing to a cold one, and then a thorough drying of the body and a rest for a quarter or half an hour. A Russian bath differs from this only in that moist air at 150° F., or less, is used instead of dry air for the first bath.

It has been said "that a person ought never to stay in either the hot air or steam-room if in any wise oppressed, or to use very cold water afterward if one feels any shrinking from it." Nor should one who is very corpulent or subject to organic heart disease take a Turkish or Russian bath without the advice of a physician. But for healthy persons they are very pleasant, and in most cases beneficial, provided they are not taken too often and that one does not indulge in them too long at a time.

The terms sun-, mud-, sand-, and pine-needle baths are self-explanatory. These are used in treating certain diseases, and are supposed to do some good, especially in rheumatic affections.

Clothing.

There is scarcely anything that can be said on this subject with which almost every one of ordinary intelligence is not in some respects conversant. According to Dr. Poore, the main objects to be sought in clothing the body are: "1. To maintain the temperature and, by preventing the loss of animal heat, to diminish to some extent the demands for food. 2. To allow the chief heat-regulating mechanism—*i. e.*, the evaporation from the skin—to proceed with as little hinderance as possible. 3. To allow all muscular acts the greatest possible freedom, and to avoid the compression of the body in so far as may be possible. 4. To protect the body from heat, cold, wind, and rain. 5. To disguise as little as may be the natural beauties of the human figure."[1]

The substances from which articles of clothing are usually manufactured are wool, silk, cotton, linen, leather, and furs, although almost everything that can possibly be fashioned to suit the needs or fancies of the wearer is or has been utilized for the purpose. Goods of all manner and kind are woven from the first four substances mentioned, either singly or in combination one with another, and felts are made from wool, hair, or fur, these latter being made, not by weaving, but by an interlacing and matting together of the fibres by pressure and rubbing.

In a general sense *wool* is probably the most valuable of clothing materials, in that in a variable climate, or where there are sudden changes of temperature, it is the safest for

[1] Stevenson and Murphy: Treatise on Hygiene.

the wearer to use. While, taking fibre for fibre, it probably does not vary so much from linen or cotton as a heat conductor as is generally believed, it is usually woven in such a way as to entangle large quantities of air in its meshes, thus preventing either sudden cooling or heating; and besidé, it is extremely hygroscopic, taking up water and perspiration very readily and giving them off slowly, thus reducing the cooling by evaporation to a minimum and regulating the heat-dissipation of the body. All who are at all subject to rheumatism or to such symptoms as are dependent on sudden temperature changes should wear woollen garments next to the skin the year round, varying the thickness and weight, of course, to suit the season, and children and others subject to digestive disturbances will usually be greatly benefited by the constant use of woollen (or, in case that is too heavy, a silken) band about the abdomen.

As it is ordinarily woven, some persons cannot tolerate wool next to the skin on account of its irritating properties. These latter are obviated, however, if the undergarments be made of pure wool woven by methods similar to that introduced by Dr. Jaeger, or of a mixture of wool and cotton. The Jaeger method, by the way, provides for the escape of moisture from the material and for the air permeating freely through its interstices.

Silk is a good non-conductor of heat, and is almost as hygroscopic as wool, so that it is good material from which to make warm clothing. Its great natural beauty and the facility with which it takes coloring matter also make it desirable from an æsthetic stand-point, but its great disadvantage is its high cost. For those who cannot wear wool next the skin and to whom the cost is no objection, silk is an excellent material for undergarments.

Cotton is probably the most generally used for clothing of all the fibres. It is hard and durable, is not as hygroscopic by far as wool, and is, above all, cheap, so that it furnishes the bulk of the clothing for the masses. If smoothly woven and of a light color, it makes extremely cool garments for warm climates or seasons. On the other hand, if warm clothes are desired, the cotton must be woven so as to have large air spaces in the fabric, the air acting as an especially good non-conductor of heat and preventing the lowering of the body temperature. Cotton should not be worn next the skin by those subject to sudden temperature changes, nor during exercise, unless it is changed in the latter case immediately after the exercise, or some additional clothing is added to the body to prevent too rapid evaporation and cooling.

Linen is valued for its purity of color when bleached, and for its durability. It is more expensive than cotton, but its hygroscopic and heat-conducting properties are about the same as the latter. It is especially desirable for making clothing for hot climates and for articles of dress that are easily soiled and need frequent cleansing.

Furs provide extreme protection against the wind and cold, both on account of the impermeability of the skin and of the large quantity of air entangled in the fur itself.

Leather is utilized for foot-coverings, etc., on account of its durability, pliability, and practical imperviousness to moisture, especially when oiled; and in cold countries is also used for body garments, on account of its resistance to the wind and the efficacy with which it keeps the body surrounded with a layer of warm air.

With the possible exception of *rubber*, which is especially useful for the protection which it gives from wet and wind and rain, other materials from which clothing is made need not be mentioned here, because of the comparative rarity of their use and their close resemblance to those already mentioned. The value of any material for clothing purposes, however, may be said to depend upon the slowness with which it permits the passage of heat to or from the body and the evaporation of water, the amount of air its meshes contain, its impermeability to the wind, or else its special adaptability to some special purpose.

Certain materials are manufactured from combinations or mixtures of two or more of the four fibres first mentioned, and it sometimes become necessary to distinguish these one from another and to determine the proportion of each in the goods. This is done by microscopical examination, each fibre having its own peculiar characteristics, and by chemical reactions. Some of these latter are as follows: Wool and silk dissolve in hot liquor potassæ or sodæ of a specific gravity of 1050, while cotton and linen are not affected. Wool and silk are stained yellow by strong nitric or picric acid; cotton and linen are not. Sulphuric acid affects wool but little, slowly dissolves silk, and changes cotton or linen into a gelatinous substance that is colored blue by iodine. Hot concentrated zinc chloride dissolves silk, but not wool; and copper dissolved in ammonia rapidly dissolves silk and cotton, linen more slowly, but only swells the wool a little.

Cloths are often fraudulently sophisticated in the process of manufacture, and their value greatly lessened thereby. Wool is mixed with "shoddy," which is made from old and used woollen rags, torn asunder and then respun with an addition of fresh wool; silk is heavily weighted with salts of tin, iron, or with other substances, and cotton and linen are stiffened and glossed with an excessive amount of starch, white earth, or the like. Shoddy can be determined by the use of the microscope; the weighting of silk by chemical reactions and solutions; and overstarching, etc., of cotton and linen by washing and drying.

It will not be advisable here to go into the consideration of the influence which the shape and style of the individual garments of ordinary use have upon health, for that would require a much longer discussion than the present space would allow; but the general rule may be laid down that each article of clothing should be adapted to the peculiar needs and occupation of the wearer, and that it should in no wise interfere with the proper development, use, or physiological functions of any part of the body.

When exposed to the sun's rays or to other sources of radiant and incandescent heat, fabrics absorb heat, irrespective of the constituent materials, but in the following order as regards color: White, light yellow, dark yellow, light green, Turkey red, dark green, light blue, and black, the latter color absorbing more than, and light blue almost twice as much as white, the material in each case being the same. In the shade the absorption depends more on the material than on the color.

Lastly, it should be remembered that, as disease germs are readily conveyed from place to place and from one person to another by the clothing, and especially by that which is hygroscopic by nature, care should be taken to keep the garments in as cleanly and aseptic condition as possible, to disinfect them whenever they have been exposed to infection, and, for those who are much among the sick or liable to infection, the use of smooth, closely woven, non-hygroscopic over or outer garments that can be readily cleansed, such as cotton or linen, is to be highly recommended.

Light.

The important influence of sunlight in the development and maintenance of a healthful condition in all higher organisms, both animal and vegetable, is well known by every one; but as yet there is a lack of information as to the exact physiological methods and processes which are due to this great force. We know that for the plants chlorophyll is the intermediary agent which largely assists in the conversion of carbonic acid and the storage of carbon in various compounds, and that the presence and action of this chlorophyll are largely dependent upon the light-supply; while for the animal kingdom, and especially for the human race, it is evident that the effect of sunlight is manifested more or less directly upon the blood and skin, though the whole body quickly manifests a marked appreciation of its presence or absence. But when this has been said, there is little else that can be added as a matter of positive information. No one knows just how the pallid and anæmic child that has been reared in the shade and dark can be converted into the tanned and ruddy picture of health in so short a time, but the results are unquestionable.

The subject demands much further study, and it may not be out of place to indicate one or two directions in which the investigation may, perchance, be wisely pursued.

In the first place, there has doubtless been too little appreciation of the fact that the sunlight in its totality has many other rays of force than those which manifest themselves alone to our sense of sight. The existence of the ultra-violet rays and the fact that these are more powerful actinically than those of the ordinary spectrum have been satisfactorily demonstrated, and the only question is as to what the true power and influence of these invisible rays may be. It is not certain as yet that some of them, at least, are not closely related to the new manifestation of force discovered so recently by Röntgen, and there is good reason to believe that the penetrative powers of light as regards the human body are not yet fully known or appreciated.[1] Nor can we tell how much of that power of the sun whose effects we feel and see is in nature on that borderland between light and electricity that is as yet so vague and unknown.

Again, the destructive effect of sunlight, and of light from minor sources as well, upon the germs of disease and other low forms of life, is now a matter of common knowledge, though many are not aware that it has been proven that this germicidal action of light is directly in relation to its actinic power. Considering this, with the statements of the preceding paragraph, may we not surmise that hostile organisms, even in the deeper tissues, are overcome both in this way and by the improved condition of the blood due to the light, and that this helps to explain the good results that follow the open-air treatment of many diseases and abnormal conditions? The tubercle bacilli are especially susceptible to its influence, and every one knows that an abundance of sunlight is just as essential to the tuberculous patient as is plenty of good food, pure air, or proper clothing.

More might also be said in reference to the possible and

[1] Some experiments by the author and by numerous others seem clearly to indicate that some of the radiant energy from the sun, and in lesser degree from other sources of light, is able to penetrate substances hitherto considered opaque and to produce phenomena similar to those due to the Röntgen ray. Consequently, if the experiments referred to are well founded, the penetrative ability of this energy, as regards the human tissues, would seem to be more than probable.

probable chemical activity of the light in and upon the metabolic processes of the animal body; but as there is still the uncertainty of hypothesis and theory, it may be wiser to simply leave the foregoing suggestions as food for thought and incentives to further research and investigations.

CHAPTER IX.

SCHOOL HYGIENE.

IT might have been remarked in the chapter on Personal Hygiene that the best time for applying and observing the laws of hygiene is in the days of childhood and youth, for then the whole organism is plastic and yields readily to both external and internal impressions and forces.

This being so, the great influence of the factors common to school life may be readily conceived, and inasmuch as the average child will be subject to them for a large part of from eight to ten or more years, the importance of a study of school hygiene will not be denied. It concerns the parent, the physician, and the citizen, and its investigations must consider the personal hygiene of the scholar, the condition of his health, his habits, the amount of work done, the sanitary environment and requirements of the school-room or building, the furniture, the ventilation and heating, and the influence of all these upon the individual's state and development.

Next to the scholar himself and his parents, these matters are of especial interest to the physician, for, beside being one, who from his special training and education is often called to act upon school committees and boards of education, he has to treat many disturbances of health in the young which have their origin or cause in the harmful or insanitary conditions of school life.

There are disturbances to which all children are subject, whether in school or out; but a special class are markedly influenced by school life or work, and to these abnormal conditions we may give the term "School Pathology." Of some of these overwork is the cause; others are set up by other factors.

Overwork, coupled with depressed vitality, may give rise in children to one or more of the following troubles: Dyspepsia, headaches, nervous derangements, chorea, epilepsy, neurasthenia, backaches, menstrual disorders, and, in some cases, consumption. On the other hand, bad arrangement of seats and desks, improper location of windows, blackboards, etc., may cause spinal and other physical deformities, defective eyesight, etc. Of the first class, even where the amount of work may not seem or may not really be too much for the capacity of the child, worry about rank or over an approaching examination may have a harmful effect upon a nervous temperament. This is especially so if the examinations come at the end of a spring term, when the scholars are all more or less worn out and debilitated. The forcing process should be avoided as far as possible, and if grades are to be given at all, they should be as much as possible for the work and attendance during the term, and not so much for the actual work done at examination time.

Moreover, young children should not be kept in school for too many hours in the day, nor should the school be looked upon by parents as a place to which to send children to keep them out of the way and from mischief. Edwin Chadwick has shown that a child from five to seven years can only attend to one subject for about fifteen minutes; one from seven to ten, for twenty minutes; from ten to twelve, for twenty-five minutes, etc., and that the length of individual lessons and likewise the total day's work should be arranged accordingly. The very early years of school life should be given to inculcating correct habits of attention and of morals and to training the will and power of concentration, rather than to the teaching of any special knowledge.

But it is probably the work attempted outside after school hours, and not the actual work done in the school, that is most responsible for the breaking down of health, especially in older scholars. In Cleveland, in 1881, of 186 girls in the high school, 29 per cent. of those who studied less than two hours, 70 per cent. of those studying from two to four hours; 93 per cent. of those studying from four to six hours, and 100 per cent. of those studying over six hours daily out of school, had poorer health while at school. Of these same girls, the percentages of those whose health was "very poor while at school," dividing them the same way as regards overwork, were respectively 14 per cent., 40 per cent., 66 per cent., and 100 per cent. This loss of health was attributed by the parents to stair-climbing, irregularity of meals, worry about rank and examinations, etc., but Dr. Goodell says: "So commonly do I find ill health associated with brilliant scholarship, that one of the first questions I put to a young lady seeking my advice is, 'Did you stand high at school?'" Another writer says: "The effects of anxiety are worse than carrying heavy loads."

While a child is at school its mind should not be wearied by outside tasks, as music or painting lessons, nor the body weakened by social dissipations, late hours, and indigestible food. Girls are more susceptible to disturbances, and are more subject to them, because they are more willing to undertake extra or double work than boys, and because they are more ambitious and worry more about rank. In all children the obtaining of good health and a sound constitution is of the first importance. Youth is the time for gaining health, not for losing it; for building up sound bodies and constitutions, not for breaking them down, and school life should always have the former as one of its greatest ends. Of what use is all the learning one may gain before the age of eighteen, if there be no strength to use it afterward in the battle of life?

School-life is sometimes responsible for dyspepsia by interfering with the regularity of meals, the children missing the midday meal and having to depend upon a meagre lunch, often of sweets and indigestible food. This is especially important when the rest of the family dine at noon, and there is only a light meal served in the evening. Again, many habitually lose their breakfast through fear of being late, or else bolt the food without masticating it, and gulp down hot coffee or tea before starting on a run for school. But often the loss of appetite is due simply to lack of fresh air and proper exercise. Such dyspepsias are to be treated by attention to the foregoing points rather than by medicine.

Headache is a common disturbance among school children, and may be due to any one of several causes, among which are overwork—producing irritability and disturbances of cerebral circulation—bad air, eye-strain, etc. The eyes should always be examined when headaches are persistent, and any defects corrected by proper glasses. Associated with the headaches frequent bleeding from the nose may occur, and should not be overlooked, as it may indicate circulatory disturbance.

One of the most common symptoms of nervous derangement is sleeplessness or restless sleep, and this condition should give warning that something is wrong. Dr. Folsom says: "I doubt whether there is an exaggerated prevalence of manifest or well-marked diseases of the nervous system among school children. If due to the school-drill, my impression is that they come for the most part later in life, after the children have left school, and because of constitutions weakened during school years, instead of strengthened as they should be." Children subject to chorea or epilepsy should not attend school, not only for their own sake, but for that of the other children, who may be unduly affected by their nervous manifestations. They should be educated quietly and cautiously, with proper treatment and plenty of outdoor life. Neurasthenia or general break-down may occur, usually from overwork, and especially among young women. It may come on unexpectedly after the examinations, when the strain and excitement are removed. Menstrual disorders are also apt to occur among girls that are being overworked mentally, and we ought to remember that at the time this function is developing the system is undergoing a heavy strain. Also, to certain women rest from customary work is necessary at the time of the periodical recurrence, and excuses for absence at this time ought to be freely granted. It has been said that "girls get through as much work as boys, working in their own way."

The development of consumption may be due to the school-life, though it is hard to say how frequently this is the case. Bad air and overwork are both important factors in its production, and if these are forced on underfed or predisposed children the disease may be provoked. "In a consumptive family the steadfast rule should be that the mind be wholly subservient to the body's welfare."

The main cause of spinal and other deformities and defective eyesight is apt to be found in faulty construction of seats and desks, improper location of windows, etc., though excessive work or strain may maintain a low vitality and act as a predisposing condition. The latter point is shown by the fact that spinal curvatures are more prevalent in those especially prone to weakness of the muscles, as women and girls.

But no desk or seat will remove original weakness of muscle as the one important predisposing condition, and children cannot be made strong by supports. "Spinal curvature is not only a product of low vitality, but does harm by permanently fixing vitality at a low standard." Bad seats and desks not only cause spinal deformities, but help to cause defective eyesight by making the scholar hold the book too near the eyes and by making him bend his head so that the circulation of blood is impeded and ocular congestion favored. However, no seat can be devised in which a child will maintain a correct or "normal" position for any length of time, as this is an impossibility for young children; but the true aim should be to furnish a seat in which one will naturally assume the correct position after having temporarily taken any other. "Movement is a child's way of resting; rest is a kind of work, to be taught by degrees." Seats should have backs to prevent fatigue, but a comfortable back gives support to the lower part of the spine rather than to the shoulders and upper part of the spine. Many foregin authorities advise seats with backs only high enough to support the lower part of the spine, and low enough for the scholar to rest his elbows upon them while studying. The following points, suggested by Dr. Lincoln, are worth noting: "1. The chair is often too high for young scholars. The most convenient plan may be to provide footstools. 2. The seat from back to front ought to be long enough to support the whole thigh. A more or less spoon-shaped hollow in the seat is commonly thought desirable. The curve of many settees is such as to produce pain at the point where the tuberosities of ischium rest on the wood; the support is there not wide enough. 3. Seats must have backs. The straight, upright back reaching to the shoulders is bad; a straight back, slightly tilted, is not bad. American seats are commonly curved, with curved backs. 4. The edge of the desk should come up to, or overlap, the edge of the seat. The recognition of this fact is a recent discovery. 5. Most of our best desks are too high relatively to the seat, doubtless to prevent the pupil from stooping. Something is gained in convenience of reading by this plan, but it interferes with correct positions in writing. The elbows, hanging freely, should be only just below the level of the lid." For near-sighted children the higher desk may be a necessity in writing; if the desk is made low a portable writing-stand may be placed on top of it when necessary.

Windows on only one side of a large school-room may not give sufficient light for the desks most remote from them. Consequently, there should be windows on two sides, preferably adjoining ones, of large school-rooms. The windows should be at the back and to the left of the scholar, thus giving the best light upon the desk for either reading or writing. They should not be placed in front of the scholars, as the continuous light and glare is very trying and injurious to the eyes. They should extend almost to the ceiling and have square tops, to admit of as much light as possible. Blackboards should have a dead-black surface, not a glossy one, and should be on the sides of the room on which there are no windows. Walls should be of a neutral tint, not glaring white.

Construction of School-houses. The principles already given as to ventilation, heating, water-supply, etc., apply here as elsewhere. From 1800 to 2500 cubic feet of fresh air should be supplied to each scholar per hour. In cold weather this should, of course, be satisfactorily heated. The air-ducts, both inlets and outlets, must be large enough to change the air without causing injurious and uncomfortable draughts; and these ducts should be as short and free from bends as possible, or better, the rooms should open into the supply and exhausts shafts directly. The air may be warmed either by steam or hot-water coils or by a furnace, though preferably by the former, to avoid "baking" the air, and also preferably by the indirect system. There is no objection to having additional heating apparatus in the school-room, provided it is guarded so that the scholars may not be accidentally burned. Any system that will give a sufficient supply of fresh air properly heated will of necessity be more expensive than the old way of not ventilating at all except by opening the windows at recess time, but experience shows that the increase in expense is not so very great, as so much heat is lost by opening the windows in this way, and the benefit to the children more than compensates for the additional outlay. Country schools may be heated by stoves surrounded by sheet-iron drums, and ventilated with fresh air brought in from without near the bottom of the stove. Passing up between the stove and drum the air is warmed and gives good ventilation without chilling or draught. As great a length of stovepipe should be exposed as possible, to get the full benefit of the heat from it.

The school-house should be on dry and well-drained soil, as dampness is not only depressing to all constitutions, but is an important factor in the causation of phthisis and strumous diseases. There should not be too much shade about, and as many rooms as possible should have sunny exposures. If the sun is annoying during the session, it may be excluded by inside blinds or shutters, but we must not lose sight of its helpful influence in the destruction of bacteria and purification of organic matters. Basements of school-houses should be well lighted, water-tight and dry, and should be kept scrupulously clean, that moisture and noxious gases may not be drawn into the rooms above. If properly arranged and cared for, they may be used as play-rooms in bad weather when it would be unwise to send the scholars out of doors.

The water-supply should be free from all impurities and as good as can be had. In the country, if from a neighboring farm-house spring or well, it may be contaminated by leakage from cesspools and barnyards. Or the school water may be taken from a neighboring spring or stream which is receiving contamination from the school-house cesspool or other sources. For this reason, teachers should be taught to make the test for chlorides and the reason for it, and should make this test frequently. If cause for suspicion arises the use of the water should be stopped at once.

Water-closets and urinals, where in use, should be kept clean by a competent janitor, and the principal or head-teacher should see that this is done. In the country, the pail or earth-closet system should be substituted for the usual privy-vault or cesspool, and it should be the duty of some one apart from the teacher, regularly appointed and paid by the school directors of the district, to see that removals are made at proper intervals; the teacher should maintain supervision over the daily condition of affairs.

If possible, the out-houses should be connected with the school-house by covered ways, that the children may not be exposed in inclement weather; but these ways should be open or else constantly ventilated by open windows on either side. Cesspools should be at least fifty feet distant, and should drain away from the school-house.

Ample provision must be made for the rapid escape and for the safety of scholars and teachers in case of fire or panic. Fire-drills should be regularly practised in all schools of two stories or more, and presence of mind inculcated, that emergencies may be met with safety. The comfort of the child should not be forgotten in the construction of the school-house, though preservation of health is the main aim.

School Quarantine. As certain diseases are contagious, it is necessary that school authorities have a right to forbid the attendance of such persons as have been exposed to infection until all danger of transmitting the disease to others is passed. This power is usually, however, exerted only in the case of those diseases most dangerous to life and health, though the stringency of the regulations varies at different places. Smallpox, scarlet fever, diphtheria, measles, and even whooping-cough ought always to be quarantined, and it would be better to keep children out of school who are afflicted with minor diseases of this class till all danger of infection is over, as it is only by rigid measures like this that we may finally be able to wipe those maladies out of existence. Local boards of health should make and enforce rules looking to the prevention of the spread of the graver contagious diseases, and should, when necessary, close schools and school-buildings till all danger is past. Dr. Lincoln gives the following as a system of general regulations: "1. Persons affected with diphtheria, measles, scarlet fever, or smallpox (varioloid) must be excluded from the schools until official permission is given by the board of health for their readmission. 2. Persons living in a family or house where such a case occurs are also excluded until similar permission is given. 3. This permission is not to be given until sufficient time has elapsed since the occurrence of the last case to insure safety, nor until the premises have been disinfected under the direction of the board of health. 4. If a child suffering from one of the above diseases attends school, the premises of the school must be disinfected under the direction of the board of health before they are used again. 5. Physicians, teachers, school officers, and school children knowing of such cases of disease should at once report them to the board of health. 6. The board should also notify the school authorities of all such cases. 7. Notice must be sent to the family by the school authorities, acting conjointly with the board of health."

Children having had one of the above-named diseases may return to the school with safety after the following periods: "Scarlet fever, six weeks from date of rash, provided desquamation and cough have ceased. Smallpox and chicken-pox, when every scab has fallen. Whooping-cough, after six weeks from commencement of whooping, provided the characteristic spasmodic cough and whooping have ceased, or earlier if all cough have passed away. Diphtheria, not less than three weeks, if convalescence is completed; there being no longer any form of sore throat nor any kind of discharge from the throat, nose, eyes, ears, etc., nor any albuminuria." Rules and regulations like the above, when promulgated, "should have the force and authority of law, and should be enforced, if necessary, by the entire power, including school officers, etc., of the State." It is to be hoped that we shall soon have a means of inoculating persons against all contagious diseases, as we now do against smallpox. At present boards of health and school boards should insist on the vaccination of all school children. In Illinois, from 1880 to 1883, the deaths from smallpox among unvaccinated children were 48 per cent.; among the vaccinated, only 0.9 per cent. In this city all who desire it are vaccinated free of charge by the vaccine physicians, and it is compulsory for all school children.

Regulations similar to the following, suggested by Lincôln, should be in force in every school district: "Every child entering the public schools must show a certificate from some reputable physician, giving name, age, residence, approximate date of vaccination, date of examination, result of examination, the last two to be of the physician's own knowledge. The fact of vaccination must be entered on the school record and on lists for promotion and transfer. The school authorities shall annually report the number of those not protected to the State Superintendent of Education. School authorities may order the exclusion of non-protected persons, after sufficient notice, where they think the measure required for the public health. Re-vaccination at the age of fifteen may be required under similar circumstances. Those unable to pay should be furnished with free vaccination by the school authorities. A physician's certificate of protection by a previous attack of smallpox is equivalent to a certificate of vaccination."

Contagious ophthalmia is a disease often prevalent in institutions and occasionally in primary schools, and requires great care to prevent its invasion and spreading, as well as to effect a cure. Those afflicted with it should be quarantined until there is no further discharge or till the granulations on the inner surface of the eyelids have disappeared. Enfeebled health and poor and insufficient food favor its development, but the chief means of contagion is by the use of the same wash-basins and towels by a number of children.

School children should not be allowed to attend the funerals of companions dead of a contagious disease, nor should funerals be allowed in school-houses under any circumstances, owing to the effect on the thoughts and sensibilities of nervous children.

Boarding-schools and institutions should have an infirmary where contagious diseases may be isolated, and should make that isolation as complete as possible from other scholars and inmates. At the beginning of a term it may be well to subject any who have been exposed to contagion to a delay until the probable period of incubation for the special disease is passed, the period dating from the time of exposure. With the above precautions it will rarely be necessary to close a school, unless a disease be markedly epidemic and malignant.

CHAPTER X.

DISINFECTION AND QUARANTINE.

As has already been stated, disinfection is that part of prophylaxis which has to do with the destruction or modification of the exciting causes of disease, and we may accordingly define a disinfectant as "an agent capable of destroying the infective power of infectious material." Moreover, as with our present knowledge we are practically limited in the use of disinfection to the infectious diseases only, a disinfectant must also be a *germicide*. Theoretically, it should also have the power of destroying the poisonous properties of the toxins which the disease germs produce, and which create the characteristic symptoms of the specific diseases; but whether all good disinfectants have this power is by no means proven, and is not altogether essential, since by killing the germs we check the further production of the toxins, and disinfectants are mainly used not so much to cure or stop a disease in a patient as to prevent its extension to others. But, in a popular sense, the term disinfection is given a wider meaning than is above indicated, including not only the use of antiseptics and deodorants, but often the actual removal of filth and all matters favorable to the growth or spread of disease germs. It is needless to say that these latter may be part of the prescribed duties of a disinfector, but are not the essential functions of a disinfectant.

It will be well here to make the distinction between disinfectants and antiseptics and deodorants, as the terms are often wrongly used interchangeably, and there is a common belief that whatever is a deodorant or an antiseptic is also a disinfectant. An antiseptic is an agent that retards or arrests bacterial growth and the consequent production of toxins or ptomaines, though it does not necessarily kill the micro-organisms themselves; and though some antiseptics are germicidal, others are not and, therefore, as a class they cannot be considered or used as disinfectants. But, on the other hand, "agents which kill bacteria in a certain amount prevent the multiplication of the latter in culture fluids, when present in quantities considerably less than are required to destroy vitality." So, a diluted germicide may act as an antiseptic and may be used therefor. For instance, chlorinated lime, which is a good disinfectant in solutions of proper strength, may arrest further bacterial growth or action in a mass of sewage or filth and prevent the latter acting as a culture-medium for disease germs, even though the agent be totally inadequate in quantity to kill all the micro-organisms present. In the same way, it may act as a *deodorant* —which, by the way, is an agent that simply removes or destroys offensive odors, and is not necessarily either a disinfectant or an antiseptic—both by checking the further action of saprophytic bacteria and the formation of putrefaction odors, and by actually decomposing and oxidizing those of the latter already formed.

In practical disinfection it is also well to remember that while masses of dead organic matter may not in some cases contain disease germs and may be even hostile to them, in general the reverse of this is more likely to be true, and decaying matter often furnishes a good field for the increase of pathogenic organisms. Moreover, the noxious gases given off to the air and the poisonous products added to the drinking-water from such masses may also do much harm by depressing the system, lowering the vitality, and acting as predisposing conditions to the incurrence of such filth diseases as cholera, yellow fever, typhoid and typhus fever, diphtheria, etc.; and when time or opportunity do not permit of the removal of such dangerous accumulations, their power for harm should be checked permanently or temporarily by the use of suitable disinfectants or antiseptics.

But when we are actually dealing with disease germs, disinfection, to be trustworthy, must be carried out to the best of our ability with the means at our command and with strict attention to the minutest details. "There can be no partial disinfection of infectious material; either its infectious power is destroyed or it is not. In the latter case there is a failure to disinfect."

This is because the undestroyed living bacteria still have the power of reproduction, and may, within a very short time under favorable circumstances, equal or even exceed the number that was present before the unsuccessful disinfection was attempted.

The knowledge as to the efficacy of any substance as a disinfectant is obtained from the accumulated experience of practical sanitarians and from experiments on susceptible animals and in culture media with infectious matter treated with presumably disinfecting agents. The knowledge gained must stand the test of scientific deduction, and a substance is not a disinfectant simply because, in one given case, infection did not occur after its use. To be of value the deductions must be made from considerable accumulated and practical experience. "Negative evidence should be received with great caution;" but if the experience of practical sanitarians is confirmed by careful culture and inoculation experiments, our knowledge of the value of any agent becomes more definite and our practical work more exact. From these inoculations and experiments it has been found that the infectious germs of different diseases differ in their power to resist the different disinfectants; but nevertheless it may be stated that "in the absence of spores, a disinfectant for one is a disinfectant for all." Consequently, we are able to simplify and classify the agents at our disposal, and to make more effectual use of them. Note that there is nothing in the tests mentioned to disprove the efficacy of disinfectants, whatever the nature of the infecting material, and whether the germ theory be accepted or not.

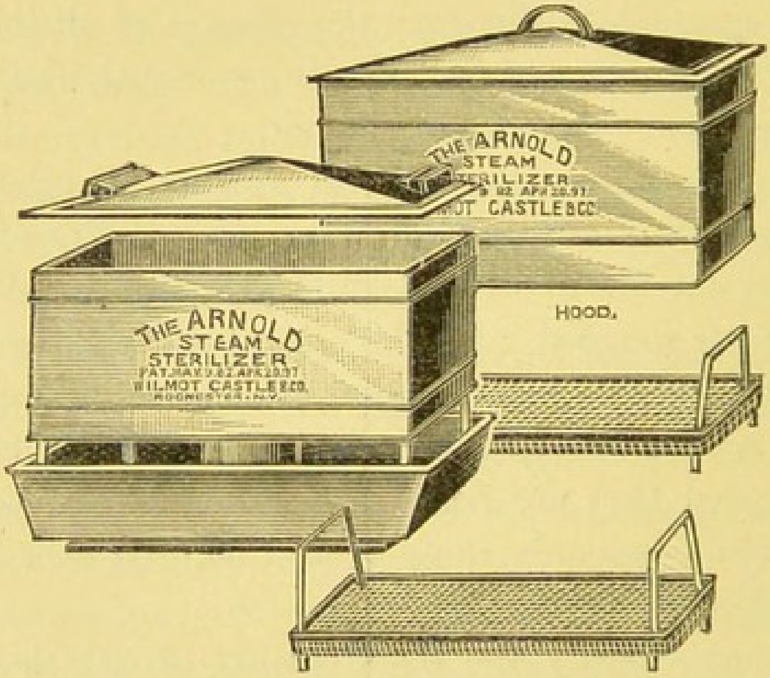
Some agents that are powerful against all other organisms completely fail in destroying the vitality of spores, and thus our list of disinfectants available in *all* cases is still further reduced. In the case of a disease germ that does not produce spores, as that of cholera, and probably also of scarlet fever, smallpox, yellow fever, etc., agents may be used that are really powerless against spores, but in doubtful cases only those should be used that have the power of spore destruction.

We may classify the disinfectants of which we may make practical use as *thermal* or *chemical*, though there are undoubtedly certain secretions and tissues in the body which have the power of destroying infective matters, giving each person more or less immunity against certain diseases, and these we may term *physiological* disinfectants.

Of the thermal disinfectants *fire* is the most efficacious, as it destroys all organic matter, but it can only be used to destroy articles of little value or that cannot be safely disinfected in any other way. For instance, it will usually cost more than they are worth to disinfect thoroughly by other methods old mattresses that have been used in an infectious case, so it is best to burn them.

All things considered, *steam* is probably the most efficient disinfectant, as it is cheap, easily used and manipulated, and is less liable to injure the articles to be disinfected. We employ it under pressure, when its temperature is correspondingly increased, or in the streaming state (live steam), the latter being almost as efficient as the former,

FIG. 35.

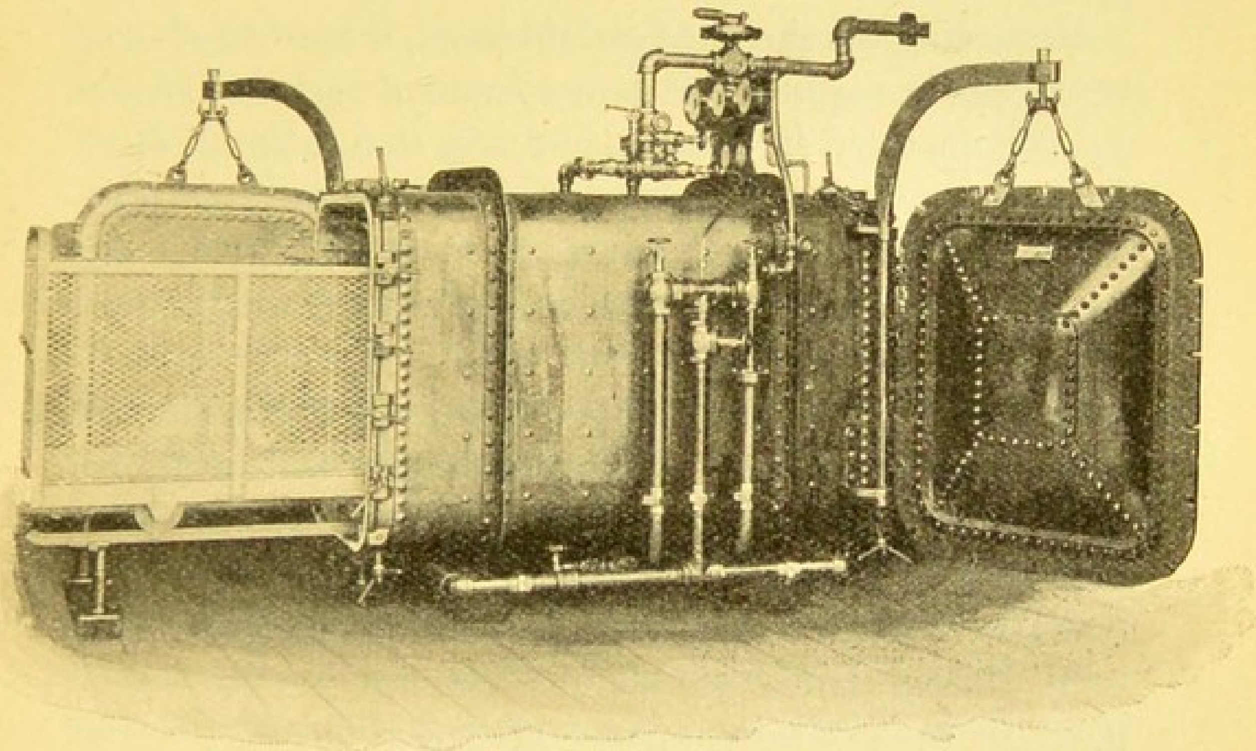


Steam sterilizer for small articles.

but requiring a little longer time. For instance, steam at 240° F. is said to kill the most resistant spores almost instantly, and streaming steam at 212° F. will probably produce the same effect within thirty or forty minutes. Special apparatus for disinfecting large articles by steam is now or doubtless soon will be established in every large city by the municipal authorities and others, as a sanitary precaution and to prevent the spread of epidemics.

In the absence of spores, bacteria are killed by *hot water* even below the boiling point, and it is probably safe to say that boiling for half an hour will kill all known disease germs, especially if a little washing soda be added to the water; although spores of certain harmless bacilli are said to have resisted boiling for several hours. In the absence of chemical disinfectants, boiling water may be used to

FIG. 36.



Steam disinfecting chamber for clothing, bedding, and other large articles.

disinfect excreta, etc., and all clothing from the sick or the attendants upon the sick should be well boiled before washing, whether other disinfectants are used or not.

Dry heat is far less penetrating than moist, and must, accordingly, be used at much higher temperatures and for a longer time. At 300° F. it will require three or four times as long to do what steam at 212° or 220° F. will do, and, moreover, it is very apt to injure clothing or other organic materials exposed to it at high temperatures for so long a time as is necessary. Consequently, it is only to be used to disinfect articles that would be spoiled by moisture or chemicals, and even then it is better to employ the "fractional" method—*i. e.*, exposure to high temperatures for short periods only, but for a number of times, with sufficient intervals between the exposures to allow the development of any spores that may possible be present.

Regarding the chemical disinfectants, it must be remembered that it requires a certain amount of each to disinfect a given quantity of bacteria, and also that, with all disinfectants, time is an important element, and none act absolutely instantaneously. Heat, however, facilitates and increases the rapidity of action of the chemical disinfectants.

Chlorinated lime (chloride of lime) is one of the best and cheapest disinfectants. It should contain at least 25 per cent. of available chlorine, should be kept covered from air and moisture, and fresh solutions should always be made as needed. Its power is due to hypochlorite of lime, which is freely soluble in water and readily decomposes in contact with organic matter, giving up chlorine gas—a most powerful disinfectant. "Germs of all kinds, including the most resistant spores, are destroyed by this solution; but it must be remembered that the disinfectant itself is quickly decomposed and destroyed by contact with organic matter, and that if this is present in excess, disinfection may not be accomplished, especially when the germs are imbedded in masses of material which are left after the hypochlorite of lime has been all exhausted in the solution." Labarraque's solution, a solution of *chlorinated soda,* is a fair disinfectant, but does not keep well, and chlorinated lime is equally as good and much cheaper. However, the soda solution has scarcely any diagreeable odor, and makes a pleasant disinfecting bath for the person. It must contain at least 3 per cent. of available chlorine.

Bichloride of mercury is one of the best germicides that we have, and is effective in comparatively weak solutions. It corrodes metal, and so cannot be used to disinfect waste-pipes, etc.; and it combines with and coagulates albumin, which interferes somewhat with its action. This coagulation is prevented to a degree by the addition of tartaric acid to the disinfecting liquid. The same result is said to be obtained if one part of peroxide of hydrogen (fifteen volume solution) be added to three parts of a corrosive sublimate solution of any strength. But for the above reason it is best not to use corrosive sublimate in disinfecting excreta, as these always contain more or less albumin, and a lime solution is better and more certain. As carbolic acid also coagulates albumin, it is not well to use it for a like purpose.

Carbolic acid is effective in the absence of spores, and, according to Koch, should have first place in disinfection against the cholera germ. It is of doubtful value, however, in cases of typhoid fever, as it is said that the typhoid bacilli can be cultivated in a medium containing $\frac{1}{2}$ per cent. of carbolic acid. Solutions should always be made by first dissolving the acid in glycerin, and should usually contain 5 per cent. of acid.

Copper sulphate is a fairly good disinfectant in the absence of spores; is a deodorant, and is cheap. It may be combined with bichloride of mercury to color the solution of the latter and to get the benefits of its deodorant powers, which the corrosive sublimate does not have. Use may be made of the following formula: Corrosive sublimate (bichloride of mercury), 4 ounces; copper sulphate, 1 pound; water, 1 gallon.

Zinc chloride is a good antiseptic and deodorant, but not a very powerful disinfectant. A 5 or 10 per cent. solution will kill germs without spores.

Calcium hydrate, when mixed with water to make a thin whitewash (milk of lime), is said to be a good disinfectant, especially for excreta, etc., and is one of the cheapest and easiest to obtain. It should be added to the infectious matter in excess or until the mixture is decidedly alkaline, and will require from one-half to two hours to disinfect thoroughly.

An extremely valuable disinfectant for local or topical applications to the person is *hydrogen peroxide* or *dioxide* (H_2O_2). It is harmless, even when taken internally; is effective in comparatively weak solutions, and is especially active in the destruction of pus organisms. It is usually supplied in the form of a 15 per cent. solution in water and, at present, only its high cost prevents its more extended use.

Until the discovery, in 1892, of the great disinfecting power of formaldehyde or formic aldehyde by Trillat and Aronson, about the only gaseous disinfectants of practical value were *chlorine* and *sulphur dioxide*.

Of these, chlorine is the most powerful and efficient, but the distressing and oftentimes serious symptoms which it produces when accidentally inhaled, and the bleaching effect that it has upon many articles, have both tended to prevent its common employment. Like the sulphur dioxide, it acts best in the presence of moisture, and, therefore, steam should be simultaneously introduced and liberated in the room or enclosure in which either of these disinfectants is used. Sufficient chlorine for 1000 cubic feet of space may be generated by carefully pouring two fluidounces of strong sulphuric acid and three fluidounces of water, previously mixed and cooled, upon eight ounces of sodium chloride (common salt) and two ounces of manganese dioxide. The acid must be added to the water little by little and with care, and the salt and manganese should be in an earthen vessel upon a bed of sand, to prevent injury to the floor or carpet.

Sulphur dioxide (SO_2), though not so positive in its action as chlorine, is more frequently employed on account of the lesser risk and trouble connected with it. It probably kills germs not containing spores if sufficiently concentrated and in the presence of moisture, and is, therefore, useful in the fumigation of rooms and of articles that cannot be subjected to steam heat or chemical solutions. But it will bleach or tarnish many articles, and for this reason and the fact that it is much inferior to formaldehyde, it will hereafter probably be almost entirely supplanted by the latter whenever that can be obtained.

To secure sufficient concentration at least three pounds of sulphur should be burned for every 1000 cubic feet of space, care, of course, being had that there is no risk of igniting the floor or any articles in the room.

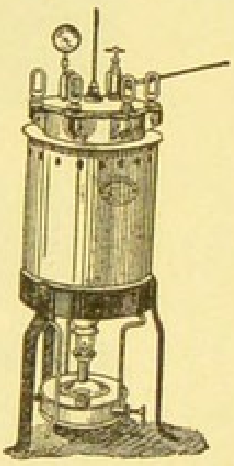
Formaldehyde (formic aldehyde), both in its gaseous state and in solution, is undoubtedly one of the best and most efficient disinfectants now in use. It has considerable penetrating power, although less than steam or than was claimed for it at first by its more enthusiastic advocates, while for surface disinfection it acts almost immediately. It is, therefore, much better in this respect than the chlorine or sulphur dioxide already mentioned, and where it is properly used, only such articles as bedding, mattresses, and pillows, that can be better treated with steam, need be removed from an infected apartment. Clothing, rugs, hangings, etc., that can be freely exposed to it are quickly sterilized. Another important feature is that it does not act destructively on either clothing or furniture, and that, although it is quite irritating to the conjunctivæ of the eyes and to other mucous membranes when concentrated, it is virtually non-poisonous.

Formaldehyde is readily absorbed and held in solution by water to the extent of 40 per cent. by weight of the latter, but as soon as this proportion is exceeded there is a polymerization of the gas and a solid (paraformaldehyde or paraform) is precipitated, which is only resolved again into formaldehyde at a temperature of 275° F. The 40 per cent. solution is practically identical with the preparation which is commercially known as formalin, and has usually an addition of 10 per cent. of methyl alcohol to further guard against precipitation. Very weak solutions (1 or 2 per cent.) of the gas are still effectively disinfectant, while its virtue as an antiseptic persists even when the dilution is carried to a remarkable degree.

One peculiar effect of the solutions is that of rendering connective tissue and all gelatinous substances insoluble in either hot or cold water, and it is probably to this that its germicidal activity is largely due, since the food supply of the bacteria, if not the substance of the latter themselves, is partly of this nature. For the same reason it hardens and disagreeably roughens the skin, which tends to prevent its use for topical applications.

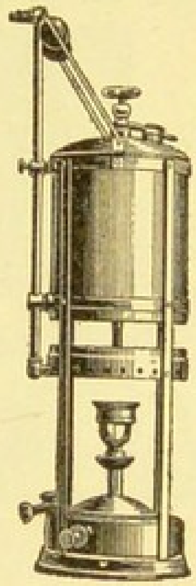
Several methods have been devised for the production or liberation of formaldehyde in rooms and buildings in such volume as positively to secure both surface and penetrative disinfection. Of these, the best results seem to have been obtained where a solution of the gas, such as formalin, is heated and vaporized. For instance, in Trillat's apparatus the solution is heated, calcium chloride also being added to further insure against the precipitation of paraform. A simpler device, called a regenerator, allows the solution to flow in a fine stream through a copper coil heated to redness by a flame beneath, the gas and vapor then passing directly into the room in a superheated and effective condition. Both of these methods have the advantage that the apparatus may be operated

FIG. 37.



Trillat's autoclave or apparatus for liberating formaldehyde.

FIG. 38.



Regenerator for vaporizing formaldehyde solutions.

outside of the room to be disinfected, and the action accordingly controlled; also that the amount of gas liberated depends directly upon the strength and quantity of the solution evaporated.

In the Schering method, the solid paraform is heated in a receptacle over an alcohol lamp, the volume of resulting formaldehyde depending, of course, upon the amount of paraform used. This method has yielded some excellent results experimentally, and is of special value in disinfecting small rooms, closets, and sterilizing cases made for instruments, dressings, etc.

Probably the cheapest and most common form of apparatus is that which has been devised, in the form of a portable lamp, to develop the gas directly by the oxidation of methyl alcohol, the vapors of the latter being made to pass over or through tubes or coils of heated metal, and to be thus converted into the disinfectant gas. Considerable formaldehyde can doubtless be produced in this way, but

Fig. 39.

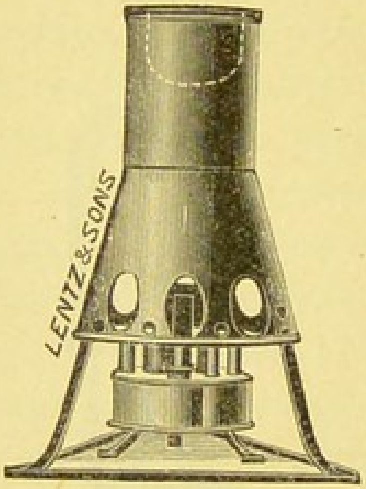
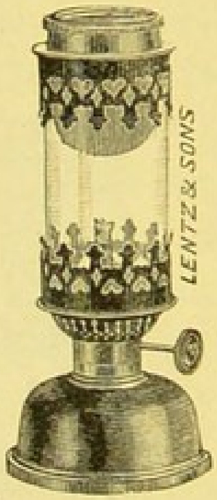


Fig. 40.



Schering's lamps for volatilizing paraform.

the amount at any time is uncertain and the results indefinite, since part of the alcohol vapors are polymerized and part are further oxidized into compounds such as carbon monoxide and carbon dioxide. Therefore this method is only to be advised for comparatively small apartments or enclosures, and not where certainty of disinfection is important.

Whenever formaldehyde is employed as a gas all the apertures in the room should be carefully and tightly closed, since, having the same specific gravity as the air, its diffusion takes place rapidly. Moreover, after a sufficient volume of the gas has been liberated, it should be allowed to act as long as possible, preferably for twenty-four hours at least, since the time element is just as important a factor with this as with other disinfectants.

Lastly, the gas is an excellent deodorant, combining as it does with the effluvia from decomposing substances to produce odorless compounds. Its odor, in turn, may be quickly dissipated from a room by evaporating a little ammonia therein.

The following table of Koch and Jaeger is added to show the comparative disinfectant strength of some substances occasionally used for the purpose:

Disinfectant.	*Strength.*	*Objects submitted to experiments.*	*Time required for destruction.*
Bichloride of mercury	1 to 20,000	Anthrax spores.	10 minutes.
	1 to 1,000	Anthrax spores.	1 minute.
Silver nitrate	1 to 12,000	Anthrax spores.	70 hours.
	1 to 4,000	Cholera and typhoid	2 hours.
	1 to 2,500	Diphtheria.	2 hours.
Acid, hydrochloric	2 to 100	Anthrax spores.	10 days.
Acid, sulph.	2 to 100	Anthrax spores.	53 days.
	15 to 100	Anthrax spores.	8 days.
Ferrum chlorate	5 to 100	Anthrax spores.	6 days.
Calcium chloride	5 to 100	Anthrax spores.	5 days.
Potass. permanganate	5 to 100	Anthrax spores.	1 day.
Caustic lime	0.0246 to 100	Cholera.	6 hours.
	0.0074 to 100	Typhoid.	6 hours.
Acid, carbolic	3 to 1,000	Staphylococcus and streptococcus pyog.	8–11 seconds.
	10 to 100	Anthrax spores.	24 hours.
Formaldehyde (K. Walter).	1 to 100	Nearly all pathogenic germs.	Less than 30 minutes.
	3 to 100	Anthrax spores	15 minutes.
		All other pathogenic germs	1 minute

In any case of infectious disease special attention should be given to disinfecting the excretions and secretions which are known to be most likely to contain the disease germs, viz., the desquamating epithelium in measles and scarlet fever, and likewise the renal secretion in the latter; the dejecta in typhoid fever; the sputum and possibly the dejecta in tuberculosis; secretions from the throat in diphtheria, etc.

During the course of the illness there should be no more communication than is absolutely necessary between the occupants of the sick-room and those in the rest of the house, and a sheet should be hung at the door and kept moist with some disinfecting solution, as this will largely prevent the escape of infected dust particles through the doorway. All articles going from the room, whether dishes, clothing, or food, should be submerged in a disinfectant or covered with a cloth wet with it, and should be burned, boiled, or otherwise disinfected as soon as possible thereafter. Excreta should be disinfected as soon as discharged from the body, but should not be emptied into a water-closet, sewer, or cesspool till the disinfectant has had ample time to do its work. Ventilation should be as perfect as possible; sunlight should be admitted whenever it will not injure or annoy the patient, and, above all, cleanliness in every respect should be insisted upon as being most essential.

It is taken for granted that, if possible, before the occupancy of the room by the sick, all upholstered furniture, heavy drapery, and everything not absolutely necessary were removed from the room. Even the carpet should be taken up and rugs used temporarily in its place. If this is done, the work of disinfecting the room after it is no longer needed by the patient will be greatly facilitated.

Where the use of formaldehyde is not available, the final disinfection should be carried out as follows: All bed-clothing, etc., should be either submerged in some disinfectant solution or in boiling water, or else covered with a sheet wet with a disinfectant, and boiled as soon as possible thereafter. No clothing should be sent away from the house to be laundered. Bedquilts, blankets, mattresses, etc. should be subjected to steam sterilization if possible; if not, the blankets and quilts should be carefully sterilized by boiling, and the mattresses would better be burned. The carpet or rugs should be carefully taken up, carried to an open space, well beaten, and then hung in the open air for a time, provided they cannot be sent at once to some place where steam sterilization is available. All furniture and the woodwork of the room should be washed with corrosive sublimate solution (1 to 500 or 1000), taking care to get the fluid into all crevices. The floor may be scrubbed with lye, and then mopped and flooded with a corrosive sublimate solution. The walls should also be wiped with cloths wrung out of this solution and any paper upon them removed before fumigaton, unless it be new and free from cracks. Or the walls may be rubbed down with the crumb of bread and the latter burned, as the bread contains much gluten, to which the dust and bacteria adhere. Fumigation will scarcely be necessary, and is usually of somewhat doubtful efficiency. If it is employed, all openings from the room, cracks, crevices, etc., should be closed on the *outside*, and sufficient gas (chlorine or sulphurous acid) liberated by suitable means. The vessels containing the gas-generating substances should be placed in larger vessels containing water to avoid the danger of fire, and vapor of water should be liberated in some way simultaneously with the gas, say by placing hot bricks or the like in the water, as neither chlorine nor sulphurous acid has much disinfecting value except in the presence of moisture. The room should then remain closed for twenty-four hours and, lastly, should be well ventilated for a day or two before being furnished and occupied again.

Should it be possible to use formaldehyde, the disinfection is much simplified, for comparatively few articles need be removed from the room, while the remainder will probably be thoroughly sterilized by the proper use of a sufficient quantity of the gas, say that liberated from one pint of a 40 per cent. solution for each 1000 cubic feet of space.

Quarantine.

Quarantine may be described as the methods and measures imposed by a government—local, State, or national—to prevent the introduction of infectious disease into the country or from one locality to another. Although the term in itself is misleading, being derived from the Italian "*quarante*," and signifying the period of detention of the first Venetian quarantines, it is now generally taken to indicate the entire routine of inspection, disinfection, and detention, without regard to the length of time involved.

While all civilized nations have from the earliest times recognized the importance of separating those afflicted with epidemic disease from the well, the development of the idea and practice of quarantine has necessarily been consequent upon the growth of commerce; and while there had practically always been isolation for leprosy, the first quarantine enactments, in our meaning of the term, were put in force in Venice about the beginning of the fifteenth century as a barrier to both the black and the Egyptian plague. Then it was realized that epidemic diseases were transmitted by those attacked, a bureau of health and a lazaretto were established, the effects of those who died of the plague were destroyed, and the period of detention of incoming vessels, passengers, and cargoes was fixed at *forty* days.

As time went on and the plague spread over the whole of Europe, the number of lazarettos was largely increased, especially in the eighteenth century. Of these, the one at Marseilles became the most noted, not only because it was located at one of the most important ports of the Mediterranean, but because of its excellent care and management. Thanks to the increased efficacy of quarantine and other sanitary regulations, as the knowledge concerning them developed, the plague rapidly subsided soon after the beginning of the present century, and interest in it was supplanted by that in relation to the frequent epidemics of cholera and yellow fever that began to alarm the civilized world, and it is to prevent the ingress of these latter diseases, together with small-pox and typhus fever, that the present quarantine regulations are in the main devised.

With the knowledge already gained regarding the nature and causes of infectious diseases, their periods of incubation, etc., it is at once evident that it will be neither necessary nor wise to fix upon a prolonged and arbitrary time during which vessels or passengers must be detained in quarantine. All that is needed is that the proper inspecting officers shall be satisfied that there is no danger of contagion entering the country, and where any detention is necessary it is only for so long as will suffice for the disinfection of the vessel, cargo, and passengers' effects, and to cover the period of incubation of the suspected disease.

The present quarantine laws of the United States, and the latest regulations of the Treasury Department based upon them, are especially designed to afford the greatest possible protection to the country against the importation of disease with the least possible detention of incoming vessels and passengers. An important innovation that facilitates both these ends has been the establishment of quarantine in foreign lands, as it were, viz., the inspection and, if necessary, disinfection by officers of this government of all vessels, passengers, and cargoes leaving a foreign port for any port of the United States. This undoubtedly greatly diminishes the danger of the introduction of any contagious disease; but, in addition, there is that section of the law that provides that the President may, whenever the condition of affairs shall seem to warrant it, "prohibit, in whole or in part, the introduction of persons and property from such countries or places as he shall designate and for such period of time as he shall deem necessary."

Accordingly, every vessel clearing from a foreign port for this country must obtain from the United States consular officer of the port, or from the medical officer appointed for the purpose, a bill of health, "setting forth the sanitary history and condition of said vessel, and that it has in all respects complied with the rules and regulations in such cases prescribed for securing the best sanitary condition of the said vessel, its cargo, passengers, and crew." Before signing the bill of health the consular or medical officer must be satisfied that the conditions certified to therein are true, and must personally inspect "all vessels from ports at which cholera prevails, or at which yellow fever, smallpox, or typhus fever prevails in epidemic form," and "all vessels carrying steerage passengers." Moreover, the vessel must be clean in all parts before taking on either passengers or crew, and all parts liable to infection must be disinfected, if any infectious disease has occurred on the last voyage. The bedding provided for steerage passengers must also be destroyed or else disinfected before being used on another voyage.

The regulations also indicate what kinds of cargo, coming from or through infected districts, may or may not be shipped, and what kinds must invariably be disinfected under any circumstances.

As to the passengers, while they are divided into two classes, cabin and steerage, no person suffering from cholera, smallpox, yellow or typhoid fever, scarlet fever, measles, or diphtheria is allowed to ship; nor should passengers ship from an infected port. Steerage passengers and crew who have been exposed to smallpox must be vaccinated before shipping unless they can show proof of immunity by former attack or satisfactory vaccination. If the steerage passengers and crew have been exposed to typhus-fever infection they may not embark until fourteen days after such exposure and the disinfectión of their baggage, while steerage passengers from cholera-infected districts must be detained in suitable quarters for five days, "the said period to begin only after the bathing of the passengers, disinfection of all their baggage and apparel, removal of all food brought with them, and isolation from others not so treated." The same rules as to detention and disinfection are to be applied to those coming from places where the plague, yellow fever, or smallpox is prevalent in an epidemic form, and if one of these diseases or cholera breaks out in the detention barracks there must be a repetition of the five days' isolation, disinfection, etc., dating from the removal of the last case. Cabin passengers from cholera or other infected ports or districts should produce satisfactory evidence as to their place of abode for the five days immediately preceding embarkation, and if there is any reason for the belief that any one of these or his baggage has been infected, such passenger is to be detained as long as the inspecting officer may deem wise, and his baggage is to be disinfected.

Every passenger must also have an inspection-card, stamped by the consular or medical officer, giving name of passenger, and of ship, port, and date of departure, etc.; and all baggage of passengers must have a label bearing the seal or stamp of the United States consular or medical officer, the name of port and of the vessel carrying the baggage, and the statement and date of inspection or disinfection.

It is evident that if these regulations at foreign ports, together with those required at sea—viz., rigorous cleanliness and free ventilation of the vessel, daily inspection by the ship's physician, isolation and disinfection of the sick, etc.—be properly observed, there can be but little chance of the germs of quarantinable disease gaining entrance to our country, and, since the duration of the voyage will in most cases exceed the period of incubation of most of the contagious diseases, if none of these manifest themselves on shipboard at sea there will be no need for any detention at the port of entry beyond that which the inspecting officer stationed there requires for the performance of his duties, viz., to inspect the vessel, bill of health, crew, and passengers, and their lists and manifests, ship physician's clinical record of all cases treated, and, when necessary, the ship's log.

This inspection service is to be maintained at every port throughout the year, and is in force not only with respect to all vessels from foreign ports, but regarding any vessel with sickness on board, vessels from domestic ports where cholera or yellow fever prevails, or where smallpox or typhus fever prevails in epidemic form, vessels from foreign ports carrying passengers having entered a port of the United States without complete discharge of passengers or cargo, and vessels having been treated at national quarantine stations that are located a considerable distance from the port of entry of said vessels. Moreover, the duties of the inspecting officer above stated are only the required minimum standard, and such other regulations may be added by legal State or local authorities as may, for special reasons, be necessary.

If the inspecting or health officer is satisfied that the vessel is not infected, and all the foregoing requirements have been complied with, he gives his certificate, to be delivered to the collector of customs of the port, and no vessel is permitted to land any of its passengers or cargo unless it have this certificate, together with the bill of health, etc., from the port of departure, as evidence that the regulations have been properly observed. On the other hand, if vessels arrive under the following conditions they are to be remanded by the authority of the Secretary of the Treasury to the nearest national or other quarantine station, where proper accommodations and appliances are provided for the necessary disinfection and treatment of the vessel, passengers, and cargo; and only after treatment and after obtaining a certificate from the proper officer that the vessel, cargo, and passengers are each and all free from infectious disease, or from danger of conveying the same, can a vessel be admitted to entry to the ports named in the certificate.

The conditions under which arriving vessels are to be placed in quarantine are these : "A. With quarantine disease on board, the quarantinable disease for the purposes of these regulations being cholera (cholerine), yellow fever, smallpox, typhus fever, and leprosy. B. Having had such on board during the voyage or within thirty days next preceding arrival; or, if arriving in the quarantine season, having had yellow fever on board after March 1st of the current year, unless satisfactorily disinfected thereafter. C. From ports infected with cholera or where typhus fever prevails in epidemic form, coming directly or *via* another foreign port, or *via* United States ports, unless they have complied with the United States quarantine regulations for foreign ports; also vessels from non-infected ports, but bringing persons or cargo from places infected with cholera, yellow fever, or where typhus fever prevails in epidemic form, except as subsequently noted. D. From ports where yellow fever prevails, unless disinfected in accordance with these regulations, and not less than five days have elapsed since such disinfection.

"The following exceptions may be made to Rules C. and D. with regard to vessels quarantined against on account of yellow fever: (1) Vessels arriving from November 1st to May 1st may be admitted to entry. (2) Vessels bound for ports in the United States north of the southern boundary of Maryland, with good sanitary condition and history, having had no sickness on board at ports of departure, en route or on arrival, provided they have been five days from last infected or suspected port, may be allowed entry at port of destination. But if said vessels carry passengers destined for places south of this latitude the baggage of said passengers shall be disinfected, and such baggage shall be labelled. (3) Vessels engaged in the fruit trade from ports declared safe for this purpose by the Supervising Surgeon-General of the Marine Hospital Service may be admitted to entry without detention, provided they carry no passengers and have carried no passengers from one port to another, and have no household effects or personal baggage in cargo, and have complied with the rules and regulations made by the Secretary of the Treasury with regard to vessels engaged in said trade."[1]

Moreover, all passengers other than those occupying first or second cabin, and all persons arriving on vessels that have had smallpox on board, must be vaccinated or detained in quarantine not less than fourteen days, unless they can show satisfactory evidence of recent vaccination or of having had smallpox; and all effects and compartments liable to convey infection must be disinfected.

"No case of leprosy will be landed, and vessels arriving at quarantine with leprosy on board shall not be granted pratique until the leper with his or her baggage has been removed from the vessel to the quarantine station. If the leper is an alien passenger and from a foreign port, action will be taken as provided by the immigration laws and regulations of the United States. If the leper is an alien and a member of the crew, and the vessel is from a foreign port, said leper shall be detained at quarantine at the vessel's expense, until taken aboard by the same vessel when outward bound."[2]

There are ten national quarantine stations and a number of others under State or municipal control; those which have steam disinfection chambers and other efficient equipments are located at Portland, Me.; Boston, New York, Sandy Hook, Delaware Breakwater, Reedy Island in the Delaware River, Cape Charles, Baltimore; Wilmington, N.C.; Savannah, Blackbeard Island, Ga.; Charleston, Dry Tortugas, Key West, Mullet Keys, Pensacola, Mobile, Chandeleur Islands, New Orleans, Galveston, San Diego,

[1] Quarantine Laws and Regulations of the United States.

[2] Ibid.

San Francisco, and Port Townsend; the ten national ones being included in the list.

The essential requisites for a properly equipped quarantine station, after the selection of a proper location—which should be convenient, but not in the line of future city growth—are the following:[1] 1. A boarding station, including boat-house and boatmen's quarters. 2. A boarding-boat, preferably a steamer. 3. An anchorage for the detention of infected vessels. It should be safely out of the track of commerce, convenient but not too close to the main quarantine establishment, sheltered, and with good holding ground for anchors. 4. A fumigation steamer with appliances for generating and forcing sulphurous-acid (or formaldehyde) gas into vessels, and with tanks and pumps for disinfecting solutions. 5. A wharf, in water at least twenty feet deep, and upon which are constructed a warehouse, tanks for disinfecting solutions, and a disinfecting house containing steam disinfecting chambers. 6. A lazaretto or hospital for the treatment of contagious diseases. 7. A hospital for non-contagious diseases. 8. Barracks or quarters for the detention in groups of those who may have been exposed to contagion or infection. 9. Quarters for medical officers. 10. A cremation furnace.

When a vessel is remanded to quarantine by the inspecting officer at a port of entry, its treatment and that of its cargo and passengers will depend largely upon the disease with which it is infected, being more severe if the latter is cholera or yellow fever. In case of infection by either of these diseases, the vessel is at once sent to the anchorage, and must remain there until the passengers have been dis-

[1] Rohé's Hygiene.

charged and the vessel purified, and in any case there must be no direct communication allowed between quarantine, or a vessel in quarantine, and any person or place outside.

Moreover, if cholera has occurred on board, all passengers and all of the crew, except such as are necessary to care for her, must be at once removed, the sick to be sent to the lazaretto or hospital, others specially suspected must be carefully isolated, and the remainder separated into small groups, between which there must be no communication. Those who are especially liable to convey infection must be bathed and furnished with sterile clothing before entering the barracks, and no articles capable of carrying infective matter, especially food, should be taken into the barracks. If the disease has occurred in the steerage, all the steerage passengers must be bathed and their clothing disinfected; and in any case all steerage baggage and effects, and any other baggage, etc., that has been exposed to the infection, all articles of the cargo likely to be infected, and all living apartments, furniture, and such other portions of the vessel as may possibly retain or convey infection must be disinfected. The water-supply must be changed at once, the tanks thoroughly disinfected by steam or permanganate of potash solution, and refilled with water from a pure source or with water recently boiled. The water-ballast of a cholera-infected vessel, or of one from a cholera-infected port, should never be discharged in fresh or brackish water without previous disinfection, and the ballast-tanks should be refilled with sea-water or else be disinfected before refilling. Nothing is to be thrown overboard from a cholera-infected vessel in quarantine, but everything that is to be destroyed, even deck-sweepings, should be burned in the furnace.

The disinfection of the holds of vessels is to be by mechanical cleansing, by an acid bichloride of mercury solution (1 to 800) applied under pressure, and by sulphurous-acid gas (10 per cent. volume strength) for from twenty-four to forty-eight hours. All ballast must be discharged or disinfected before the disinfection of the hold, and all solid ballast must be disinfected before being discharged into fresh water. The steerage and forecastle are to be disinfected by live steam, if possible, for at least half an hour, and, if not, by sulphur dioxide and bichloride solution, as was the hold. Baggage, bedding, carpets, etc., are to be removed with caution and to be disinfected by steam or by boiling, and, finally, all woodwork of the vessel is to be thoroughly cleansed mechanically and then washed with an acid bichloride of mercury solution (1 to 1000).

Under date of August 5, 1897, the Secretary of the Treasury issued a circular to State and local quarantine authorities "amending Article 5 of the quarantine regulations to be observed at ports and on the frontiers of the United States, by adding two paragraphs, 8 and 9.

"*Disinfection of steerage, forecastle, and cabin of vessels by formaldehyde gas.* After the removal of the bedding, carpets, and furnishings, all apertures being tightly closed, the steerage, forecastle, and cabin of a vessel may be disinfected by formaldehyde gas in a percentage of not less than 2 per cent. per volume strength, the time of exposure to be not less than twelve hours. The gas may be generated by the following method :

"From an aqueous solution, containing 40 per cent. of the gas, known under the names of formaldehyde, formol, or formolose. The gas is best evolved from these solutions by the addition of from 10 to 30 per cent. of a neutral salt, preferably calcium chloride or sodium nitrate, and heating the mixture in a special boiler. One litre of a 40 per cent. solution of formaldehyde gas will evolve about 1425 litres (50.1 cubic feet) of the gas at 20° C. (68° F.), and will be sufficient for 17 cubic metres (2505.5 cubic feet) of space.

"After the disinfection of apartments by formaldehyde gas, the latter should be neutralized by ammonia gas, evolved from water of ammonia by heat, or by evaporation from water of ammonia sprinkled upon the floor. The quantity of water of ammonia required for neutralization, after the above-named method, is as follows: $1\frac{1}{4}$ litres (1.26 quarts) of water of ammonia for each litre (1.01 quarts) of formaldehyde solution.

"*Disinfection of clothing, bedding, upholstered furniture, articles of leather, etc., by formaldehyde gas.* These may be disinfected by formaldehyde gas in the ordinary steam disinfecting chamber, the latter to be provided with a vacuum apparatus and special apparatus for generating and applying the gas. The gas should be applied in a dry state in not less than 20 per cent. per volume strength, the time of exposure to be not less than one hour.

"The application of the disinfectant can, of course, be modified to suit the circumstances of the case, but the foregoing will be useful as indicating the principles which must be followed."

As to the passengers and others who have been isolated in groups, they are to be inspected twice daily by the physician and remain under his constant surveillance, and can have no communication with any one in a different group or outside of quarantine, except through the quarantine officer. The water- and food-supply is to be strictly guarded, and is issued to each group separately. The latter is to be simple in character and abundant in quantity, but no fruit is to be permitted. Strict cleanliness is to be enjoined, disinfection wherever necessary, and, in case cholera appears in any group, the sick will be immediately removed to the hospital, and the rest of the group bathed and their effects disinfected, and all then removed to other quarters, if possible. None are to leave quarantine until five days after the last exposure to infection and the final disinfection of such effects as were taken to barracks; and no convalescent may leave quarantine until a bacteriological examination shows him to be free from infection.

As has been stated, the treatment of vessels infected by other diseases is not necessarily so severe as the above, but in each case every effort is made to allow no loophole for the entrance of infection into the country; and in the case of yellow fever there is to be the same isolation of all not required to care for the vessel and a detention of at least five days after disinfection has been thoroughly performed and completed. The detention for typhus fever is to be twenty days, and for smallpox fourteen days, the detention dating from the last exposure to either disease.

No vessel may leave quarantine until she has a certificate from the health (quarantine) officer that she has in all respects complied with the quarantine regulations, and that, in his opinion, she will not convey quarantinable disease. She is then said to be granted *free pratique.*

The law further provides that "When practicable, alien immigrants arriving at Canadian and Mexican ports, destined for the United States, shall be inspected at the port of arrival by the United States consular or medical officer, and be subjected to the same sanitary restrictions as are called for by the rules and regulations governing United States ports; that inspection cards will be issued by the

United States officer at the port of arrival to all such immigrants, and labels affixed to their baggage, as in the case of foreign ports; and where such immigrants are not inspected at the port of arrival they shall enter the United States only at certain designated points on the frontier, and then only after such inspection, detention, disinfection, vaccination, etc. as may be necessary or required by the officers there stationed.

There is also provision for the inspection of State or local quarantines from time to time by the Supervising Surgeon-General of the Marine-Hospital Service, or by an officer of that service detailed by him; and for the observance at all quarantines of such additional rules and regulations as may from time to time be promulgated by him.

Inland Quarantine. Under this heading may be considered the means that may be employed to prevent an epidemic extending from one locality or district to another, although the principle and aims are practically the same as those of maritime quarantines, viz., to define certain boundaries beyond which no person or thing capable of carrying infection may pass, and to establish certain points of ingress or egress on these boundaries where there may be the necessary detention, inspection, disinfection, etc.

The *sanitary cordon* "consists of a line of guards, military or civil, thrown around a district or locality, either to protect the same from the surrounding country when infected, or to protect the surrounding country from the infected district or locality." "It is not intended to bottle up all the people who are caught within an infected district, but, on the contrary, is intended as a means of exit to those who will not carry with them contagious diseases to the people beyond."[1] It may be single or double; in the latter case the inner line closely encircles the well-defined infected locality, and the outer line the whole suspected territory. This latter may be removed as soon as it is evident that the space between it and the inner line is not infected. To be efficient the cordon must be so guarded that, even though it be many miles in length, no unauthorized person may pass through it, while at certain places upon it *camps of probation* or detention must be established, where all persons coming from the infected locality may be kept under observation for a time equal to the period of incubation of the disease in question. These camps of probation or detention are to be distinguished from the *camps of refuge*, which were first suggested by Surgeon-General Woodward in 1878, and which are "simple residence-camps established to receive the population of an infected community when it has been determined to depopulate the infected district."

At these camps of probation provision must be made for inspecting every person and disinfecting all baggage before entering camp, for isolating the occupants and housing and feeding them in the most comfortable and sanitary manner during the detention, for inspections twice or thrice daily, for the isolation and care of the sick in hospitals at a safe distance from camp, and for the issuance of a certificate granting "free pratique" when the period of detention is over.

A notable instance of the sanitary cordon was that about the city of Brownsville, Texas, and along the Rio Grande, in 1882; and of a probation camp, that at Camp Perry, Florida, in 1888.

[1] Rohé's Hygiene: Quarantine.

In addition to these measures it may be necessary or advisable to establish a *railroad quarantine*, as follows: At certain convenient points, which will be the only points of egress by rail from the infected district, an inspection service and disinfecting station are to be maintained throughout the epidemic. Here all the baggage and freight is to be properly disinfected and all passengers are to be examined by the official inspectors; if the latter are from the infected locality, or have not a certificate from some recognized health officer as to where they have been for the previous days corresponding to the incubative period of the disease, they are to be at once remanded to the nearest camp of probation, there to undergo the necessary detention. Moreover, it may seem advisable to prevent any passenger cars going beyond the infected district, and to disinfect all freight and baggage cars that do so.[1]

[1] In the foregoing chapter the author has attempted to present briefly the principles and the regulations of quarantine as practised in the United States at the present time; but the reader is referred for further details to the extremely interesting and valuable chapter on the subject in Rohé's "Text-Book of Hygiene," by Dr. Wyman, the present Supervising Surgeon-General of the Marine-Hospital Service.

CHAPTER XI.

THE REMOVAL AND DISPOSAL OF SEWAGE.

THE waste from dwellings is of three kinds: house-sweepings and the ashes from fires; the waste from kitchens, scraps of food, etc., commonly known as garbage; and sewage, the most important, consisting as it does of the solid and liquid excreta of the body, together with waste water from wash-tubs, bath-tubs, kitchens, laundries, etc.

Ashes alone have little effect upon the health, except that they absorb moisture readily, and if allowed to accumulate in a cellar may do much to keep it damp and mouldy. For the same reason, if they be mixed with refuse vegetable matters, putrefaction is favored and noxious emanations given off. The dust from ash heaps may also be carried into the house and largely increase the solid impurities of the air therein. Consequently, ashes should be frequently and regularly removed from the premises.

Kitchen garbage readily decays, and if allowed to remain in the vicinity of the house may pollute both the air and soil about it; but inasmuch as it has some value as a food for animals, there is usually no difficulty in having it removed by scavengers without expense or delay. Care must be had, however, that this is done properly, and that all receptacles are kept in as cleanly a condition as possible. Most large cities now find it safer to collect and cremate the garbage at the expense of the municipality, rather than to allow private individuals to keep large numbers of animals within or near the city limits for its consumption. Even though the former plan be the more costly, experience shows that this garbage may be completely consumed in properly arranged crematories at convenient localities without inconvenience or annoyance to the residents of the vicinity, thus saving the expense and time necessary for conveying the garbage beyond the municipal limits.

The kind of waste to which we give the name of *sewage* is, however, of most importance to sanitarians, since it is always a possible factor in the production of disease, and since it presents the most difficulties in respect to its removal from dwellings and the ultimate disposal of it.

In addition to the substances already named, and which usually come from dwelling-houses, sewage may contain the liquid excreta from stables, the refuse from factories of all kinds, the drainage from polluted soils, and the excess of rain-water not taken up by evaporation or retained in the soil. Its composition must, therefore, be always complex and variable; but there will practically always be present in it chloride of sodium, ammonia, carbon monoxide and dioxide, hydrogen and ammonium sulphide, fetid and decomposing organic matter, and myriads of bacteria. Fresh sewage will not be as offensive to the senses as that in which putrefaction has commenced, nor will the gases arising from it be as dangerous to health. Frankland has shown that "solid or liquid matter is not likely to be scattered into the air from the sewage itself by any agitation it is likely to undergo until gas begins to be generated in it;" and it is really doubtful whether the air of a properly constructed and well-ventilated sewer can be shown to contain a harmful excess of injurious gases and organisms. However, it is essential that sewage should always be removed from the premises of a dwelling as soon as possible after its production and before decomposition begins.

When the above-mentioned constituents of sewage are to be disposed of collectively, the *water-carriage* system is usually the best. Although the *pneumatic* system (wherein air-tight pipes extend from the dwellings, etc., to reservoirs from which the air is periodically exhausted and the sewage thus drawn into them), would seem to be advantageous where the topographical conditions do not permit of natural drainage, it is always subject to the danger of breaks occurring and destroying the action, and seems to have been practically successful in but very few instances.

On the other hand, where house refuse only is to be considered and where the waste water can be kept from the other parts of the sewage, or where the water-supply, the physical conditions, or the cost of constructing the necessary sewers prevent the use of the water-carriage method, recourse must be had to the *pail* or *earth-closet* system. The use of primitive privy-vaults or cesspools is most insanitary and dangerous, and should be condemned in almost every instance. Where the necessity for one of these seems imperative, it should always be made absolutely water-tight, so that none of the contents may escape to pollute the surrounding soil and soil-air and to contaminate the ground-water in the neighborhood. Moreover, the pits should be properly ventilated and should be cleaned out regularly and often, which may be done satisfactorily and without offence by some form of odorless excavating apparatus, such as is now commonly used. No drains or sewers should empty directly into a cesspool, but these should always be trapped and have communication with the open air, and no cesspool should empty into a common or public sewer. It should be noted that the contents of such a vault, or of a simple pit in the earth, undergo putrefaction rather than natural decomposition, because of the lack of sufficient oxygen supply and of the adjunct action of the nitrifying bacteria which are found only in the uppermost layers of the soil. It is also probable that many disease germs will survive and multiply better in the contents of such a vault than in sewage or refuse treated by the methods to be hereafter described.

In the pail system the more solid waste matters, and especially human excreta, are collected in a suitable pail or tub, which, holding only a limited amount, must of necessity be removed and emptied regularly and often. If the outbuildings used for this purpose be kept clean and properly ventilated, such a system will be both economical and healthful.

Advantage may here be taken of the great deodorizing, nitrifying, and oxidizing power of fine dry earth, and various forms of *earth-closets* have been devised to be used in conjunction with the pail-system. If a quantity of dry earth, in bulk about twice that of the dejecta, is thrown upon the latter after using the closet, they will be rendered perfectly inodorous and inoffensive. For this purpose loam and clay are best, though sifted ashes may be used with almost as good results, but sand or gravel will not be so efficient as the loam or ashes. Moreover, owing probably to the action of the nitrifying bacteria in the earth, all trace of the peculiar nature of the organic compound is quickly destroyed, and the mixture soon becomes practically humus and an excellent fertilizer.

The pail or earth-closet must, of course, be separate and apart from the dwelling, as it is impossible to have the same means of keeping the gaseous emanations and effluvia out of the house as with the water-carriage system; and it also goes without saying, that the liquid house-slops, wash-water, etc., must be kept separate from the fecal waste, which should be kept as dry as possible to lessen putrefaction and to increase its possible value as a fertilizer. Nor should this liquid waste be allowed to soak into and pollute the soil about the house. It should be collected in a water-tight reservoir, whence it can be removed at frequent intervals, or, better yet, carried by suitable drains to a kitchen garden or other land at a proper distance from the house, and be there disposed of by irrigation or sub-irrigation.

As one can readily see, this pail system is especially well adapted to isolated houses and small communities, where each householder can take care that the necessary details are properly attended to, and where, as is likely, there is not a general water-supply, or where the expense of constructing the necessary sewers would be too great. But even in cities as large as Manchester, England, "where four-fifths of the people are obliged to have earth-closets," the system is said to have proved entirely advantageous and practicable.

Where there is a common and general supply of water throughout the house or to a number of houses there must be some provision for carrying off the waste water, and as this latter will have probably become polluted in its use, it will be advantageous to utilize it to remove the other sewage. In fact, where the conditions are favorable the water-carriage system will usually be found the best of all, because it is more nearly automatic, and depends least on human interference and efficiency.

The necessary apparatus comprises, on the one hand, that which belongs to the building and its premises, viz., the house fixtures, pipes, and drains; and, on the other hand, the common or public sewers which receive the sewage from the above and convey it to its place of ultimate disposal.

Sewage-plumbing and House-drainage.

The essence of any good system for the removal of sewage from a dwelling or building is simplicity. Therefore, inasmuch as it has already been stated that sewage should always be removed from the premises as soon as possible after its production and before fermentation or putrefaction begin in it, it is evident that in such a system we should have for our object and should provide for: "1. The speediest possible removal from the house to the public sewer of excretal and other refuse by means of water. 2. The prevention of the deposit of foul matter in any part of the drainage system and of percolation into the soil of polluting liquids. 3. The establishment of a current of air through every part of the soil-drains and pipes, in order to disperse any foul gases that may form and to allow them to escape with safety into the open air. 4. The prevention of any entry of air from soil-pipes, drains, and waste-pipes into the house. 5. The exclusion of the air of the common sewer from the house-drains and the house; the last being, perhaps, the most important, as the air of the public sewer may at any time contain the active germs of specific disease."[1]

This is to be done in the manner to be described. The *soil-pipe* is that which receives the sewage from water-closets and, usually, from the waste-pipes of other fixtures,

[1] L. C. Parkes: Hygiene and Public Health, 2d edition, p. 139.

such as the bath-tubs, washstands, sinks, etc., and which connects them with the *house-drain;* the latter is the conduit connecting the soil-pipe with the sewer. *Waste-pipes* convey the contents of washstands and other fixtures to the soil-pipes or to a branch of the house-drain.

The soil-pipe is usually located almost entirely within the house, although, were it not for the danger of its contents freezing, it would be better to have it fastened to the wall outside. It is usually made of cast or wrought iron, should be at least four inches in diameter, should convey the sewage as directly as possible from the fixtures to the house-drain, and must extend unobstructed from the latter to several feet above the roof, ending where winds and currents from high walls and chimneys will not interfere with its free ventilation. Every branch of the soil-pipe more than eight feet in length, or to which two or more water-closets are connected, should also be extended above the roof, or else be extended and connected to the main soil-pipe above the highest fixture connected therewith, as there must be no closed ends wherein foul or stagnant air may collect. All joints must be absolutely air-tight, and the pipe must be so secured that any vibration or settling of the building will not be likely to destroy its continuity. In new buildings, especially, all soil-pipes should be exposed or else covered in with panels easily removable at any time to permit of inspection or repairs. Any hidden pipes or those difficult of access should be of extra heavy materials, and extra care should be given to the joints and supports. The soil-pipe and house-drain should both be as smooth as possible interiorly, and in the construction they must be carefully inspected to prevent any of the material used in caulking or cementing the joints from projecting within to prevent the free flow of sewage.

Outside of the house the house-drain may be of iron or of glazed and impervious earthenware, but no earthen pipe

FIG. 41.

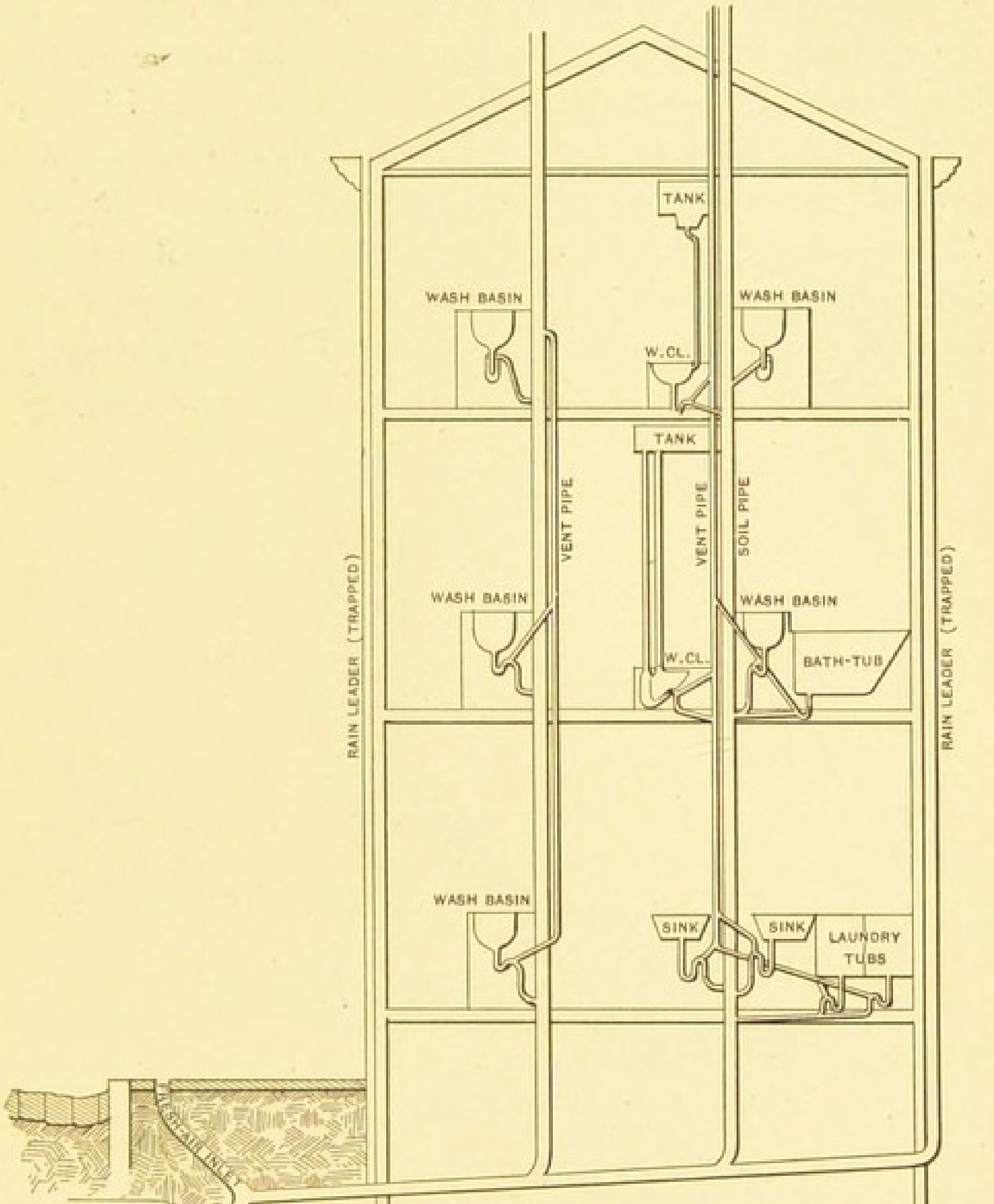
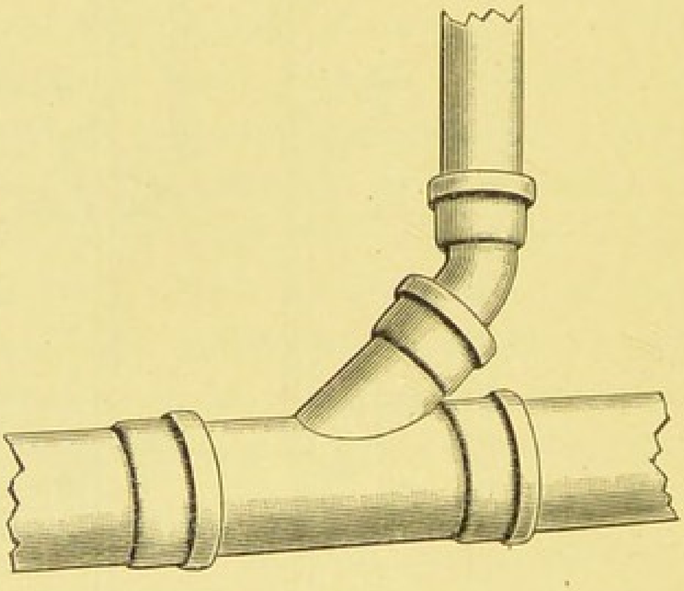


Diagram illustrating the sewage-plumbing of a house. The traps of the rain-leaders at their junctions wlth the house-drain, and the name of the latter, have been accidentally omitted.

should be permitted within five feet of a foundation wall, and where any part of the house-drain is within the building it should be of iron and securely fastened to the foundation-wall above the cellar floor. The connection between it and any soil-pipe should be by means of a rounded elbow and not by an abrupt right angle. The house-drain should not be less than four nor more than ten inches in diameter, should be laid on a firm foundation, should have air-tight joints, and should have a slope toward the sewer of at least one-half inch to the foot. A house-drain should not empty into a cesspool, unless it is absolutely necessary, and in such case the cesspool must be well ventilated and also separated from the drain by a trap. Nor should any cesspool empty into a sewer.

FIG. 42.



Method of connecting soil-pipe with house-drain.

If a house-drain empty into a sewer of the "combined" system there must be a trap just before its junction with the sewer to prevent the passage of sewer-air back into the house, and there must also be an opening for fresh air between this trap and the foot of the soil-pipe, so that there may be a constant current of air through the drain and soil-pipe to the exit above the roof, and the air in the soil-pipe thus kept from becoming foul and stagnant. But if the house-drain empties into a sewer of the "separate" system, there need be no trap between the drain and sewer, for the reasons to be hereafter stated; however, the fresh-air inlet between sewer and soil-pipe is always advisable, as it tends to further assist ventilation.

Where rain-water conductors empty into house-drains or sewers, they should be separated from the latter by traps having a seal of not less than five inches, to prevent sewer-air passing up through them to the vicinity of windows, etc.

In the house all water-closets and other fixtures should be as near the soil-pipe as possible, that there may be no long stretches of foul waste pipe underneath the floors, and all connections with the soil-pipe should be made at an acute angle, that the discharge into the latter may not interfere with its free ventilation. Each fixture must be separately trapped and the trap must be located as near its fixture as possible. There must be no connection between a fixture and the soil-pipe or house-drain which is not trapped.

A little reflection will show that provision has been made for each of the five specified requisitions for the system, and that if the foregoing specifications are observed, the air in the soil-pipes will be almost as pure as that of the house itself, and the absorption of foul gases by the water in the house-traps and their subsequent dispersion into the atmosphere of the house will be almost impossible. But there must always be both an inlet and an outlet for air to the house-drain and soil-pipe, and free communication between these; otherwise the air in the soil-pipe cannot be changed, and foul gases will accumulate, which by their pressure might overcome the seal of some of the traps.

Traps are "appliances placed between house conveniences (fixtures) and soil-pipes and drains or sewers, to

FIG. 43.

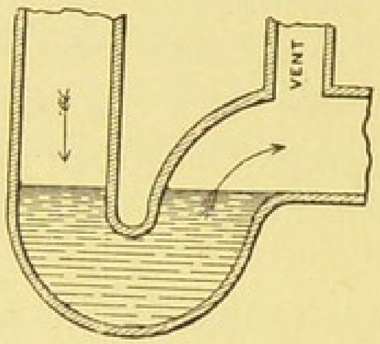
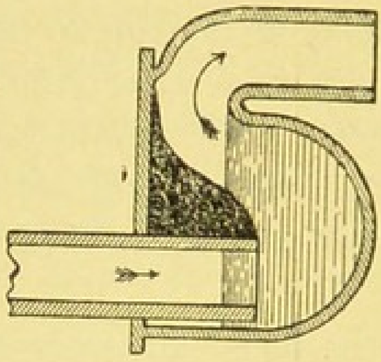


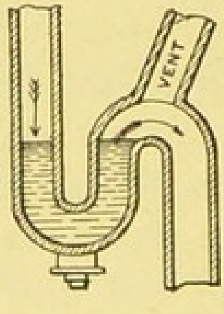
FIG. 44.



These illustrations show how a uniform calibre prevents the accumulation of dirt in a trap, and how angles and corners favor such accumulations.

prevent sewer-gas gaining an entrance into the house." Most traps are too complicated. The simpler a trap the better, provided it have sufficient seal. Mechanical appliances are liable to become clogged and not to fit

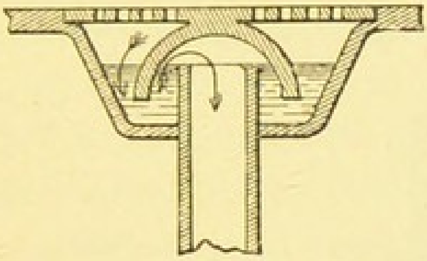
FIG. 45.



S, or siphon, trap, with opening for ventilation pipe.

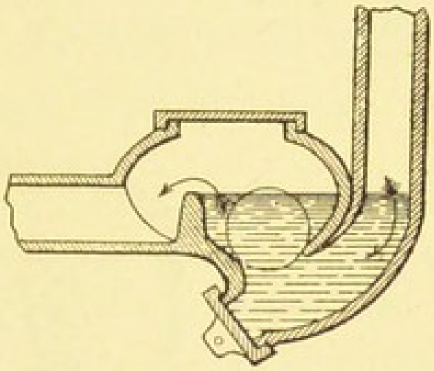
tightly, thus allowing the passage of sewer-air. The S, or siphon, trap is as simple as any, is of uniform diameter throughout, has no corners or projections to catch dirt, and is thoroughly cleansed by each fair flow of water through it. The value of a trap does not depend so much on the amount of water it contains as on the depth of the seal. On account of evaporation the water-seal of a trap soon

FIG. 46.



Bell trap.

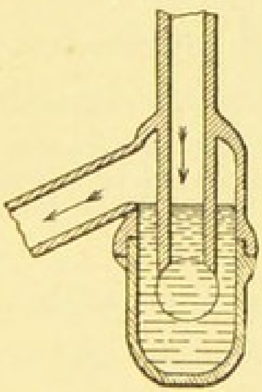
FIG. 47.



Cudell's trap.

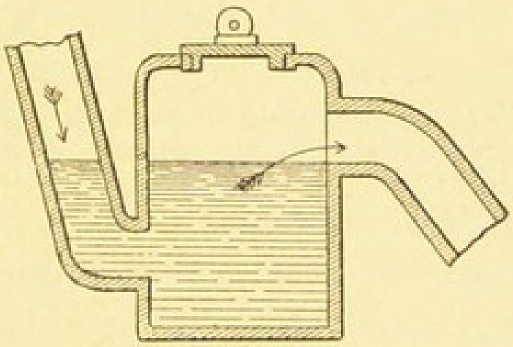
becomes lessened or destroyed, unless its fixture be in frequent use; it is, therefore, advisable to have as few fixtures of any kind in the house as the comfort or convenience of the inmates will allow. So, also, if a house is to be left

FIG. 48.



Bower's trap.

FIG. 49.

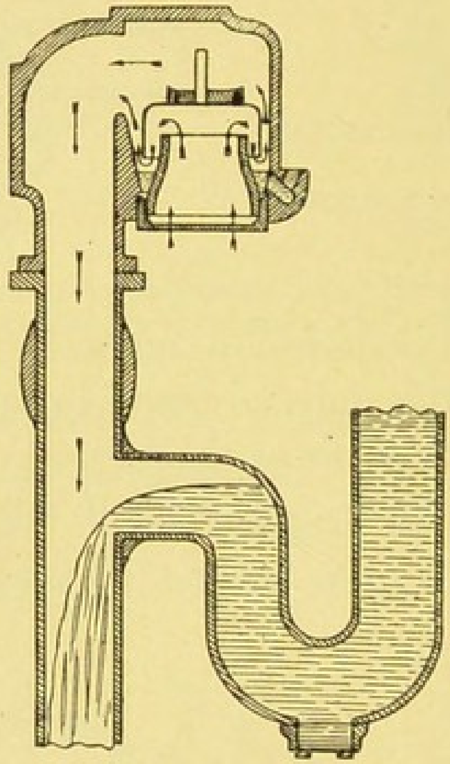


Pot trap (for kitchen sinks, etc.).

unoccupied for a time, it is well to cover the water in the traps with oil or glycerin to prevent the evaporation of the former.

The seal of a trap may be broken by siphonage, either by a rush of water through it from its own fixture, or by a rush down the soil-pipe from a fixture higher up, and this is especially liable to occur if the trap be some distance from the soil-pipe, or if the fixtures above discharge a large amount of water at once. To prevent this openings are sometimes made at the top of the traps on the

FIG. 50.



McClellan's anti siphon attachment. Sectional view of vent, with cup lifted out of the mercury by the inflowing current of air, indicated by the arrows. (ROHÉ.)

side next the waste- or soil-pipe and connected with vent-pipes, which should open into the soil-pipe above the entrance of the waste-pipe from the highest fixture, or into a separate ventilation-pipe. But this greatly increases the expense, and as the vent-pipes, to be efficient, must be almost two inches in diameter, they also favor evaporation from the trap. If the trap is properly constructed, the soil-pipe of proper size and height, and if the fixtures be placed as near the soil-pipe as possible, there will be but little danger of siphonage occurring. Where it does occur, McClellan's anti-siphon attachment is said to work advantageously, being inexpensive and permitting a free ingress of air to the trap, but no egress of air from the soil-pipe into the house. It is also said that if the fixture be connected to the soil-pipe by a divergent opening, siphonage will be less likely to occur.

All waste-pipes, soil-pipes, and house-drains should be tested before use by closing all openings and forcing in air to a pressure of at least thrity pounds to the square inch. Leaks may be detected by plugging the lower openings and filling the pipes with water, or by pouring an ounce of oil of peppermint into the highest fixture and quickly following this with several gallons of hot water, the heat volatilizing the oil, whose odor escapes at every opening in the pipes unprotected by a trap or water-seal. The heat imparted by the hot water will also help to trace out hidden soil-pipes.

All fixtures should be exposed to the free ventilation of air underneath and about them, and water-closets and washstands should not be closed in with carpentry work. Traps should also, if possible, be where they may be opened and inspected at any time. Under each fixture there should be a drip-safe to catch any leakage or overflow of water, but the pipes, if there be any, leading from these should never empty into waste- or soil-pipes; they should lead preferably to the open air; and not to the cellar, as the air in most cellars is bad, and thus gains access to the house. Even if these drip-safe pipes are trapped and open into the soil-pipe, the water in the trap is replenished so rarely that evaporation soon destroys the seal and allows the air to pass from the soil-pipe into the house.

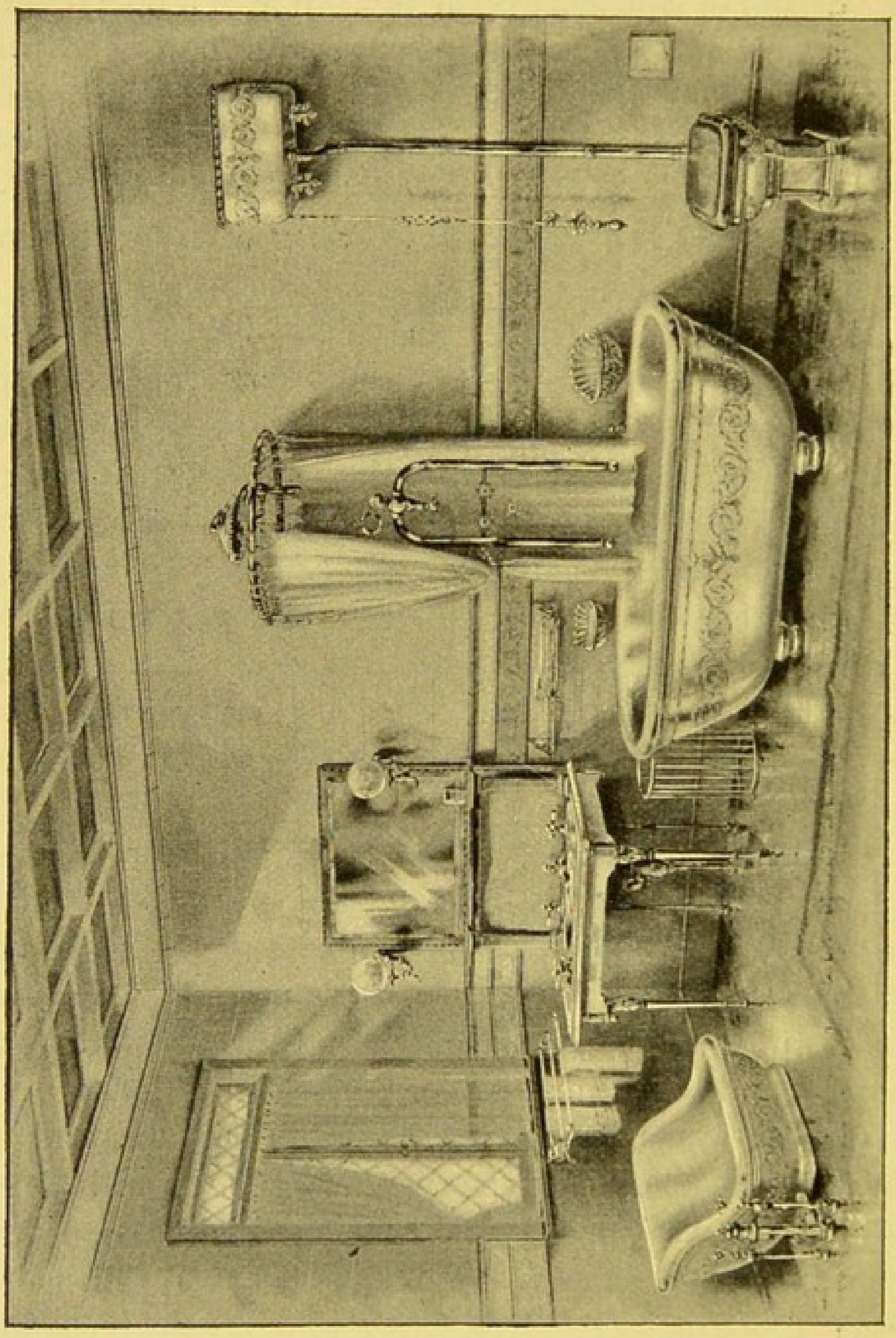


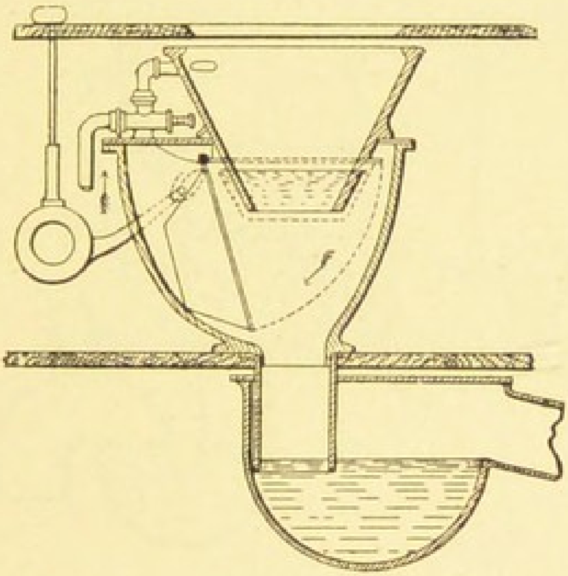
FIG. 51.

A modern bath-room. (Copyrighted by the J. L. Mott Iron Works Co.)

The overflow pipe of old-fashioned washstands and bath-tubs is objectionable, as it collects dirt of all kinds, soap, epithelium, etc., and it is almost impossible to clean it. Besides, it will often be found opening into the waste-pipe *below* the trap, thus allowing the free passage of sewer-air into the room. When new fixtures are being put in they should, preferably, be such as make use of the stand-pipe principle in the stoppers, and that have no separate or concealed overflow-pipe or outlet.

Water-closets. The requisites for a good water-closet are: that it does not allow the escape of sewer-air from

FIG. 52.

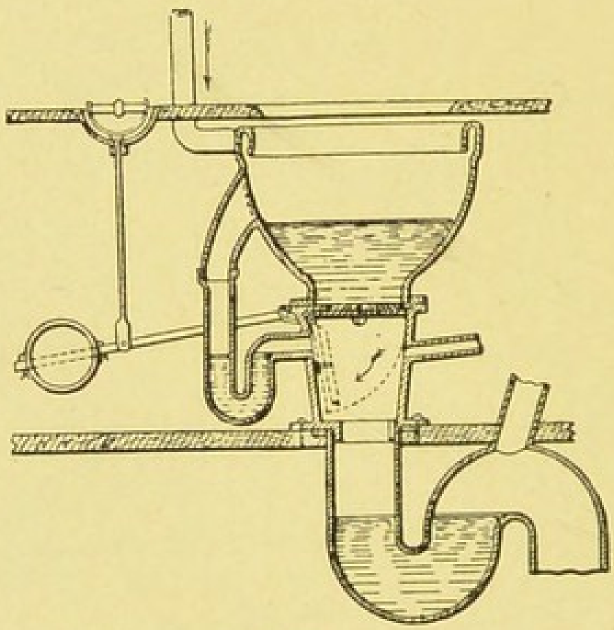


Pan closet.

the soil-pipes into the house; that it is thoroughly and easily cleaned each time after use; that there are no hidden parts in which filth can collect, or which cannot be readily cleaned; that the flushing or washing out of a closet be done in such a way that dirt or spray be not thrown into the air of the room; that there be sufficient water-supply to wash out the bowl and trap each time, and to refill them to the proper level; that the trap itself is not siphoned or left empty by a discharge of water from this or another fixture.

Of the different kinds of water-closets the pan and the valve closets are the oldest and the worst, and should not be used. They consist of a receiving bowl, the bottom of which opens into a swinging pan or is closed by a valve. The pan or valve and the lower part of the receiving bowl are enclosed in a larger bowl, the container, connected with the soil-pipe and trap. The depth of water in the

FIG. 53.

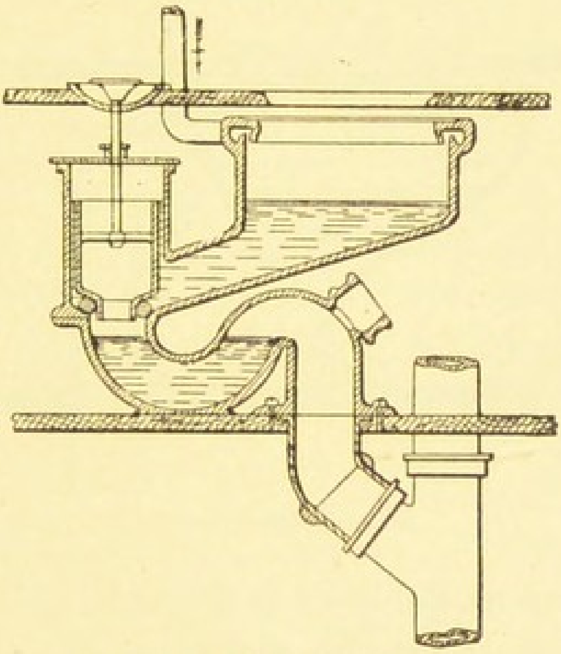


Valve closet.

receiving bowl is regulated by the depth of the pan in pan closets, and in valve closets by the location of an overflow outlet. In both kinds the contents of the receiving bowl are discharged into the container by the tipping of the pan or valve, and, consequently, the sides of the container, as well as the under side of the pan or valve, soon become thickly coated with filth. This, being hidden, accumulates, decomposes, and contaminates the air in the container, which air is of necessity discharged into the room as often as it is displaced by the contents of the receiving bowl. In valve closets the overflow-pipe from the receiver furnishes an additional way by which the foul air may pass from the container into the atmosphere of the room. It needs no argument to show that these closets are decidedly dangerous to health.

Plug or plunger closets are those in which the outlet above the trap is stoppered by a plunger, this being usually in a chamber at the side of the receiving bowl.

FIG. 54.

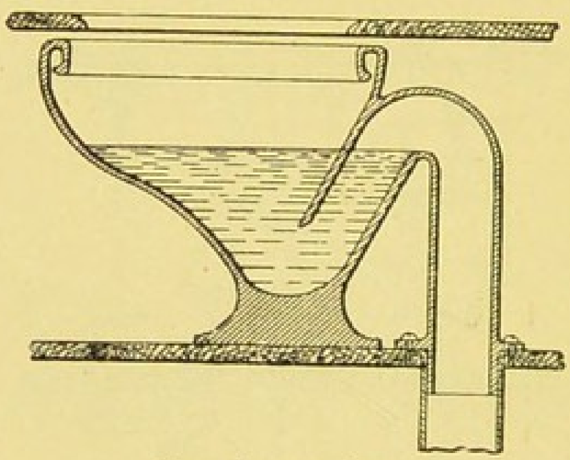


Plug or plunger closet.

The bowl and side chamber holding a considerable quantity of water, the trap is well flushed out each time of use; but the side chamber and plunger, being hidden and not easily cleaned, soon become coated with filth and dangerous to health, as there is nothing to prevent the air from passing from this chamber into the room. Moreover, the plug may not close the opening completely, thus allowing a continual waste of water. A trapped overflow-pipe in the plunger keeps the closet from overflowing.

Hopper closets consist simply of a bowl connected below with an ordinary trap, and, as there is nothing to get out of order, this kind is theoretically one of the best. The objection to long hoppers is that dirt is apt to stick to the sides and become offensive, but this can be prevented if it is so arranged that water begins to flow down the sides as soon as the closet is put to use, thus preventing adhesion. Short hoppers have not this objection, as the feces fall directly into the water in the bowl and are carried out

FIG. 55.



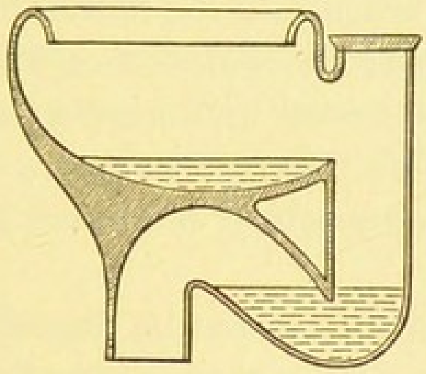
Short-hopper closet.

through the trap as the bowl is flushed. All water-closets should have a flushing rim encircling the top, so that all sides of the bowl may be washed down and cleansed each time the closet is used.

Wash-out closets retain considerable water in the bowl, and are emptied by a strong flush of water from the flushing rim. They are simple, do not readily get out of order, and are much in favor at the present time. As they are a modification of the short-hopper closet, so is the siphon closet a modification of the wash-out.

In the siphon closets the contents of the bowl and trap are lifted out by a siphonic action, and then the bowl and trap are refilled, as in the case of wash-out closets, by an after flush. In the Dececo closet—a siphon closet—use is made of the principle involved in the Field flush tank. Hopper, wash-out, and siphon closets should be supplied

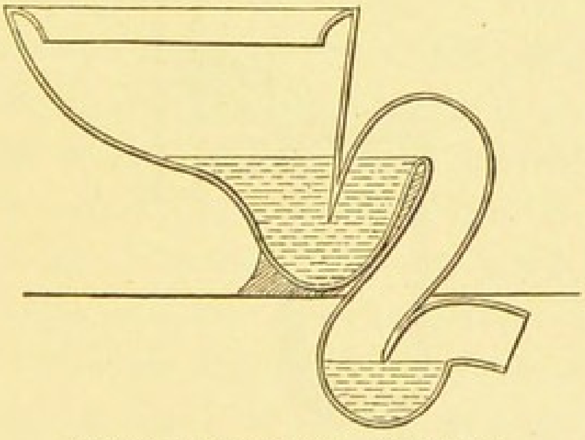
FIG. 56.



Wash-out water-closet. (PARKES.)

from water-closet cisterns, which should give down a certain and sufficient volume of water with only a short pull on the chain. The bowl and trap should also be refilled from the cistern after use.

FIG. 57.



Dececo siphon closet. (PARKES.)

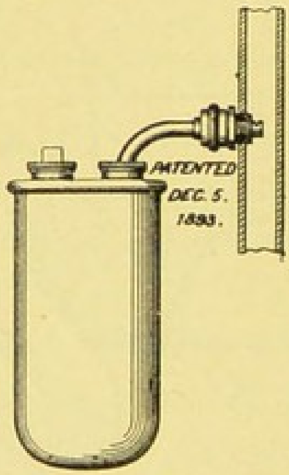
Water-closets should not be connected directly to the water-supply pipes of the house, as air from the closets may be sucked into them at times when the water-supply is cut off, and the water afterward contaminated by it.

But this is hard to avoid in pan, valve, or plug closets, and is another serious objection to their use.

Vent-pipes from the bowl and seat of water-closets must be large, and must not open into the soil-pipe but into the open air; they must not open near a window nor any place from which air is taken into the house, but may open into a flue which is constantly heated, as a kitchen chimney, or may themselves be heated and have a current maintained in them by a small lamp or gas-jet. In this way the room in which a water-closet is located may be effectively ventilated.

Water-closets should never be placed in dark closets, nor in bedrooms or living-rooms, but should always be in separate rooms that have free communication with the open air by means of a large window or by a ventilating shaft of at least four square feet area throughout its entire length. It is also advisable that bedrooms should not

FIG. 58.



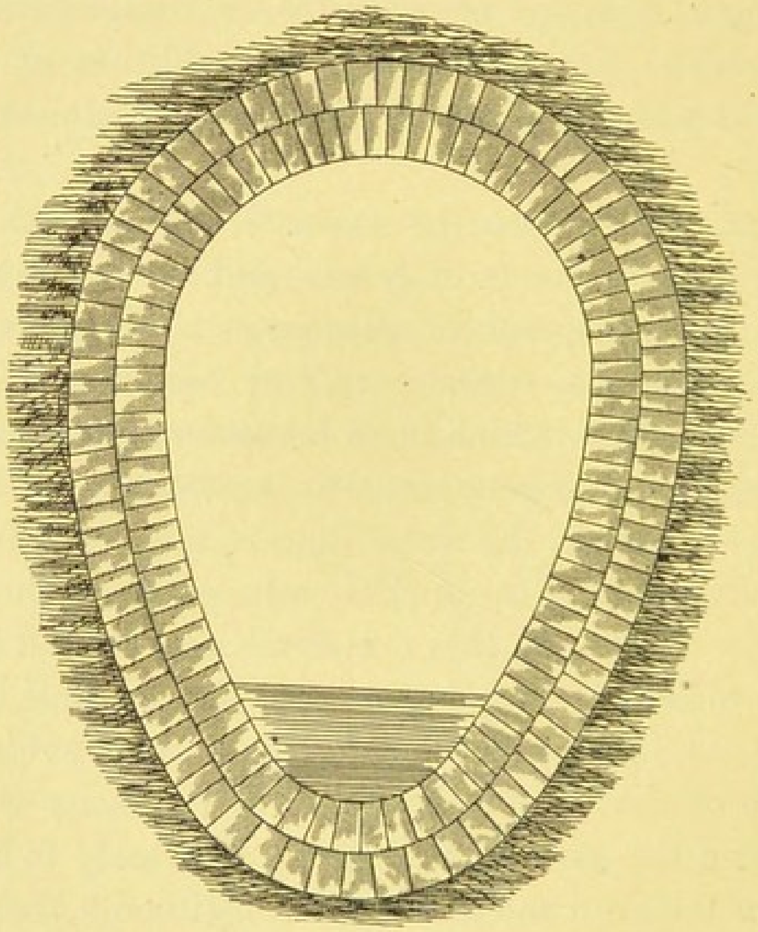
Automatic ejector for disinfecting traps, water-closets, etc.

communicate directly with bath-rooms, etc., containing water-closets, unless there is every assurance that the closet and plumbing connected with it are first class in every particular.

A recent device which is intended for attachment to the flush-pipes of water-closets and to the waste-pipes of other fixtures between them and their traps, automatically discharges with each flow of water through the respective pipes a sufficient quantity of a disinfectant to destroy and prevent all growth of micro-organisms in the traps or their contents. This, when used, will aid not only in preventing the escape of harmful or disagreeable gases into the house, but will render the addition of disease-germs to the contents of the public sewer almost impossible.

Sewers. These are the conduits provided to receive and convey the contents of house- and other drains to the place of final disposal or discharge. They may be of either of two kinds—"*combined*" or "*separate.*" Sewers of the former class, which have heretofore been most commonly used in this country, are constructed to carry off all kinds of sewage, the waste liquids, etc., from factories, street washings, and the surplus rain-water of the district drained by them. As this necessitates a size and capacity sufficient to receive the greatest probable rainfall upon the area drained, in addition to the sewage, it is evident that the depth of the normal daily flow of the latter will be so shallow and the current so sluggish as greatly to favor the settling of the solid and semi-solid constituents, the obstruction of the sewers, and the development of bacteria and sewer-gas. To obviate this and to insure a more rapid flow by keeping the depth of sewage as great as possible, the smaller conduits, at least, are generally made ovoid in section, the smaller end, of course, being downward. "Combined" sewers are not only more expensive to construct and to keep in repair than those of the separate system, but greater care must be had to see that they are at all times properly ventilated. The main advantage claimed for them is that the expense of constructing separate conduits for factory wastes, street washings, and the excess of rain-water is avoided; but this is a doubtful one, both in respect to economy and sanitation.

FIG. 59.



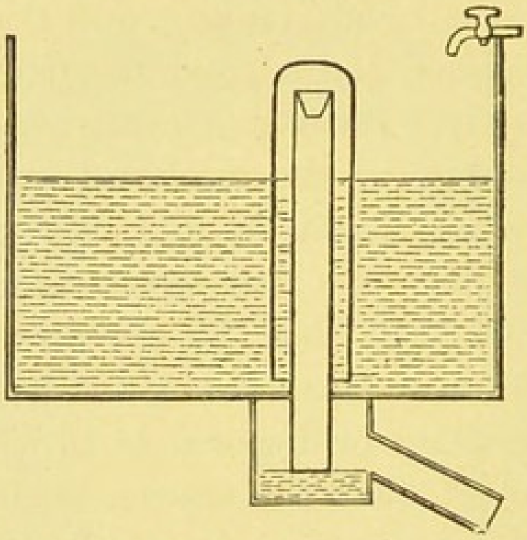
Section of ovoid sewer of "combined" system.

The ventilation of sewers of this kind is usually sufficiently provided for by the inlets for street washings and rain-water, located at street corners, etc.; but if these are not close enough together to keep the sewer atmosphere constantly changing and reasonably pure, other ventilation openings must be made. But in all cases the air from sewers of the combined system must be excluded from house-drains, etc., by the traps which have already been described.

To the sewers of the "separate" system only the sewage proper from dwellings and, occasionally, from small factories, is admitted, the rain-, surface- and soil-waters being removed by other drains or channels. The advantages of this system, which is now indorsed by almost all sanitarians, are that the volume of sewage to be carried is comparatively small and constant, and that it can be calculated very approximately from the daily water-supply and population; that the cost of construction is much less than that of sewers of the combined system, and that, while it is perfectly available and satisfactory for large cities, it is the only one that small communities would consider or can afford; that the sewage is more concentrated and uniform in composition, and can thus be better utilized as a fertilizer or disposed of in whatever manner may be desirable; that the sewers, having smaller and smoother walls, are more frequently and effectually flushed, and that they are more completely ventilated and altogether better suited to the work to be performed. The disadvantages of sewers of this class are that a community must have two sets of drains, one for sewage and the other for rain, street, and factory waters, and that after a long dry season the street washings, etc., may be very foul; but these are outweighed by the advantages above mentioned.

"No sewer of this system should be more than six inches in diameter until it and its branches have accumulated a sufficient flow at the hour of greatest use to fill this size half full, because the use of a larger size is wasteful and because ventilation becomes less complete as the size increases. The size should be increased gradually and only so rapidly as is necessary by the filling of the sewer half full at the hour of greatest flow; and the upper end of each branch sewer should be provided with an automatic flush-tank of sufficient capacity to secure the thorough daily cleansing of so much of the conduit as from the limited flow is liable to deposit solid matters by the way."

FIG. 60.



Field's annular siphon flush-tank. (PARKES.)

There should be no traps between house-drains and sewers of the separate system, since, having no rain-water inlets, the latter would otherwise have no openings for ventilation. Moreover, since the "separate" sewers are so regularly and thoroughly flushed, the air in them is not likely to be so impure, and there is not the same reason for excluding it from the house-drains, etc., as there is regarding the air from "combined" sewers. The junctions of house-drains with sewers of the separate system should be by divergent openings, so that the air may pass freely into the drain as the sewage empties into the sewer.

Should one desire, however, to separate his house-drain from the public sewer by means of a trap, and thus prevent the ingress of sewer-air into his premises, the ventilation of the sewer can be secured by providing a vent-pipe between the trap and the sewer. But in no case must the inlet-pipe on the other side of the trap, between it and the house, be omitted; nor should the two air-pipes be so near together that air from the former will be likely to be drawn into the latter.

All sewers should be laid on a good foundation with sufficient fall to give at least a velocity of two feet per second to the flow. If made of bricks they should be laid in a mortar made of cement and sharp sand, and all sewers should be as smooth as possible inside to prevent the arrest of particles of sewage. Sewers of the combined system should not be pervious to the soil-water, as the liquid sewage is as apt to pass from them to the soil and to pollute it dangerously, as the soil-water is to pass into the sewers. But the rain-water drains of the separate system may also be employed to drain the subsoil.

The ultimate disposal of sewage is a matter of considerable importance which commonly does not receive the attention it deserves. The usual method in this country of discharging the sewage into a running stream is reprehensible, because the natural purification of a water thus contaminated must always be slow and more or less uncertain, and because the risk to those using the polluted water must be a constantly increasing one. Where the district drained and supplied by the stream is a sparsely settled one, and where the volume of fresh or running water is very large in proportion to the quantity of pollution it receives, the objections to the disposal of sewage in this way may be theoretical rather than practical; but as the population increases and the ratio of pure water to filth decreases beyond certain limits, the question becomes more serious and pertinent.

Other methods of sewage disposal resemble closely those already described for the purification of water, in that they make use of subsidence, chemical treatment, and filtration. The sewage is collected in large tanks, with or without the addition of certain chemicals, such as lime, alum, and sulphate of iron, to increase the precipitation, and the suspended impurities are allowed to settle to the bottom of the tanks, whence they can be removed, squeezed partially dry in hydraulic presses, and either disposed of as a fertilizer or cremated. The clear effluent or liquid part of the sewage may be allowed to flow at once from the settling tanks into a convenient watercourse, provided it is there well diluted, or may be filtered through an area of porous soil or through prepared filter beds. If the filtration is properly done the filtrate will contain nothing harmful, and may be allowed to flow where it will without danger. A properly prepared filter bed of twelve inches of sand upon eighteen inches of gravel or magnetic carbide of iron, with an area of one acre, is said to be able to purify from one to two million gallons of clarified—effluent—sewage in twenty-four hours.

Other ways in which sewage may be disposed of are by intermittent downward filtration, by irrigation, and by sub-irrigation. The soil to be used for this purpose should be porous and loamy; if clay, it should be well broken up and mixed with ashes; sand does not do well, especially at first in these methods. The sewage impurities are removed partly by mechanical filtration, but especially by oxidation, the latter being due partly to the air in the interstices of the soil, but chiefly to the saprophytic bacteria, which rapidly convert the organic impurities into nitrates and nitrites. In each of these methods the sewage should be applied intermittently, so that the air in the soil may be periodically renewed.

By intermittent filtration we mean "the concentration of sewage at short intervals, on an area of specially chosen porous ground, as *small* as will absorb and cleanse it; not excluding vegetation, but making the produce of secondary importance. The intermittency of application is a *sine qua non* even in suitably constituted soils, wherever complete success is aimed at." The land should be levelled and underdrained with tile drains at the depth of five or six feet, and should be divided into four parts, no part to receive sewage for more than six hours. An acre of properly prepared soil will thus dispose of the crude sewage of 1000, or the clarified sewage of 5000 people.

Irrigation means "the distribution of sewage over a large surface of ordinary agricultural ground, having in view a maximum growth of vegetation, consistently with due purification, for the amount of sewage supplied." Sub-irrigation is a modification of this, the sewage being delivered through porous drains a few inches beneath the surface of the soil. Unless very porous, the land should be underdrained; it should also be levelled to prevent the sewage flowing off the surface too rapidly. The underdrains need not be nearly so close together, however, as in the intermittent filtration system. The crops raised on irrigation farms are perfectly healthful in every respect, and there can be no reasonable objection to their use; there would be decided objection, however, to watering the vegetables with sewage water.

The sewage of from one hundred to three hundred persons per acre of irrigation area can be safely disposed of by this method, and it is to be especially recommended for isolated houses, for small communities, or for charitable or other State institutions.

Electricity has also been suggested as an agency for the purification of sewage, but seems to be still too expensive for the purpose.

CHAPTER XII.

VITAL STATISTICS.

SCIENCE is classified knowledge. By arranging known facts and units into groups, and considering them from different points of view, we discover the scope of a particular science, and are also led to the discovery of new facts.

In hygiene it is necessary to have this classification of facts to know what progress we are making, for the true test of any sanitary procedure is its efficacy in preserving health and preventing disease, and we cannot know whether it is efficient or not unless we tabulate and study the results and at the same time eliminate disturbing factors. In this connection it is to be noted that our facts must be accurate and derived from sufficient experience, and that the disturbing factors are especially liable to be numerous.

It is evident that we may study disease by direct observation at the bedside and at the *post-mortem* table, or by experiment; and while our knowledge in the past has been gained principally by the former method, we now, since the advent of modern bacteriology, may further investigate many diseases by reproducing them in susceptible animals. In this way we soon learn that some diseases are much more preventable than others, and we endeavor to discover the respective causes and predisposing conditions of each that we may the more readily estimate their effects and take measures to restrict and prevent their action.

Our observations may be of two kinds: 1. By noting and comparing individual cases, or by following the track of a particular outbreak or epidemic. 2. By observing large classes and groups of men, which necessitates a record of births, marriages, diseases, and deaths. The consideration of such records constitutes the study of vital statistics, the most important object of which is, as Dr. Billings says, "to give warning of the undue increase of disease or death presumed to be due to preventable cause, and also to indicate the localities in which sanitary effort is most desirable and most likely to be of use." The reader will also notice how the study of vital statistics broadens out into the science of demography—the study of the life of people and communities.

At this point it will be well to note certain elementary principles which must be observed in any statistical inquiry, in order that the results of that inquiry may have any value whatever. These are:

1. Our facts, or *numerical units*, must have precise, definite, and constant characteristics. For example, in tabulating the death- or sick-rate from typhoid fever, every case used in the calculation must be accurately diagnosed and must be undoubtedly one of that disease. If there is any doubt as to preciseness, it is better to omit that unit.

2. The units are to be arranged into *groups*. These groups must have dividing characteristics so definite that there can be no doubt into which group each unit will come. No unit must be in more than one group at one time. It is difficult to group complex facts so as to properly analyze them and to discover all possible phases.

3. Having decided and arranged the groups, we must have a *constant numerical standard* by which the relation of the various groups to the total units may be expressed. It is generally 100 or some multiple of 100.

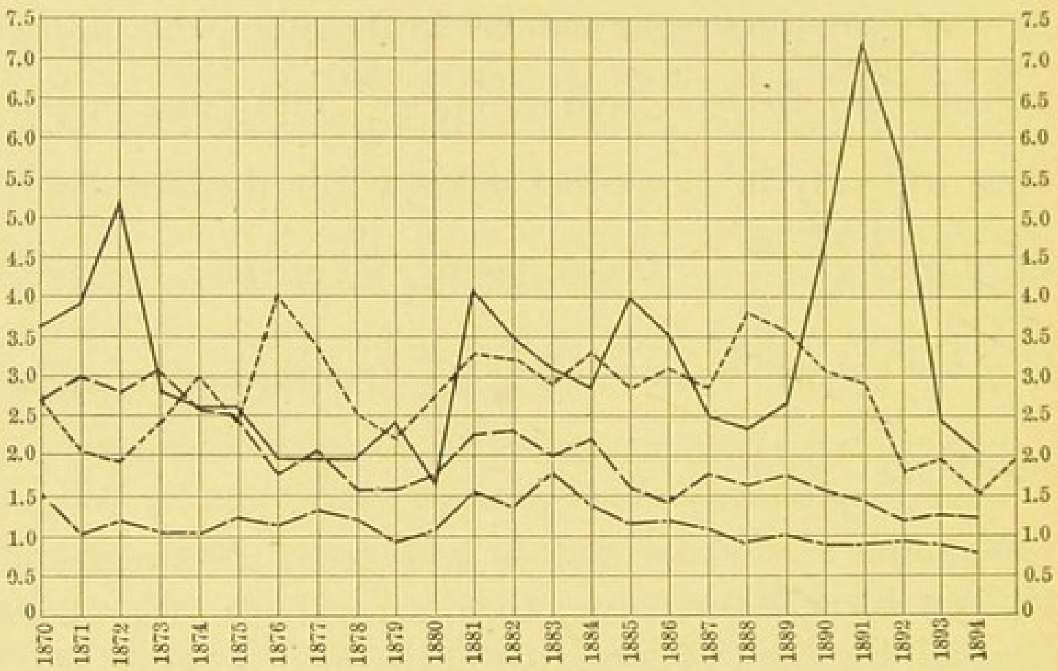
4. We must determine the *variation* in the proportion or relation of the component groups to the whole in similar series of cases. While only an approximation to an invariable proportion may be had in any one series, it may be shown mathematically that as the number of units in the series increase there is a greater probability that the proportions will remain the same, and that we may calculate the limits of variation by Poisson's formula, as follows: If, in the formula $m + n = q$, m be the number of units in one group and n the number in the other, the proportion of m to q will be $\frac{m}{q}$, and of n to q, $\frac{n}{q}$, and these proportions will vary in succeeding series within the limits indicated by $2\sqrt{\frac{2\ m\ n.}{q_3}}$ Consequently, the greater the value of q, the less will be that of $2\sqrt{\frac{2\ m\ n}{q_3}}$, or the limit of variation from $\frac{m}{q}$ and $\frac{n}{q}$.

Example: Suppose that in a series of 1000 cases of typhoid fever 700 recover; then, according to the above formula, the limit of variation in the next series of 1000 similar cases would be 40, and the recoveries would be between 660 and 740.

The *arithmetical* mean is usually employed in medical inquiries, though the increase in population is estimated by geometrical progression. The *probable error* or variation from the arithmetical mean is about two-thirds (0.6745) of the *mean error*, which latter is *the mean of the mean error in excess and the mean error in deficiency.* The mean error in excess is the difference between the mean of the series and the mean of all the units of the series above the mean. The mean error in deficiency is the difference between the mean of the series and the mean of the units below the mean.

The relative value of two series is as the reciprocals of the squares of their probable errors. Thus if the probable error of series A is 10 per cent. and that of B is 2 per cent., the value of A to B will be as $\frac{1}{100}$ to $\frac{1}{4}$, or B will be twenty-five times as valuable as A.

FIG. 61.



Graphic chart, showing percentages of typhoid-fever deaths in total mortality in four cities. Unbroken line, Chicago; lower line, New York; short dashes, Philadelphia; long dashes, Boston.

The relative value of two or more series is also as the square roots of the numbers of units in the respective series. From the above it is evident that the results from an average cannot be absolutely applied to any particular case, for there is always the chance of such variation as may be determined by Poisson's formula or by the estimation of the probable error. We apply averages to the aggregates of facts, and they will approach exactitude if they are founded on a sufficient number of facts. We must be careful in estimating the value of means and averages and in giving credit or blame accordingly. Dr. Guy says: "Averages are numerical expressions of probabilities; extreme values are expressions of possibilities."

Statistical results are frequently expressed by graphic representations (see Fig. 61), and these are very valuable, especially for class or similar demonstration.

The numerical units employed in the study and the calculations of vital statistics are persons living and persons dead, and the groups into which these units are classified are characterized by such distinctions as age, sex, occupation, locality, etc. The sources from which we derive our information regarding these units are two, viz., the *census* or count, which every civilized country makes periodically, and the returns of births, marriages, deaths, and cases of contagious disease made to local governing sanitary bodies, such as boards of health, etc. These latter returns localize the units and help especially in the classification, in which locality is a factor.

The census returns give not only the population, but particulars as to sex, age, race, occupation, etc. Of these the age-record is most important, as the death-rate varies most according to age.

The *natural increment* of a population is the excess of births over deaths, but the *actual increment* differs from this, however, according to the difference between emigration and immigration. And as the rate of increase does not always remain the same, estimates of population at times other than of the census cannot be exactly accurate. Thus, we may have a lowered death-rate and yet a decrease in both the natural and actual increment, owing to a greatly lowered birth-rate and to increased emigration, both of which may be primarily due to a long period of oppression or financial distress. However, to estimate the population for times other than the census year, we assume that the rate of increase, whether positive or negative, that prevailed between the last two census enumerations, will continue until the next is taken.

Now, as populations increase in regular geometrical progression when the rate of increase is constant, which we assume, it can readily be shown that $\log. R = \frac{1}{10}(\log. P' - \log. P)$, where R is the annual ratio of increase, P the population of the census before the last, and P′ the population of the last census. If we now multiply the log. of R, the annual ratio of increase, by the number of years since the last census, and add to it the log. of the last census (log. P′), we will have the log. of the population at the middle of the present year—*e. g.*,

$$8 \frac{(\text{log. of the pop. 1890} - \text{log. pop. 1880})}{10}$$

$+$ log. pop. 1890 $=$ log. of the population on June 30, 1898.

For the reasons already given, such an estimate will not be absolutely accurate, and it would, consequently, be well to have a census taken every five years for certain data. The more accurate the estimate for any year happens to be, the more reliable will be the statistical results. It is also to be noted that in this country the census is taken at the middle of the year, and that death-rates, etc., are based on the population estimated, as above, for the middle of the given year.

We may also estimate the population from the number of houses and use this as a check on the above estimate. The number of persons living in each house averages about the same for each city, but differs for different cities. Local authorities always tend to overestimate the population, and a police census is invariably too high. Another method of approximately estimating the population in small and slowly increasing districts is to add to the population of the last census one-tenth of the difference between it and the population of the preceding census for every year since the last census.

As has been stated, we get the number of births, marriages, deaths, etc., from the registration records, the proper data being furnished to the registration bureau by duly authorized persons. For instance, the law should require a burial permit for each death in order to identify the person and to guard against criminal acts or neglect, and the death certificate on which the burial permit is issued should give the name, sex, color, age, occupation, and especially the cause of death of the deceased. The diagnosis concerning this last item should be as correct as possible, and the primary as well as the secondary cause of death should be given. And while it is difficult to determine the actual cause of death in many cases without a *post-mortem* examination, there is, fortunately, not much uncertainty usually in diagnosing the diseases of which we most want statistical information, especially the so-called preventable or infectious diseases.

As a consequence of the above, the certificate as to the cause of death will need to be signed by some one competent to determine that cause, viz., by an educated physician; and it is, therefore, necessary that the State should define who is and who is not an "educated physician." And as this information and the other required returns which the physician makes, as well as his professional services in general, are for the sake and benefit of the citizens of the State, it is evidently to the State's interest that it be very careful and explicit as to the qualifications of the physicians whom it allows to practise within its borders.

Another reason for the enforced return of a certificate and the issuance of a burial permit for every death is, that that is about the only way in which it is possible to secure a record of all the deaths. Any system for collecting the list of deaths only at the end of the year will lose from 25 to 40 per cent. of the number.

The gross death-rate varies with the size of the community. Newly settled communities have a lower death-rate than older ones, because the proportion of adults is larger and of children smaller in the former. With large communities and short periods the probabilities of error are very great, and the longer the period the less likelihood of error. Birth-, marriage-, and death-rates are usually calculated as rates per thousand of the population living at the middle of the given year, and are determined by multiplying the number of births, marriages, or deaths by 1000, and dividing the product by the population.

Fair death-rates are 9 to 16 per 1000 in rural districts and small villages; 14 to 18 per 1000 in towns of 5000 to 20,000; 17 to 20 in cities of 25,000 to 100,000, and 18 to 21 in cities over 100,000. If the death-rates are much lower than this, the chances are that the population has been overestimated or that all deaths have not been recorded. If more than this, there is probably some special cause for the high mortality.

In statistical computations we must exclude the populations and deaths in hospitals, prisons, etc., except for such of the inmates as belong to the district in which such institution is located.

To find the weekly or daily death-rate, the number of deaths for the week or day must be divided by the so-called weekly or daily population: the weekly population = $\frac{\text{total population}}{52.17747}$; the daily population = $\frac{\text{total population}}{365.24226}$. The monthly population equals the daily population multiplied by the number of days in the month.

The zymotic death-rate is the rate from the seven principal zymotic or infectious diseases, viz., smallpox, measles, scarlatina, diphtheria, whooping-cough, fever (typhoid, typhus, or other continued fever), and diarrhœa.[1] It is given per 1000 of population, and in the same way we can give the special rate for any particular disease. For example, the zymotic death-rate for England and Wales from 1861 till 1870 was 4.11, for 1871–80 it was 3.36, and for 1881–90, 2.30; a striking proof of the decided benefits following proper attention to hygiene and sanitation.

The mortality from certain diseases is affected by age, sex, race, occupation, density of population, seasons, cyclical changes, etc.

Contrary to the general rule, the *rate of infant mortality* is not expressed per thousand of population, but measured by the proportion of deaths of infants under one year to the births registered in that year, and is determined by multiplying the number of deaths by 1000 and dividing the product by the number of births.

The infant mortality-rate is always high, owing to various causes; viz., early marriages and weakly parents, hereditary tendencies or diatheses, insanitary surroundings and unfavorable social conditions, improper feeding, insufficient clothing, infant life insurance, etc.

[1] Wilson: Hand-Book of Hygiene, p. 566.

Death-rates vary greatly for the different ages, being much higher for the first five years of life. For this reason, it is well to express the death-rate of children under five as the rate per thousand of the children under that age, rather than as a percentage of the total number of deaths. Otherwise, a town with a large number of children might apparently have an abnormally high death-rate. There might also be a difference in the death-rates of two localities due to sex-distribution, for the sexes differ in their susceptibility and resistance to the various diseases. More boys are born everywhere than girls, but more males die than females, so that the tendency is to a preponderance of the latter, except in newly settled countries or localities. Age- and sex-distribution favor a low mortality in rapidly increasing towns, new localities, and manufacturing districts; in rural districts they tend to increase the death-rate.

Consequently, when the death-rates of two or more towns or localities are to be compared, there must be corrections for age- and sex-distribution. The mean annual death-rate of the country for the decade preceding the last census for each age and sex is applied to the town or district, with age- and sex-distribution according to the last census. The total number of deaths thus calculated, multiplied by 1000, and divided by the population of the last census, gives the *standard death-rate* of that town. The mean annual death-rate of the country divided by the standard death-rate gives the *factor for correction*, which being multiplied by the recorded death-rate of any year gives the *corrected* death-rate. The *comparative mortality figure* is determined by multiplying the corrected local death-rate by 1000 and dividing by the death-rate for the whole country, and only indicates that the same population which gave 1000 deaths in the whole country gave or would have given so many deaths in the town or district in question.

The morbidity- or sick-rate of a community is difficult to estimate, since there is usually no complete record and registration of cases of disease. Where returns are required to be made of the infectious diseases, the morbidity due to them may be determined in the same way as the mortality for the locality. It is estimated that there is a total of about two years' sickness in a community for every death, and members of beneficial societies are said to average about one and one-half weeks' sickness annually. In this connection, the following definitions are given of terms that are employed in discussions of vital statics, especially in relation to longevity:

The *mean age at death* of a population is the average age at which death occurs in that population, and is indicated by the total of the ages at death divided by the number of deaths. Inasmuch as it depends largely on the age-distribution of the population, it is neither a good test of longevity nor of sanitary conditions, except when it is calculated or taken from life-tables for an entire generation.

The *probable duration of life* is the age at which any number of children born will be reduced one-half, the chances thus being even that each will survive to that age.

For a million children the probable duration of life is for males less than forty-five years; for females, forty-seven years.

The *mean duration of life* is the same as the mean age at death when the population is stationary as to age- and sex-distribution. Otherwise, it is indicated by the mean after-lifetime.

The *expectation of life* is the *mean after-lifetime* of a person at any age, as indicated by a life-table, or, in other words, it is the average number of years which persons of that age continue to live. At birth it is identical with the mean duration of life, and "as applied to communities, it is the mean lifetime of a generation of persons traced by the life-table method from birth to death, and is the only true test of the health of populations." According to Dr. Farr, "a life-table is a barometer which indicates the exact measure of the duration of life under given circumstances, and is indispensable in gauging the influence of sanitary or insanitary conditions."

The essential factors of a life-table are the number and ages of the living and the number and ages of those that die, and these factors are obtained from the mean population for each age and sex and from the total death returns between two censuses.

CHAPTER XIII.

THE EXAMINATION OF AIR, WATER, AND FOOD.

In this final chapter the author has endeavored to arrange a series of methods for the examination or analysis of the subjects respectively considered, in such a manner that any one who has had a little laboratory experience may be enabled to determine their hygienic condition, sanitary influence or degree of purity, and this at the cost of a minimum of time and expense.

The methods outlined have been selected from a variety of sources, and some have been specially modified for the purpose; so that while it is not claimed that they will give the absolutely accurate results desired by the professional bacteriologist or chemist, it is believed that, if carefully carried out, they will not fail to yield the information sought for, viz., whether the sample of air, water, or food examined is sanitarily pure or safe for use within the accepted limits.

Only such apparatus is to be used as can be readily obtained or improvised without much expense, and every effort has been made to render everything clear to the student and reader, so that he may not hesitate to undertake the necessary investigation whenever occasion requires or an opportunity offers.

For further details regarding any of the methods, should these be found necessary, reference may be made to the text-books indicated, as they will render clear any points that may here seem uncertain or abstruse.

Air.

The solid impurities in the atmosphere may be collected for microscopical examination as follows: Tightly cork a large glass funnel and fill it with cracked ice. As the aqueous vapor of the air condenses on the exterior, the dust particles adhere to the moistened glass, and are carried down by the condensed water into a vessel placed below, in which they are allowed to settle. From this they are transferred by means of a pipette to clean slides and examined under the microscope. Dr. Dixon's apparatus may often be used advantageously, especially where it is desired to examine the dust in the air of a number of localities within a short time.

To make a qualitative bacteriological examination the air may be drawn through sterilized glass tubes coated interiorly with gelatin. Bacteria and their spores, moulds, etc., adhere to this coating, and from each individual or group of individuals colonies develop, from which pure cultures and subsequent bacteriological experiments may be made; or the sterilized gelatine may be exposed in flat (Petri) dishes to the air for a short time to allow the bacteria, etc., to fall on the surface. The tubes or dishes are then covered and set aside to allow the colonies to develop.

To make a quantitative bacteriological examination a known quantity of air may be drawn through a tube filled with sterilized granulated sugar. The sugar is then transferred to tubes or flasks of melted and sterilized gelatine, and dissolves and leaves the bacteria, etc., free to develop in the gelatine, which may be poured out before cooling upon sterilized glass plates or flat Petri dishes. A temperature just sufficient to melt the gelatine will not be too high to harm the bacteria.

The number of colonies that develop may be assumed to represent the number of living micro-organisms in the volume of air drawn through the tube or that fell in the dishes.

Test for Carbonic-acid Gas, CO_2. *Prof. Boom's Modification of Wolpert's Method.* Make a mark on any test-tube, say one inch from the bottom. Fix the bulb of an atomizer to a small glass capillary tube, sufficiently long to reach to the bottom of the test-tube, and in such a manner that a definite quantity of air is forced from the bulb through the tube at each compression. To use: Fill the test-tube exactly to the mark with a saturated solution of lime-water, take the apparatus into the out-door air and find out how many compressions of the bulb are needed, driving the air slowly through the lime-water each time, to make the lime-water just turbid enough to obscure a pencil-mark on white paper placed beneath the test-tube and viewed from above.

Then rinse out the test-tube, fill exactly to the mark again with lime-water, and repeat the process in the room the air of which is to be examined. We then assume that the out-door air contains the normal amount of CO_2, 0.04 per cent. (unless we happen to know the actual amount in the atmosphere at the time), and estimate the percentage of CO_2 in the air of the room by the following proportion:

The number of compressions of the bulb required in the outer air : the number of compressions required in the room : : x : 0.04; x = the percentage of CO_2 in the air of the room. If the actual percentage of CO_2 in the outer air is known, substitute this for the 0.04 per cent. in the formula. Care must be taken in using this device not to draw any of the lime-water up into the bulb.

A Modification of Angus Smith's Method. To a moderately large, wide-mouth bottle (one quart) fit a perforated rubber stopper, the perforation being just large enough to admit the tip of a 1 c.c. pipette, fill the bottle with the air of the room by filling it with water and then emptying it in the room; fit in the stopper and introduce 1 c.c. at a time of a standardized alkaline solution, slightly colored with a few drops of a neutral alcoholic solution of phenol phthaleine; close the perforation with a piece of glass rod and shake the bottle well after each addition of the alkali, noting when the color ceases to be discharged by the CO_2 of the contained air. Then, since the quantity used of the alkali solution indicates a certain definite amount of CO_2:

The number of c.c. used multiplied by the amount of CO_2 *each c.c. represents, multiplied by* 100, *and divided by the capacity of the bottle in c.c. less the number of c.c. of solution used* = x = the percentage of CO_2 in the air examined.

A suitable alkaline solution may be prepared as follows: Dissolve exactly 4.766 grammes of pure sodium carbonate (free from the water of crystallization) in one litre of distilled water. Each c.c. of this solution is equivalent to 1 c.c. CO_2. For use: to 10 c.c. of this solution add a few drops of neutral alcoholic solution of phenol phthaleine and dilute to 100 c.c. Each c.c. of this dilute solution is equivalent then to 0.1 c.c. of CO_2, and used as above will give close results. The phenol phthaleine is used as an indicator, as it loses its color as soon as all the CO_2 is absorbed and the alkalinity of the soda solution is destroyed. The stock solution should be kept in well-filled, tightly stoppered bottles. Example: If 9 c.c. of the above dilute solution be used, and the capacity of the bottle is 1200 c.c., then

$$\frac{9 \times 0.1 \times 100}{1200 - 9} = \frac{90}{1191} = x = 0.0755,$$

the percentage of CO_2 in the air of the room.

Pettenkofer's Method. Into a large, clean bottle filled as above with air of the room, 50 c.c. of a clear saturated solution of lime-water (or barium hydrate) is introduced, the bottle stoppered and then well shaken so that the air may be thoroughly mixed with lime-water. The strength of the lime-water, being unknown, is determined by means of a solution of oxalic acid of such a strength that 1 c.c. corresponds in alkalinity to 0.5 c.c. of CO_2. (Such a solution is made by dissolving exactly 2.84 grammes of pure crystallized oxalic acid in one litre of distilled water.)

Into 25 c.c. of lime-water in a beaker, this acid solution is run from a graduated burette until the alkalinity of the lime-water is just destroyed, the neutral point being indicated either by means of a few drops of phenol phthaleine solution in the beaker, or by turmeric paper, the latter being colored brown, and the phenol phthaleine retaining its color as long as the solution is alkaline. When the lime-water is exactly neutralized the exact amount of the acid solution used is noted. Then, after the time necessary to allow the complete absorption of the CO_2 in the testing bottle by the lime-water therein, viz., eight to ten hours, 25 c.c. of that lime-water is measured into a beaker and the alkalinity determined exactly as above by means of the oxalic-acid solution.

Now, inasmuch as part of the alkalinity of the lime-water in the bottle has already been neutralized by the carbonic acid in the air of the bottle, and as 1 c.c. of the acid solution corresponds to 0.5 c.c. of CO_2, it will require less of the acid solution to neutralize the lime-water from the bottle than was required for the same quantity of stock lime-water, and this difference expressed in c.c. will express the number of c.c. of CO_2 in the air of the bottle or of the room from which it was taken.

For, though each c.c. of acid solution is equivalent to only 0.5 c.c. of CO_2, the loss of alkalinity of only one-half the lime-water introduced into the bottle has been determined and the total loss of alkalinity would have to be expressed by a difference of twice as many c.c. of acid solution used multiplied by 0.5 c.c. CO_2. The quantity of carbonic acid in the bottle having been thus determined and the capacity of the bottle found by measuring the quantity of water it will hold, the percentage of carbonic acid in the air is readily determined.

Example: 25 c.c. of stock lime-water requires 30 c.c. acid solution; 25 c.c. of lime-water from bottle requires 27 c.c. acid solution.

Therefore, 30 c.c. — 27 c.c. = amount of carbonic acid in the bottle, which contains (for example, say) 2550 c.c.

Then $\frac{3 \times 100}{2550 - 50} = \frac{300}{2500} = 0.12$ per cent. CO_2 in the air of room at current temperature and pressure.

Water.

To test for color, turbidity, etc., compare with distilled water, using tall glass jars, and looking down through equal depths upon a white surface. The smell of a water may be detected by heating it to about 140° F. for a few minutes in a glass-stoppered bottle. This test may or may not indicate fecal contamination. Few polluting impurities, when only in moderate quantities, give any taste to water, and a dangerously polluted water may have a good taste. Iron in small quantities, one-fourth of a grain to a gallon, will give a taste to the water.

Use caution in tasting suspicious waters. Aeration is indicated by the lustre of the water and by the presence of air bubbles on the sides and bottom of the vessel.

FIG. 62.

Bottle for collecting water at different levels.

Test for Chlorine. *Solutions required.* (1) Standard nitrate of silver solution: to 1 litre of pure distilled water add 4.788 grammes of pure silver nitrate; one c.c. of this solution is equivalent to 1 m.g. of chlorine. (2) Potassium chromate solution—a 5 or 10 per cent. solution of potassium chromate made up in distilled water free from chlorine.

Process. To 100 c.c. of the water add a few drops of the potassium chromate solution, and then run in from a burette or graduated pipette the silver solution, adding it drop by drop and stirring the water with a glass rod. Continue until a faint but permanent orange-red tint has been produced, showing that all the chlorine has combined with the silver, the persisting reddish color being due to silver chromate. The number of c.c. of silver used indicate the number of m.g. of Cl in 100 c.c., or parts per 100,000; this multiplied by 10 gives the number of m.g. of Cl in one litre, or parts per million. If the water contained but little chlorine, accuracy will be furthered by evaporating 250 of the water to 50 c.c. over a water-bath, and proceeding as above; the result multiplied by 4 will give the amount of chlorine in one litre.

Test for Nitrates. *Solutions required.* 1. Phenol-sulphonic acid: 6 grammes of pure carbolic acid; 37 c.c. strong sulphuric acid, and 3 c.c. distilled water. 2. Standard potassium nitrate solution: Add 0.722 grammes of fused potassium nitrate to one litre of distilled water. Each c.c. of this solution contains 0.1 m.g. of nitrogen as nitrates. The water used in making the solution must be free from nitrates.

Process. Evaporate 10 c.c. of the water to be examined (or 25 c.c. if it is presumably low in nitrates) just to dryness, add 1 c.c. of phenol-sulphonic acid, stir with a glass rod, and add 1 c.c. of distilled water and three drops of H_2SO_4, warm, and add 25 c.c. distilled water and NH_4HO to excess and dilute with water to 50 c.c.

Treat 1 c.c. of the standard solution in an exactly similar manner and compare the tints produced, diluting the darker until the tints match exactly, and calculating the amount of nitrogen present by the amount of dilution necessary—*e. g.*, the tint from 1 c.c. of standard potassium nitrate solution is darker and needs the addition of 50 c.c. more water—*i. e.*, up to 100 c.c. Therefore, 100 c.c. : 50 c.c. : : 0.1 m.g. N : x = 0.05 m.g. nitrogen as nitrates in the 10 c.c. of water examined. The test depends on the fact that the phenol-sulphonic acid is converted by the nitrates into picric acid, which goes to form ammonium picrate upon the addition of ammonia giving a yellow tint to the water. The amount of picric acid and picrate formed depends on the amount of nitrates present.

Test for Nitrites. *Solutions required.* 1. Sulphanilic acid: dissolve 0.5 gramme of sulphanilic acid in 150 c.c. of dilute acetic acid, sp. gr. 104. 2. Naphthylamine acetate: boil 0.1 gramme of solid naphthylamine in 20 c.c. of distilled water, filter through a plug of washed absorbent cotton, and mix the filtrate with 180 c.c. of dilute acetic acid. 3. Standard sodium nitrite solution: dissolve 0.275 gramme of pure silver nitrite in pure water and add a dilute solution of pure sodium chloride until a precipitate ceases to form, and dilute to 250 c.c. with pure water. For use, dilute 10 c.c. of this solution to 100 c.c. Each c.c. of the dilute solution contains 0.01 m.g. nitrogen as nitrites. Keep the solution in the dark when not in use. All water in these solutions must be free from nitrites; likewise all water used in tests, except the sample under examination.

Process. To 25 c.c. of water to be examined, placed in a cylindrical vessel, add 2 c.c. each of sulphanilic acid and naphthylamine acetate solution, using a separate pipette for each; in a similar cylindrical vessel dilute 1 c.c. of the standard sodium nitrite solution to 25 c.c. with nitrogen-free distilled water, and add the same quantity of the above reagents to it; compare the colors at the end of five minutes and estimate the amount of nitrites by diluting the darker tint until it matches the lighter; the result will give the quantity of nitrogen as nitrites in the water, and should not be over a trace. The above test is a very delicate one.

Test for Hardness. *Solutions required.* 1. Soap solution: dissolve 10 grammes of castile soap in one litre of weak (35 per cent.) alcohol. 2. Standard lime solution: dissolve 1.11 grammes of calcium chloride in 1 litre of distilled water; 1 c.c. of this solution is equivalent to 1 m.g. of calcium carbonate.

Process. Find out how much soap solution is needed to make a lather with 100 c.c. of distilled water, as follows: Place the water in a flask holding about 250 c.c., and run in the soap solution from a burette, a few drops at a time, corking and shaking the flask well after each addition; the lather should have a depth of at least one-fourth of an inch and be permanent for five minutes. Then standardize the soap solution by diluting 5 c.c. of the standard lime solution to 100 c.c. with distilled water, and find out how many c.c. of the soap solution are necessary to make a permanent lather as above with it; this quantity, less the number of c.c. needed to make a lather with 100 c.c. of distilled water, represents the amount of soap solution that will neutralize 5 m.g. $CaCO_3$ or its equivalent; lastly, determine in the same way the number of c.c. of soap solution necessary to make a permanent lather with 100 c.c. of the water to be examined; subtract the quantity necessary for 100 c.c. distilled water and estimate the amount of $CaCO_3$ or its equivalent present, as follows—*e. g.*, it takes 2 c.c. of soap solution to make a lather with the distilled water, and 12 c.c. with the diluted lime solution; then 12 c.c. — 2 c.c. = 10 c.c. = 5 m.g. $CaCO_3$, and each c.c. of the soap solution = 0.5 c.c. of the standard lime solution, or 0.5 m.g. $CaCO_3$; consequently, if 100 c.c. of the water examined require 17 c.c. of soap solution, it must contain $(17-2) \times 0.5 = 7.5$ m.g., and 1 litre of water contains 75 m.g. of calcium carbonate or its equivalent.

Tests for Lead, Copper, and Iron. To 50 or 100 c.c. of water in a white porcelain dish, or in a tall glass jar over a white paper, add a few drops of ammonium sulphide; a dark coloration or precipitate indicates the presence of either lead, copper, or iron, due to the formation of their respective sulphides. Then add a few drops of HCl; if the color disappears Fe only is present; if it persists Pb or Cu is present. In the latter case add a few drops of acetic acid and about 1 c.c. of a strong solution of potassium cyanide; if the color disappears it is due to Cu; if it persists it is due to Pb. If Pb only is present the above test will detect one-tenth of a grain per gallon. The above tests may be corroborated as follows: Partly fill two test-tubes with the original water; to one add a little potassium chromate solution; an opacity and the deepening of the color to canary yellow indicate lead. To the second add a drop of HCl and a few drops of potassium ferrocyanide solution; a blue color indicates iron, either ferrous or ferric; a bronze or mahogany-red color indicates copper.

Quantitative tests for the above metals may be made by making standard solutions of the respective elements, treating a measured quantity of the original water with the proper reagent as indicated above, and comparing the color produced with that given by a definite quantity of the respective standard solution.

Test for Phosphates. *Solution required.* Ammonium molybdate: dissolve 10 grammes of molybdic anhydride in 41.7 c.c. of NH_4HO (sp. gr. 0.96) and pour slowly into 125 c.c. of HNO_3 (sp. gr. 1.20); allow to stand in a warm place for several days until clear.

Process. Slightly acidulate 500 c.c. of water with HNO_3, evaporate to 50 c.c., and add a few drops of Fe_2Cl_6 and NH_4HO to slight excess; filter, dissolve the precipitate in the smallest possible quantity of HNO_3 and evaporate to 5 c.c.; heat nearly to boiling, add 20 c.c. of ammonium molybdate solution; keep the solution warm for one-half hour. If there is an appreciable quantity of precipitate, collect it on a small weighed filter-paper, wash with distilled water, dry at 100° F., and weigh. The weight of the precipitate multiplied by 0.05 gives the amount of PO_4 in the 500 c.c. of water.

Test for Free and Albuminoid Ammonia. *Wanklyn's Method.* Solutions required: 1. Standard ammonium chloride solution: dissolve 0.382 gramme of pure dry NaCl in 100 c.c. ammonia-free water; each c.c. of the dilute solution contains 0.01 m.g. of nitrogen as ammonia. 2. Alkaline potassium permanganate solution: dissolve 200 grammes of KHO (in sticks) and 8 grammes of potassium permanganate in 1 litre of distilled water, evaporate to about 750 c.c. to drive off the ammonia present and make up to 1 litre again with ammonia-free water. To make ammonia-free water, add about 1 grain sodium carbonate to the litre of distilled water and boil until about one-fourth is evaporated. 3. Nessler's reagent: dissolve 15 grammes KI in 100 c.c. of distilled water and 17 grammes $HgCl_2$ in 300 c.c. of water; add the $HgCl_2$ solution to the KI until a permanent precipitate is formed, then dilute with a 20 per cent. solution of

NaHO to 1000 c.c., add $HgCl_2$ solution till a permanent precipitate again forms, and allow to stand until clear; this reagent gives a brown or yellowish-brown coloration if NH_3 be present in water, and improves on keeping.

Process. Place 500 c.c. of the water to be examined in a retort, connect with a condenser, and boil gently so that the water may distil over slowly. The retort and condenser should have been thoroughly rinsed with ammonia-free water. Collect the distillate, 50 c.c. at a time, in Nessler tubes, add 2 c.c. of Nessler's reagent to each 50 c.c., and determine the amount of ammonia or nitrogen in each as follows: Place in another Nessler tube 50 c.c. ammonia-free water and 2 c.c. Nessler's reagent, run in from a burette the standard ammonium chloride solution until the color exactly matches that of the first 50 c.c. of the distillate. Repeat the process with each 50 c.c. of distillate until the test shows no more ammonia is coming over from the retort. The total amount of ammonium chloride solution used indicates the total amount of nitrogen of the free ammonia. Usually all the free ammonia will come over in the first 150 or 200 c.c. of distillate. Compare the colors by looking down through the tube on a white surface. If the first 50 c.c. gives a precipitate with the Nessler reagent it must be diluted and the amount of nitrogen estimated from the diluted distillate. The free ammonia being determined, allow the retort to cool and add to the water remaining in it 50 c.c. of the alkaline permanganate solution. This converts a certain proportion of the nitrogenous organic matter into ammonia; distil as before, estimating the amount of nitrogen in each 50 c.c. of the distillate until no more ammonia comes over. The amount of ammonium chloride solution thus used will indicate the nitrogen of albuminoid ammonia, and the total amount of ammonium chloride solution used in the whole process gives the nitrogen of the free and albuminoid ammonia in one litre of water.

Food.

Milk. *Good Milk.* Characteristics: Ivory white, opaque, neutral or slightly alkaline reaction, no sediment, no unusual or offensive taste or odor, sp. gr. 1029 or above; cream, 10 to 40 per cent. by volume; fats 3 per cent. or more; total solids, 12.5 per cent. or more.

Water is indicated by low specific gravity and by low percentage of cream.

Skimming is indicated by a slightly raised specific gravity (2°), by a low percentage of cream, and by a poor color, though the deterioration in color may be disguised by the addition of annatto, etc.

Watering and skimming are indicated by lowered specific gravity, by low percentage of cream, and by poor color.

The specific gravity is determined by the lactometer, in using which correction must be made for temperature, provided the latter varies much from 60° F., the standard.

The percentage of cream is determined by the cream gauge or creamometer; the milk should be allowed to stand in the creamometer for at least eight to ten hours, and should be covered.

A very high percentage of cream tends to lower the specific gravity theoretically; but when a milk is rich in fat it is also rich in solids not fat.

An acid reaction, unless very slight, indicates souring of the milk or the addition of some preserving acid. A strongly alkaline reaction indicates the addition of some substance like chalk, sodium carbonate, etc., to increase the specific gravity. Such addition is verified by an excess of total solids, and by the effervescence of the latter—after drying—upon the addition of a drop or two of HCl.

To determine the percentage of total solids: Weigh a small evaporating dish, preferably platinum, add 5 or 10 c.c. of milk, and weigh dish and milk to get weight of milk; evaporate to dryness over water-bath, completing the drying in a water-oven until there is no further loss of weight; weigh dish and contents (total solids); subtract weight of dish, multiply by 100, and divide by weight of milk. Result: the percentage of total solids.

To determine the percentage of ash: Ignite the total solids over the naked flame until all black specks have disappeared; cool and weigh; multiply weight of ash by 100, and divide by weight of milk. Result: percentage of ash.

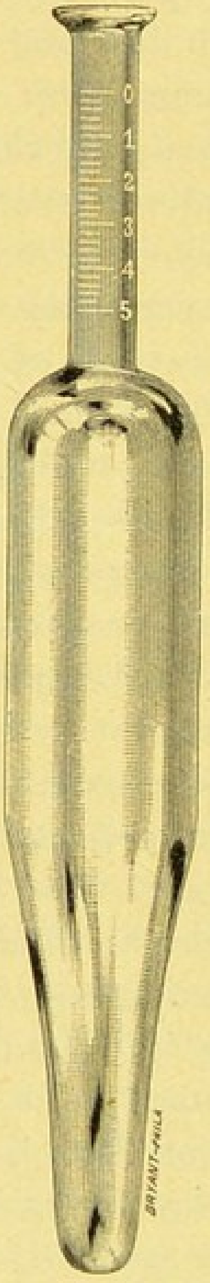
To determine the percentage of fats: Proceed as above with 10 c.c. of milk, and evaporate until the residue is a tenacious pulp, extinguish the flame, fill the dish half full of ether, stir, and pound the residue thoroughly with a glass rod, filter through a small filter-paper, reserving the filtrate; add more ether to the residue, stir as before, and filter, repeating the process three times or till the residue is perfectly white; wash the filter-paper well with ether and evaporate all the ether to dryness; weigh the residue —the fat—multiply by 100 and divide by the weight of milk. Result: percentage of fat.

Where a medical centrifuge is available for use, the following method for the fat-determination will be found to give results that are probably accurate to within one-fifth of 1 per cent. of fat:

Two solutions are necessary: 1. Fusel oil, 37 c.c.; wood or methyl alcohol, 13 c.c.; hydrochloric acid, 50 c.c. 2. Sulphuric acid, sp. gr. 1.83.

Into the milk bottle, which is made to fit the centrifuge and which has a long graduated neck, 5 c.c. of the milk to be examined is introduced by means of a pipette, and

FIG. 63.



Bottle for determining percentage of fat by means of the centrifuge.

to this 1 c.c. of the alcohol solution (1) is added and the mixture well shaken by hand. The sulphuric acid is then added, little by little, with frequent shaking, until the bottle is filled to the topmost (zero) graduation. It is then rapidly whirled in the centrifuge until only the fat occupies the neck as a clear layer, when the actual percentage can be read from the graduations. When the milk is very rich—*i. e.*, containing more than 5 per cent. of fat—it will be necessary to dilute the milk with an equal volume of water, and then to multiply the result by 2. Likewise, cream should be diluted with four parts of water and the result multiplied by 5. The same principle is employed in the Babcock and other cream testers now largely used by dairymen, etc.

Test for annatto: A percentage of cream considerably lower than the color of the milk would indicate justifies the suspicion that some coloring matter has been used. This is frequently annatto.

Coagulate one ounce of milk with a few drops of acetic acid and heat, strain, and press out excess of liquid from curd; triturate the curd in a mortar or dish with ether, decant ether and add to it 10 c.c. of a 1 per cent. solution of caustic soda; shake, and allow to separate; pour off the upper layer into a porcelain dish, put in two small disks or strips of filter-paper; evaporate gently. Annatto will dye the disks an orange or buff color. Moisten one disk with dilute sodium carbonate to fix the color; touch the other disk with a drop of stannous chloride. Annatto will give a rich pink color. This test is sensitive to one part of annatto in 1000 of milk, and with milk in any condition.

Test for boric acid: In igniting total solids boric acid or boron gives greenish tinge to flame. Place in a porcelain dish 5 c.c. of milk, one drop of strong HCl and two of a saturated tincture of turmeric. Dry on a water-bath, remove as soon as dry; cool, and add one drop of ammonia on a glass rod. A slaty-blue color, changing to green, is given if borax is present. This test will show one one-thousandth grain of borax. Less will give the green color, but not the blue.

Butter and Oleomargarine. Good butter should have good taste, odor, and color; it should not be rancid, and should not contain too much water nor salt, nor should it have any added coloring matter. The average composition should be about as follows: Fat, 82 per cent.; casein, 2 per cent. (not over 3 per cent.); ash or salts, 2 per cent.; water 13 per cent. Butter fat is a compound of glycerin with certain fatty acids, some of them volatile and soluble in hot water, others non-volatile and insoluble in hot water.

Oleomargarine consists of ordinary animal or vegetable fats, melted, strained, cooled with ice, worked up with milk, colored, and salted. These fats are usually beef or mutton fat, lard, or cotton-seed, palm, or cocoanut oil.

If care and cleanliness are observed in the manufacture, oleomargarine is not harmful nor innutritious, but it should not be sold as butter.

Fraud is to be detected by observing the difference in composition and properties of the *fats*. For instance:

BUTTER FAT.	BEEF FAT, ETC.
1. The specific gravity is very rarely below 910, never below 909.8.	Beef fat, etc., is never above 904.5.
2. The soluble, volatile fatty acids average between 6 and 7 per cent., never below 4.5 per cent.	Rarely more than ½ per cent., never above ¾ per cent.
3. The insoluble fatty acids form about 88 per cent. of the total weight of butter fat.	Generally about 95 per cent.
4. The melting point of the fat varies from 86° to 94° F.; is usually from 88° to 90° F.	Rarely, if ever, above 82° F.
5. Is readily and completely soluble in ether.	Less so and leaves a residue.
6. Under the microscope pure butter fat consists of a collection of small oil globules, with an occasional large one.	The contours of the small oil globules are less distinct, and the larger ones are more numerous and irregular in size.
No crystals, except when the fat has been melted.	Crystals of the non-volatile acids are often seen.

To determine the specific gravity: Melt a quantity of the butter in a beaker in a water-bath at about 150° F. After a time, when the fat is perfectly clear and transparent, carefully decant the fat from the lower stratum of water, curd, and salt into a fine filter; collect the filtrate and pour into a specific-gravity bottle, which has been previously weighed, both when empty and when filled with distilled water at 100° F. See that the bottle is exactly full of the fat, wipe clean, and weigh when the temperature is as near 100° F. as possible, because solidification soon begins below this temperature. Subtract the weight of the bottle, divide by the weight of the water which the bottle contains, and multiply by 1000; the result is the specific gravity.

To find the melting point: Pour a little melted fat into a small test-tube (2″ x ¼″) and cool. Partly fill two beakers of unequal size with cold water; place the test-tube in the smaller (taking care to allow no water to mix with the fat), and the smaller in the larger, and gently heat the outer beaker. Suspend a thermometer in the smaller, near the test-tube, and note the temperature when the fat *begins* to melt; this is the melting point.

To determine the percentage of insoluble (non-volatile) fatty acids: To 6 grammes of butter fat add 50 c.c. of alcohol containing 2 grammes of caustic potash (KHO) and boil gently for fifteen or twenty minutes to saponify the fat. Dissolve the soaps thus formed in 150 to 200 c.c. of water, and decompose with about 25 c.c. of dilute hydrochloric acid. The separated fatty acids are poured upon a weighed filter-paper, washed with two litres of boiling water, dried at 95° to 98° C. and then weighed. The weight of these insoluble fatty acids should not be over 90 per cent. of the weight of the butter-fat.

Flour and Bread. *Wheat Flour.* Characteristics: Almost perfectly white, smooth, and free from grit; no mouldy or unpleasant odor; cohesive when lightly compressed; no signs of parasites under the microscope; water less than 18 per cent.; ash less than 2 per cent. or more.

To determine the percentage of water and ash: In a weighed platinum (or porcelain) dish place about 50 grammes of flour, weigh, and dry over a water-bath for an hour or so; then complete the evaporation in a water-oven until there is no further loss of weight; weigh, subtract this weight, less the weight of the dish, from the original weight of the flour. Multiply the remainder by 100 and divide by the original weight of the flour. The result is the percentage of water. Then ignite the dried flour in the dish and incinerate till there are no longer any black particles and only the ash remains; cool, weigh, subtract weight of dish, multiply the remainder by 100, and divide by the original weight of the flour. The result is the percentage of ash.

To determine the percentage of gluten: By means of a glass rod, mix a weighed quantity of flour with a *little* distilled water into a stiff dough; then repeatedly wash away the starch and soluble constituents, kneading the dough with the rod or fingers, and continuing until the wash-water comes away clear; the gluten and a small amount of fat and salt remain. Spread out on a weighed dish or crucible lid, dry in a water-oven, and weigh; multiply by 100 and divide by the original weight of the flour. The result is the approximate percentage of gluten. The gluten should pull out into long threads; otherwise, it is poor.

An excess of water impairs the keeping quality and lessens the amount of nutriment in the flour. An excess of ash indicates the addition of mineral substances. A deficiency of gluten indicates that the flour is not pure wheat flour. Parasites and fungi especially affect or live in old or damp or inferior flour.

To test for mineral substances: Shake a little flour in a test-tube with some chloroform, and allow it to stand for a few moments. The flour floats and any mineral matter sinks to the bottom, when it can be removed with a pipette and examined under a microscope.

Wheat Bread. Characteristics: Fairly dry, light, and spongy; clean and nearly white; of pleasant taste; not sodden, acid, or musty; ash, not over 3 per cent.; no parasites or mouldiness; no flour other than wheat; but little, if any, alum; no copper sulphate.

Test for alum: Add 5 c.c. of a 5 per cent. tincture of logwood and 5 c.c. of a 15 per cent. solution of ammonium carbonate to 25 c.c. of water; soak a crumb of the bread in this for a few minutes; drain and gently dry. Alum is indicated by a violet or lavender color; its absence by a dirty-brown color on drying.

Test for copper sulphate: Draw a glass rod dipped in a solution of potassium ferrocyanide across a cut slice of the bread; copper is indicated by a streak of brownish-red color.

Test for ergot in flour or bread: Add liquor potassæ; a distinct herring-like odor (due to propylamine) is appreciable if ergot be present.

An excess of water, an unnatural whiteness, and a low percentage of ash in bread indicate the addition of rice. Potatoes give an increased percentage of water and an alkaline ash.[1]

[1] For further details see Fox's "Examination of Food, Air, and Water," and Kenwood's "Hygienic Laboratory."

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