DISINFECTION AND DISINFECTANTS:

AN INTRODUCTION TO THE STUDY OF.

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TOGETHER WITH AN ACCOUNT OF THE CHEMICAL SUBSTANCES USED AS ANTISEPTICS AND PRESERVATIVES.

BY

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PREFACE.

No recent attempt has been made to summarise and review the very voluminous literature on the subject of Disinfection which is scattered through our own and foreign Scientific and Medical publications, and, notwithstanding the rapid development of Sanitary Science in this country, there does not exist at the present time, in the English language, any book which deals exclusively with the composition of Disinfectants.

The present volume may, therefore, supply a want which has been felt, not only by the chemist and bacteriologist, but also by all those who, like medical officers of health and borough surveyors, are concerned with the practical work of Disinfection.

Owing to the attention which has been given to bacteriological science during the last ten years, the methods of Disinfection are now being reviewed under the more exact conditions which this knowledge has rendered possible. The time is not far distant when the importance of the thorough disinfection of all suspected areas will be fully realised by local authorities, and when all such work will be entrusted to specially qualified men, instead of being regarded as a subsidiary duty of the inspector of nuisances. The Sanitary Institute of Great Britain has for some years insisted that the duties of a Sanitary Inspector are such as to necessitate a considerable amount of practical experience and scientific knowledge. If, as at present, the proper carrying out of the work of Disinfection forms part of their duties, the responsibility of such men is considerably augmented.

It has become customary in many districts for the public analyst to advise the sanitary committee on the chemical composition of new disinfectants, and, although this practice should without doubt be generally adopted, it must not be forgotten that a continuous control over the strength and bactericidal activity must be maintained after any particular disinfectant has been finally selected.

The laudable attempts of the medical officers of health in some districts to stamp out sporadic outbreaks of infectious disease so soon as they are notified to them, are to a considerable extent nullified by the slackness which obtains in neighbouring areas, where a lavish display of untested disinfectant powders in the street gullies, or the use of a strongly smelling or high-coloured fluid of unknown composition, is relied upon to satisfy the public demand for hygienic conditions of life.

The following pages may help in discriminating between useful disinfection and the futile attempts which give a false sense of security to many localities in the time of danger.

I am indebted to Mr. H. B. Ransom, A.M.Inst.C.E., for the principal portion of the chapter on Disinfection by Heat, and his practical acquaintance with the engineering details of different forms of disinfecting plant has enabled me to give this section much greater value than it otherwise would have possessed. For several suggestions and the account of methods for the bacteriological examination of disinfectants, I have to thank my former colleague, Dr. C. Slater, of St. George's Hospital; and my thanks are also due to Dr. Louis Parkes, the Medical Officer of Health for Chelsea, for advice and for his kindness in reading the proof sheets.

SAMUEL RIDEAL.

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DISINFECTION AND DISINFECTANTS.

CHAPTER I.

INTRODUCTORY.

Definition of Terms—Primitive Methods of Disinfecting—Bacteriology—The Methods of dealing with Bacteria by Exclusion, Removal, and Destruction.

Definition of Terms.—The words "disinfectant" and "disinfection" have in recent years been used in such a variety of ways, and with such wide application, that much confusion has arisen as to the exact meaning of these terms.

Before the germ theory was universally accepted, the term "disinfection" was used to include the destruction of infectious matter and the removal of any noxious odours to which such matter gives rise. It was applied to the action of any substance which served as a mask for noxious odours, and many substances which have a powerful odour have probably become popular, as disinfectants, solely from this cause. After the germ theory had offered a plausible explanation of the origin of disease, it became possible to define a disinfectant as a germicide. Disinfection then ceased to mean simply "purification," but acquired the special meaning of "sterilisation." A true disinfectant, therefore, must not only mask the smell, but must destroy or kill the germs which give rise to it. Many poisons have the property of killing germs as well as acting upon the higher forms of life, and could, therefore, be used as universal destroyers of life; but, in many cases when disinfection is resorted to, it is desirable to use some agent which will discriminate between useful life and infectious matter. Such an ideal *disinfectant* should, therefore, be a substance that will kill those germs which act injuriously on the higher forms of life, without having any marked action upon such higher forms. A disinfectant must likewise be efficient in destroying the spores of pathogenic organisms, which, as a rule, are more resistant than the germs which form them. From this definition it will be seen that a disinfectant does much more than prevent decomposition, and does more than remove the noxious smells which often emanate from putrefying matter. A disinfectant really goes to the source of the trouble, and, by killing the organism, prevents the spread of epidemic disease. An *antiseptic*, on the other hand, prevents animal or vegetable substances from undergoing decomposition, and a body is said to be *aseptic* when it is in a condition of sterility. A substance which has the property of absorbing the unpleasant odours which are emitted from matter undergoing decay is called a *deodorant*, and such substances must be carefully distinguished from true disinfectants. Most disinfectants are deodorants; but a deodorant, unless of a permanent character, is not an antiseptic. It is true that in most cases a noxious smell accompanies decay, and, therefore, that any substance which permanently removes the smell must necessarily cause the cessation of the decay; but in other cases in which there is no appreciable odour, a deodorant would not be required. Charcoal is an example of a body that will absorb any unpleasant smell which may arise from organic matter, but which does not kill the germ producing the decay. Although commonly called a disinfectant, it should be more properly classified among the deodorants.

Primitive Methods of Disinfecting.—Man has an instinctive repugnance to all noxious odours, and from the earliest time has sought to mask their presence by the use of aromatic substances. The use of perfumes is probably a relic of the effort of primitive man to counteract this evil. Many religious ceremonies, such as the burning of incense, have also the same origin, and embalming, as practised by the Egyptians, is a good example of successful attempts to arrest putrefaction in very early ages. Sulphur has been employed from the earliest times, and Homer describes its use in religious ceremonies. In the time of Hippocrates, sulphur was regarded as an antidote against the plague. Ovid makes mention of the fact that sulphur was employed by the shepherds of his time for bleaching fleeces and for purifying their wool from contagious diseases. During the plague of Athens, Acron, according to Plutarch, stayed the spread of the epidemic by lighting fires in the middle of the public places and in the streets where deaths had occurred; and the lighting of fires during times of plague has been customary until quite recent times.

The Mosaic law, with all its minute instructions as to the purification of the people and their belongings, shows the same combination of religious ceremonial and sanitary precautions; this law, undoubtedly, contributed to the permanency of the Jewish race during its early history. The Indian who, instead of embalming or burying his dead friend, hangs the body under a tree exposed to the air, makes use of the property of desiccation, which, as is well known, is very efficient in arresting decay, and is the basis of a modern patent for keeping yeast. Earth is a very powerful deodorant and will also act as an antiseptic; the gases given off by decaying bodies are absorbed, and thus the burying of a body under proper conditions may be regarded as an efficient means of disinfection. The use of fire for cremating bodies undergoing decay or likely to cause a nuisance is, of course, an illustration of the employment of heat for the destruction of micro-organisms.

Disinfection in the Middle Ages.—During the long period of the Middle Ages, the alchemists did little to advance our knowledge of this subject; they collected a few facts, and described, with more or less accuracy, the properties of some of the more important chemical compounds; but one may search in vain for a correct account of any example of preventive medicine. Notwithstanding the ravages of the cholera, the plague, and other epidemics, as well as the frequency of leprosy, the idea of contagion was only imperfectly understood, and the common people were far less cleanly in their habits than the Jews, for example, or heathen nations who, as we have already mentioned, mingled primitive sanitary precautions with their religious services. Perhaps one of the earliest papers of any importance which we have is a *Mêmoire sur les substances septiques et antiseptiques*, written by Pringle in the middle of the eighteenth century. In this *Mêmoire* some forty-eight experiments are described, in which the author took pieces of fresh meat and placed them in contact with various amounts of substances which be believed to have an antiseptic action. Amongst the substances tried we find common salt, sal ammoniac, acetates of ammonia and potash, nitre, borax, alum, camphor, aloes, and succinic acid. These experiments, which were conducted in a very systematic manner, are even now not without some value. By taking as a standard the antiseptic action of 60 grains of salt on 2 grains of meat in 2 ounces of water, he was able to show that the other bodies enumerated above had a greater antiseptic power than this standard, and thus succeeded in arriving at their relative antiseptic value.

Bacteriology.—Even the pioneers of modern chemistry at the beginning of the present century, did little towards promoting our knowledge of disinfectants, and it was not until the biologist showed that decay was due to the action of living organisms which float in the air, that fresh attention was directed to the subject. Francesco Redi, by protecting meat from flies with wire gauze, showed that the maggots which infest decaying flesh were produced from the eggs of the flies. Subsequently the formation of moulds on the surface of jams, or other organic substances, was similarly shown to be determined by micro-organisms floating in the air. It was further noticed that infectious diseases spread more rapidly in damp warm weather when there is very little wind, and that filtration of the air through cotton wool was effectual, not only in removing the dust, but also in preventing the ingress of micro-organisms.

The gradual accumulation of such facts as these by the biologists led the chemists to realise that the removal of the odour was not, after all, the only work required to be done, and the use of fumigations with nitrous acid, hydrochloric acid, and chlorine and other pungent bodies, which had been recommended, fell gradually into disfavour.

Pasteur's work, together with the general development of the modern science of bacteriology, has given to chemists a means of ascertaining the relative value of the various chemical substances discovered from time to time. It was to Pasteur's careful investigations that the close analogy which exists between fermentation and putrefaction was established. Pasteur himself defined putrefaction as "fermentation without oxygen," and showed that all decay was due to the action of organisms, the *Bacterium termo* being the common organism which begins eremacausis.

Owing to the slight knowledge which we possess as yet of the nature of the pabulum in which these bacteria of decay live, the investigation of the way in which they act is a matter of great difficulty. In recent years, however, the life-history of known organisms has been carefully studied, and the chemical changes which are produced when they live in media of known compositions have been followed. Thus organisms have been allowed to grow in solutions of calcium formate and calcium acetate, both of which substances have a definite chemical constitution. The bacteria decompose these salts, evolving carbonic acid gas, mixed with hydrogen in the former solution, and carbonic acid, mixed with marsh gas in the latter. Lactic acid and its salts, butyric acid and its compounds, as well as other chemical substances of known constitution, have also in recent years been examined bacteriologically. From studies such as these it seems to be clearly established that, just in the same way as the yeast when it converts sugar into alcohol is killed by the alcohol it produces, so these other micro-organisms secrete chemical compounds which are inimical to their own life. In the decomposition of animal matter containing nitrogen, compounds which are soluble in weak alkaline solutions, and known as alkali albumens, are first produced, and these subsequently change into albumoses and peptones, to be again broken down into tyrosine, indol, and other compounds. These latter have strong antiseptic properties, and illustrate the fact already alluded to—viz., that the products of decomposition are in the majority of cases themselves inimical to the bacteria which give rise to them.

The Methods of dealing with Bacteria.—The ideal of disinfection is to stamp out the pathogenic bacteria, just as weeds are extirpated from a garden. This can never be done until their hotbeds, the filthy slums of cities and the neglected country villages, are cleansed and supplied with plenty of good water, and, in the cities, with air and, above all, light. Every dirty court or alley is an admirable culture-medium in which disease organisms may multiply; these issuing in a variety of ways, as by clothes, food, and even sometimes by the atmosphere, may unexpectedly decimate the so-called better neighbourhoods. There is no reason why infectious disease of all kinds should not be entirely abolished; but it can only be done when the entire population is supplied with knowledge, and placed under conditions in which health is possible. At present it is indispensable that measures of precaution should be taken continually and habitually to prevent any outbreak rather than, as too often is the case, only spasmodically when a plague like cholera threatens. The success of improved sanitation in rendering obsolete in modern Europe such plagues as carried off millions at intervals in the Middle Ages, shows that the abolition of infectious disease is possible, but we have still among us "that sad disgrace, our customary (and preventable) autumnal epidemic of scarlatina." This would certainly yield to a vigorous and systematic insistance upon isolation and application of disinfectants. With reference to the first precaution, more and better accommodation will have to be provided. As to the second, one great reason of the want of progress has been the fact, that many of the modes of disinfection, even those prescribed by high authorities, are absolutely inefficient and useless. We must get rid, to begin with, of the idea that the creation of a rival smell is any criterion of safety; we must cease to be misled by laudatory advertisements, and antiquated opinions founded on inaccurate experiments before bacteriology became a science, and we must not grudge the expense of a sufficient quantity and a proper application of the disinfectants that have been proved scientifically to really effect their purpose. The problem then resolves itself into a struggle for existence between man and inimical micro-organisms, which are known to have great vitality, powers of endurance, and facilities for penetration, accompanied by a stupendous fecundity. The means at present at our disposal for dealing with this problem can be classed under three heads:—

1. **Exclusion.**—The rough methods of quarantine and sanitary cordons have not proved a success, since the ways of ingress are so many and wide, and the intolerable oppressiveness of these regulations

leads certainly to their frequent evasion. The English methods of inspection, and temporary closure of certain routes, have proved much more effectual. The last, or personal, line of defence lies in the care and precautions taken by the individual. Most of these are indicated in Chap. XIII., "On Personal and Internal Disinfection." Cleanliness, fresh air, light, and good water are the chief.

In recent years it has also been shown that many, if not all, zymotic diseases may be excluded from the person by the introduction of special *toxines* into the individual, a process which renders him immune from the attacks of the organisms that produce the disease. These toxines are produced by the pathogenic organisms themselves, and, as already mentioned, are usually inimical to the growth of the organism, and may be regarded as their natural disinfectants. In view of these facts, Pasteur and his successors have cultivated the pathogenic organisms in broth and other media, and after sterilisation have injected the liquid products as prophylactics against various diseases. The virus can also be attenuated by passing it through different animals, or by special methods of taming, until, whilst still producing the toxines, it can be introduced into man without producing any dangerous symptoms, and thus can render him immune from fresh attacks, or place him in a position to develop the natural disinfectant sufficiently rapidly to kill off the pathogenic organisms, even after they have gained access to the blood. Dr. Roux, for example, at the Vienna Congress in 1894, reported a large number of cures of diphtheria by injecting a quantity of serum from the veins of a horse previously inoculated with Lœffler's diphtheria bacillus. Under the name of antitoxine, this diphtheria antidote is now a commercial article, and may be regarded as a special disinfectant for dealing with the organisms of this disease.

2. **Removal.**—Under this heading may be included the natural processes which obtain in a healthy individual, and artificial methods for improving his environment. It is now well established that the blood by its white corpuscles, as "phagocytes," or by its enzymes, has the power of assimilating and destroying bacteria and spores that find their way into it. If vigorous health be maintained, experience proves that a human being or animal may enjoy immunity for a time, even when in an infectious area. The limit to this protection may be reached when the micro-organisms overcome the phagocytes or other defensive substances in the blood. Many natural processes, external to the individual, such as the self-purification of rivers, aid the higher organisms in this combat. Man, by artificial methods of subsidence, mechanical precipitation by inert matters, filtration, and chemical precipitation, supplements these efforts of nature to purify the water supplies.

3. **Destruction.**—This is the office of real disinfectants, of which the physical agent heat is the most important. Next come the multitude of chemical disinfectants, many of which have been highly vaunted, but few of which are of actual value. A knowledge of the chemical constitution and relative position of these compounds throws considerable light on their mode of action; and recent progress in synthetical organic chemistry has been of great aid in furnishing compounds of known purity and constitution, which have, at the hands of the bacteriologist, been shown to possess antiseptic and disinfectant properties of ascertained value. The number of these compounds is constantly on the increase, but at present it is difficult to predict, except in some few special cases, in what direction the constitution of a compound influences its bactericidal behaviour. It seems probable, however, that the several pathogenic organisms will be best annihilated by specific chemical compounds, so that, for personal disinfection at any rate, some of the newer compounds may eventually be proved to be definite specifics.

CHAPTER II.

MECHANICAL DISINFECTION.

Insufficiency of Deodorisation—Physical Means—**Light** capable of killing Bacteria—Sunlight and ordinary Daylight—Conclusions—**Inert Substances**: Carbon—Animal Charcoal—Vegetable Charcoal—Disinfection Gratings—Use in Closets—Peat Charcoal—Coke—Soot—Coal-dust—Peat—Sawdust—Clay—Dried Earth—Spongy Iron—Infusorial Earth or Kieselguhr—Ashes and Cinders—Gypsum—**Sand Filtration**: Conditions of its Efficiency—Chamberland and Berkefeld Filters—Stone Filters—**Purification of River Water**: Clark's Method—Gaillet and Huet's Process—Natural Purification—**Desiccation**: Resistance of Microbes to Drying.

Insufficiency of Deodorisation.—The simple removal of smell, or even the act of disguising it by a chemical of more powerful odour, is frequently looked upon as disinfection. Yet it is obvious that the removal of the injurious products of putrefaction, although it may be of temporary benefit, will not prevent the organisms from reproducing a further quantity. There are also a number of micro-organisms known, in whose growth there is never any ill smell evolved, and no ammonia or sulphuretted hydrogen detected; but which, at the same time, form ptomaines, and are in other ways dangerous to health. Some of these, as pointed out by Klein, may evolve an aromatic smell and thus be tolerated.

Light as a Disinfectant.—In those cases in which it is advisable that large volumes and surfaces should be sterilised, it is not usually practicable to kill all the bacteria by chemical agents; therefore recourse must be had to their removal by physical means.

LIGHT.

The action of light is one of the most important of these physical agencies for diminishing the number of microbes.

Downes and Blunt* first demonstrated the antagonistic action of light towards bacteria. Test tubes containing sterilised Pasteur solutions were exposed to intermittent sunlight and diffused daylight for periods varying from days to months, having been previously infected by minute quantities of liquids containing bacteria, or else exposed for a time to ordinary air. A similar set of tubes were covered completely with tin-foil to exclude light, other conditions being the same. They found that direct sunlight in some cases entirely prevented the development of the organisms, in others only retarded it, and that even diffused daylight had a distinctly deterrent effect. The blue and violet rays of the spectrum were much more active than the red and orange. They further showed that the influence on spores was not exerted in a vacuum, that the nutritive value of the culture liquids was not affected, and that the bacteria were much more resistant when immersed in water than when surrounded by any other medium. From these facts they attributed the destructive effect of light to the promotion of oxidation by the influence of the sun's rays—*i.e.*, to the so-called actinism of light. (See Chapter xiii. as to the influence of light on the rancidity of butter.)

A number of other investigators continued the research with pure cultivations of pathogenic bacteria, and particularly on the production of colours by the pigment-producing bacteria. It was noticed that the sun's rays appeared to favour the development of several kinds of yeast and moulds, and that the action of light was increased by the presence of air.† Pansini ‡ found that the destruction was rapid during the first period of exposure, 360 colonies of *B. anthracis* being reduced in half an hour to 4, but that the further operation proceeded much more slowly. The spores of anthrax in a dry state were more resistant to light than when moist; in the latter case an exposure of from thirty minutes to two hours was sufficient to destroy them.

* *Proc. Roy. Soc.*, Dec. 6, 1877.

† Arloing and Gaillard, *Influence de la Lumière sur les Micro-org.*, Lyon, 1888; Uffelmann, *Hyg. Bedeut. des Sonnenlichtes*, 1889.

‡ *Rivista d'Igiene*, 1889.

Koch says that sunlight, or even ordinary daylight, will kill tubercle bacilli in from a few minutes to five or seven days, according to the thickness of the stratum.* Janowski has also proved that four to ten hours' sunlight destroyed typhoid bacilli. After passing through a solution of potassium bichromate, so as to cut off the blue and violet portions of the spectrum, the rays had no effect.† He showed also that the effect of the light was not due to increase of temperature. Geister demonstrated that an electric light of 1,000 candle power at 1 metre distance was less effective than direct sunlight.‡ Marshall Ward § showed that the dried spores of anthrax were acted on by light in the absence of food materials, and that the light did not appreciably diminish the nutritive value of the agar-agar medium. Khmeleosky finds that both solar and electric light inhibit the growth of *Staphylococcus pyogenes aureus*, *Bacillus pyocyaneus*, *Streptococcus erisipelas*, and *S. pyogenes*. Sunlight destroys their vitality in about six hours, and exposure to sunlight seems to mitigate their virulence when it does not destroy them. It also makes the media less favourable to their growth.|| Percy Frankland and other investigators have examined the action of light on the organisms in the Thames and other waters.¶ Buchner has also shown that in water typhoid and other cultures are destroyed by exposure to bright sunlight for three hours. By immersing cultures to different depths in the Sternberger Lake at Munich he has further demonstrated that the bactericidal action does not extend to a greater depth than three yards, and that hence in the self-purification of rivers the action from this cause is chiefly superficial. The conclusions of the various researches may be summarised to the following effect:—

1. Light has a deleterious action on bacteria in their vegetative, and, to a less extent, in their spore forms.

2. The action is not caused by the rise of temperature. The ultra-violet rays are the most powerful, and the infra-red the least, showing that the phenomenon is due to chemical action.

3. The effect is greatly increased by the presence of air and moisture, so much so that it is undoubtedly due to a process of oxidation, possibly brought about by the agency of ozone or peroxide of hydrogen, or both. This view is supported by experiments by Richardson,** in which it is shown that peroxide of hydrogen is formed in urine during insolation, and that the sterilising action of light can be counteracted by the addition of substances—*e.g.*, peroxide of

* *Zeitschrift für Hygiene*, vol. x., p. 285.
† *Centralblatt f. Bakteriol.*, 1890, pp. 167, &c. ‡ *Ibid.*, 1892, vol. xi., p. 161.
§ *Proc. Roy. Soc.*, 1893, p. 310. || *Brit. Med. Journ.*, 1894, p. 72.
¶ *Ibid.*, 1893, p. 20. ** *Proc. Chem. Soc.*, 1893, p. 121.

manganese—which destroy hydrogen peroxide.* Richardson shows that the insolation of water alone does not generate peroxide of hydrogen. Dr. Frankland thinks that in the case of dried bacteria, or those suspended in pure water, the destruction is occasioned by the peroxide formed within their cells.

4. The action is not generally due to any alteration of the medium by light.

5. The result varies according to the duration of the exposure, the intensity of the light, and the nature of the organism. Anthrax spores grown at 38° C. are much more easily killed by light than those obtained from the same source at 18° to 20° C.

6. There is no evidence that the virulence of anthrax undergoes any permanent attenuation through exposure to light.

7. Anthrax spores are less rapidly destroyed in distilled or potable waters than in culture media, or in an isolated condition. Their endurance is particularly long-continued in distilled water in absence of air, resistance to upwards of 110 hours' exposure having been observed by Momont.† The addition of a halogen salt, such as sodium chloride, materially increases the rapidity of destruction, while an oxy-salt, like sodium sulphate, has little or no influence.

8. The effect is much diminished by the rays passing through deep layers of water.

9. Whilst every opportunity should be afforded for insolation in the construction of water works, undue reliance must not be placed on this any more than on any other particular bactericidal agency (*Percy Frankland*).

Professor Esmarch has endeavoured to make use of sunlight as a practical disinfectant for skins and furs which cannot be sterilised in a steam disinfector. He finds, however, that, as might be expected, the light has only a surface action, especially on dark materials, and that it is, therefore, valueless when micro-organisms are likely to be present in the deeper parts.

MECHANICAL PURIFICATION OF GASES AND LIQUIDS.

Inert substances have been used (1) for the removal of bacteria by mechanical straining or precipitation, (2) for the absorption of noxious emanations.

Carbon.—*Animal charcoal*, or bone-black, more particularly absorbs substances in solution (see *Filtration*, p. 15). When thrown into sewage, especially with clay and other heavy powders, it carries down with it almost the whole of the suspended matters into the sludge, and

* P. Frankland, *Micro-organisms in Water*, 1894, p. 389.

† *Ann. de l'Inst. Pasteur*, 1892, vol. vi, p. 21.

also removes sulphuretted hydrogen, ammonia, the ptomaines, and the greater part of the other organic compounds, so as to leave the supernatant liquid nearly colourless and clear. If it could be used in sufficient quantity it would be one of the best of purifiers. It also effects a slow oxidation of the matters contained in the deposit, by means of the oxygen which most forms of carbon absorb from the air. Unfortunately, it is an expensive material, as bones are in great demand for manure. A large number of processes, many patented, have endeavoured to recover the phosphate by using the sludge as a fertiliser, but they have all, so far, met with little commercial success.

Vegetable charcoal has a still greater power of condensing gases within its pores. One volume of wood charcoal will absorb the following volumes of different gases:—Ammonia 90, sulphurous acid 65, sulphuretted hydrogen 55, carbon dioxide 35, carbon monoxide 9·42, oxygen 9·25. Those gases and organic vapours which are capable of oxidation, and possibly bacteria, are destroyed when they come in intimate contact, within the pores of the charcoal, with the oxygen derived from the air. The charcoal should be freshly prepared, or should be reheated to a temperature short of ignition, as it rapidly loses in power. By the latter means, or, better, by charring again in closed vessels, it can be re-vivified many times. Charcoal derived from different woods has slightly varying powers of absorption; as a general rule, the more porous it is the greater the activity. Vegetable charcoal has less action on liquids than animal, and being lighter than water floats on the surface. Letheby, Stenhouse, and others proposed the use of gratings containing wood charcoal as ventilators for buildings and sewers. They did not, however, prove a success, as they soon become exhausted. If the dead body of an animal be buried in wood charcoal it decays without putrefactive odour, except that ammonia is evolved. Wood charcoal removes the odour of all decaying matter, and has been largely employed to restore tainted meat, by placing it in the water used for boiling. Although the taint is removed, the food is not thereby rendered wholesome. It may, however, be usefully employed when only a slight change has occurred.

Revill * demonstrated that charcoal is not, in a true sense, an antiseptic, since it rather hastens the decomposition of putrescible matters, although, by absorbing the products, it renders the process inodorous —*i.e.*, it is simply a deodorant. Still it has considerable value for cess-pools, water-closets, and dead bodies, when a removal is necessary. Goddard & Co. in 1887 patented an automatic purifying closet in which a mixture of animal and wood-charcoal, under the name of "Sanitary Carbon," was discharged mechanically on the excreta at

* *Archives génér. de Méd.*, 1863.

each discharge. It was said to effectually deodorise the excreta, which is true, and by retaining the ammonia, to produce a manure of some value. On shutting down the lid a sufficient quantity of the carbon is scattered over the excreta in the pan beneath at a cost for each time of using of one-eighth of a penny.* In all these methods of using carbon it is found that, as the ammonia is rather rapidly evolved on exposure to air, the substance soon becomes almost devoid of nitrogen, and has practically no value as a manure.

Peat-charcoal is very light and absorbent. Its application has not been a success owing to its friability. Powdered coke, being denser, possesses much less power, yet it has been proposed in many patents for purifying sewage, either alone, or as an adjunct to other agents. As an instance, Kingzett in 1887 patented the use of a mixture of powdered coke and dry clay as a sewage precipitant. He states that the deposit can be readily pressed.

Coke alone has only a mechanical action.

Soot contains empyreumatic and bituminous matters in small quantity, and has therefore antiseptic properties due to these ingredients, but its power, though rather lasting, is not very great. It is moderately absorbent. In horticulture it is much used as an insecticide. Sprinkled about sewers and drains it removes the odour.

Coal-dust, being scarcely porous, is almost inert. Natural bitumens have long been used for embalming, but a great part of their effect is due to the mechanical exclusion of microbes. M. de Mily has recently carried out a number of experiments on the use of bitumens mixed with chopped rags (100 kilos. of rags to 10 of bitumen for 600 vines), to prevent the attacks of *Phylloxera* and other pests on ground that could not be treated with sulphur. The bituminous earth from Rhodes, which was mentioned by Strabo in 60 B.C., has also been recently used for this purpose. The results seem to have been most satisfactory.

Peat itself when dried is of value for absorbing moisture and, with it, noxious emanations. 1 lb. of it (containing 25 per cent. of water) can take up seven and a-half times its weight. 100 lbs. of powdered peat will absorb 1,438 litres of ammonia. Several patents have been taken out for incorporating it with disinfectants, for which purpose it seems at first to be admirably suited for use in stables, &c. Ernst † proposes that peat or moss should be mixed with 2½ per cent. of iron sulphate or phenol, and used for litter, privies, &c.‡ The odour of stables in which peat moss is employed is less than those in which straw is used as litter; on the other hand, powdered peat is now somewhat exten-

* *Lancet*, 1887, p. 886. † Patent No. 2,581, 1882.

‡ Westknight and Gall, Patent No. 11,011, 1886.

sively used for dry closets, and has the advantage over earth of absorbing the urine. Schröder has also shown that it has a true disinfectant action on cholera vibrios, although other pathogenic organisms are more resistant. Drs. Fränkel and Klipskin * have investigated the subject more minutely and have established the fact that the comma bacillus when mixed with peat-dust is destroyed in about three hours, whilst cholera vibrios may retain their vitality for fourteen days, unless the urine be acid. Dempster † has shown that the cholera bacillus cannot live in peaty soil. The addition of superphosphate augments the disinfecting action of the peat, whilst kainite has little influence. The authors, therefore, strongly recommend the use of peat for isolated dry closets.

Sawdust, especially the varieties derived from pine wood, is widely used, on account of the resinous and aromatic compounds it contains, which seem to ozonise the air to some extent, and also give off an agreeable odour. It is not a good vehicle for disinfectants, as it is not very absorbent, but is used to some extent in country districts where there is no water supply for retaining urine in urinals.

Clay, blast furnace slag, shale, and dried earth are all used for special purposes.

Infusorial earth, or Kieselguhr, sterilised by being subjected to a heat sufficient to cause it to glow, is said by Dr. Habart to be excellent as a dusting powder in surgery. It absorbs from five to seven times its weight of water. Mixtures of equal parts of the earth and salicylic acid, salol, or iodoform, as well as a 1 in 2,000 trituration of corrosive sublimate, have proved useful.

Ashes and Cinders.—In Belgium and Holland the household ashes are thrown daily into privies and ditches with the idea of disinfection. In Salford, Oldham, and other places, the ashes, vegetable, and street refuse were formerly carbonised and used for the same purpose, sometimes with the addition of charcoal and dry earth, as recommended by Parkes. But though the odour is in great part removed for the time, and the excreta are solidified so as to facilitate removal, no true disinfection is accomplished.

Gypsum with coal-tar, under the name of *poudre de Corne et Desneaux*, was formerly much employed in France for disinfecting wounds.‡ Gypsum is still sometimes used in stables. Asbestos, talc, pumice, in fact any dry absorbent powder, will act nearly as well.§

* *Zeitsch. f. Hygiene*, 1893, p. 333.
† *Brit. Med. Journ.*, May 26, 1894.
‡ Valpeau, *Comptes Rendus*, 1860, p. 279.
§ Vallin, *Désinfectants*, pp. 41, 56.

SAND FILTRATION.

Percy Frankland * states that out of 100 micro-organisms present in untreated river water, there were removed by the Water Companies, before distribution, in the case of the

	1886.	1887.	1888.
Thames, ...	97·6	96·7	98·4
Lea (East London Co.), . . .	96·5	95·3	95·3

Sand filtration carefully pursued offers a remarkable and obstinate barrier to the passage of micro-organisms, and there is every justification in presuming that if disease organisms are at any time present in the raw untreated water they would be retained. This was proved by experience in the cholera epidemic at Hamburg and Altona in 1892,† when in Altona the water was filtered carefully, in Hamburg not. Although the original water supplied to Altona was worse than that of Hamburg, the deaths in Altona were 221, in Hamburg 1,250, per 100,000. At the end of 1892 an outbreak occurred in Altona owing to a filter-bed breaking down, proving that the slightest imperfection in the manipulation is a constant menace during any epidemic.

Fränkel and Piefke studied the rate of filtration,‡ and came to the following conclusions:—

1. A filter running rapidly soon clogged, and did not properly remove bacteria.

2. The full effect was not obtained until the filter had been at least a day in use.

3. High pressure is inimical to efficiency.

4. The quicker filter actually passed less water in the course of the month than one which was originally slower, owing to the former becoming clogged.

5. Cholera and typhoid were not completely stopped, but the former organisms were more removed than the latter.

6. The slime that forms in the upper layers is the main agent in entangling the bacteria. Sterilised sand did not retain the microbes.

7. The efficiency was in all cases only relative, not absolute. Thus, mixed coarse and fine sand with fine gravel, of a depth of 3 feet 8 inches, removed 74 per cent.; fine sand, 5 feet deep, 86 per cent., and garden earth and peat retained nearly all the micro-organisms, but the latter two in practice were too slow § to be of any practical value as filtering media.

Mechanical filtration for domestic purposes can be effected by the

* *Micro-organisms in Water*, 1894, p. 124; also *Trans. San. Inst. G. B.*, vol. viii., 1886.

† Koch, *Zeit. f. Hyg.*, vol. xiv., p. 393; vol. xv., p. 89.

‡ *Zeit. f. Hyg.*, 1890, vol. viii., p. 1.

§ *Report of Massachusetts Board of Health on Purification of Sewage*, 1890-93.

Chamberland filter, or by the Berkefeld modification. The former consists of a cylinder of biscuit or unglazed porcelain. The latter is made of compressed and baked infusorial earth; to renew it, it is cleansed under running water, put into cold water, which is then raised to boiling, and boiled for some time. It is quicker than the Chamberland and possibly equally efficacious. If a few litres are run to waste, and it be kept in a cool place, and washed and sterilised every eight days, no bacteria will find their way through the material.*

Stone filters are absolutely unreliable.† Asbestos does not long continue to retain micro-organisms,‡ and Drs. Sims Woodhead and Cartright Wood, in a recent report, have shown that, with the exception of the filters already mentioned, there are none which are of real value. The number of bacteria per cubic centimetre (as counted under the microscope) has become one of the chief elements in valuing the merit of a water. Spring waters have superseded river waters, and towns, which have hitherto sought water from their own rivers, have had to seek other sources of greater bacterial purity. The principal processes of purification are :—(1) Deposition, either natural or assisted by the addition of precipitants; (2) oxidation; (3) the vital actions of the microbes, in which "the last word belongs to the aerobic, and, therefore, to the most inoffensive." §

Clark's well-known method of softening water by the addition of slaked lime to a water, whereby nearly the whole of the carbonate of lime is precipitated, has long been known, not only to soften the water, but also to carry down the greater part of the colouring matter and suspended impurities, mineral, organic, and living. Thus at Hampton it has been found to reduce the germs in the Thames water from 1,437 per c.c. to 177.

Other Methods.—Among modifications of Clark's expired patent are Gaillet and Huet's, which consists in the addition of caustic soda and accelerating the separation of calcium carbonate by deposition between plates, and Maignen's Anticalcaire, which contains more soda, sodium carbonate, and lime, and throws down nearly all the lime and magnesia of the water.

Percy Frankland, in a comparison of the original Clark's process with that of Gaillet and Huet, as tried on the water of the Colne Valley Waterworks, found

	Germs before.	Germs after.	Reduction per cent.
Clark, after two days subsequent rest, . .	322	4	99
Gaillet and Huet, after two hours, . .	182	4	98

* *Zeitschr. f. Hyg.*, 1891, vol. x., pp. 145, 155; Freudenreich, *Centr. f. Bakteriol.*, 1892, p. 240. † Esmarch, *ibid.*, 1892, vol. xi., p. 525.
‡ Jolles, *ibid.*, 1892, vol. xii., p. 596. § Duclaux, *Ann. de l'Inst. Pasteur*, 1894.

so that the addition of soda very greatly increases the rapidity. It must be borne in mind that even if only 2 per cent. of the organisms are left the water is not sterilised, but the subsequent addition of a relatively small quantity of a chemical disinfectant would secure such a result.* Slow deposition alone diminishes the number of micro-organisms present in a liquid. In the passage through two settling reservoirs of the New River Co., Dr. P. Frankland found that the alteration in the number of germs present was as follows :—

	Germs per c.c.
Entrance of first reservoir, ...	677
Exit ,, ...	560
,, of second reservoir (large one), . . .	183

Reduction only 27 per cent.

Buchner † introduced into clean water in repose a number of different micro-organisms. *B. pyocyaneus* multiplied abundantly, but *B. typhi* and *B. coli* (the ordinary bacillus of the intestines) died in two or three days,‡ whilst Percy Frankland in Thames water, and J. Parry Lawes in London sewers have noticed similar results.

Duclaux concludes by affirming that putrefaction itself purifies, and the microbes themselves are the chief purifying agents. It is true that although they finally convert putrefying matter into carbonic acid, ammonia, nitrates, and water, which are harmless, in the process several transition products are formed which are very poisonous. Moreover, if they multiply within the body they produce disease by mechanical irritation, by starving the nutrition, or by excreting toxic compounds, such as ptomaines, &c., into the blood. It is necessary, therefore, (1) to keep their numbers within bounds, (2) to exclude or kill the specially dangerous ones, (3) in special cases, as in preservation of food, to get rid of them altogether. Such an end can be attained in the case of sewage effluents, first by accelerated deposition, second by chemical disinfection of the clarified water, and, finally, by subsequent irrigation and filtration through land.§

Scott Moncrieff has recently proposed to utilise the micro-organisms of putrefaction for destroying the sewage itself, and has patented the use of special cultivation beds for this purpose. The process has been successfully worked at Towcester, and has been tried at Aylesbury.

DESICCATION.

It is well known that hot warm climates are the special seats of diseases of an epidemic character, and that dry localities, whether cold or hot, are comparatively healthy. Moisture and warmth being

* See also Kruger, *Ann. de l'Inst. Pasteur*, vol. ii , p. 621.

† *Archiv. f. Hygiene*, 1892, p. 184. ‡ See also Schmidt, *ibid.*, vol. xiii., p. 247.

§ Miquel, *Analyse Bactériol. des Eaux*, Paris, 1891, p. 139.

favourable to the growth of micro-organisms, it might be supposed that cold and dryness would prejudice their vitality. To a great extent this is the case. In 1871, Burdon Sanderson showed that ice-water from the purest ice contained bacteria.* Ianowski proved that snow even at – 3·9 to – 16° C. contained living micro-organisms,† Schmelk found the same in snow from a glacier in Norway,‡ Fraenkel in ice supplied from a lake near Berlin.§ Pictet has also shown that the temperature of liquid air had no germicidal action. It has thus been shown that cold alone will not kill many bacteria; it remains to see how far desiccation is effectual against them. In sandy deserts it is common to find corpses dried and free from putrescence; food can also be dried, and if kept protected may be preserved for an unlimited time. Herbs and vegetables are thus desiccated and rendered free from fermentation. Some plants, even when dried, revive when they come to a moist spot, and there are well authenticated cases of mummy wheat having germinated. Desiccation thus seems to suspend the vitality of seeds, and not to destroy it. This is true for germs; when perfectly dry they remain for the time sterile and inoffensive, and seem to be subject to aerial oxidation; but if, by the winds, or other agencies, they are carried in time to a moist situation, like a body of water, a plant, a human skin, or, still better, a mucous membrane (such as that of the lungs), they at once revive and commence to develop.

The utility of the *Eucalyptus* and other trees in marshy districts is partly due to their absorbing and exhaling the moisture of the soil. Siccative powders, like starch and steatite, are known to be useful in surgery. Many epidemics have suddenly ceased when a dry season has set in.

Both Koch and Klein have proved that the spores of most of the common species of bacteria resist drying for an indefinite period. Klein kept the spores of various potato bacilli—*e.g.*, *Peronospora infestans* (the potato blight), *Bacillus anthracis*, the hay bacillus, and those of scurf and jequirity, in culture tubes of agar agar in a perfectly dry state—*i.e.*, in a closed bell-jar over oil of vitriol—until the medium had dried up to a thin shrivelled film; and yet, even after two years and a half, on inoculating fresh materials from the above tubes, typical and good growths were obtained. On the other hand, non-spore-bearing bacteria—*e.g.*, various species of *Staphylococcus*, *Streptococcus*—bacilli of typhoid, swine fever, swine erysipelas, Koch's

* *Thirteenth Report of Med. Off. of Privy Council.*

† *Centr. f. Bakteriologie*, 1888, vol. iv., p. 547. ‡ *Ibid.*, p. 547.

§ *Zeitschr. f. Hyg.*, 1886, I., p. 302. See also Heyroth, *Arbeit. Kais. Gesund.*, vol. iv., 1888.

and Finkler's bacilli, bacilli of pneumonia, fowl enteritis, chicken cholera and grouse disease, as well as a number of others, were kept as agar cultures until the latter had well dried up. No sub-cultures could be raised from any of them. In other experiments they were dried in a current of air, or by simple exposure in a thin film on cover glasses in the manner employed by Koch, leaving them protected from dust till dry. No growth of the non-sporiferous species could be obtained in gelatine. If the drying is not complete, that is if the film be too thick, so that the superficial layer forms a protective coating for the rest, then the result of inoculation with such material will be positive; the bacteria below the surface, having been protected against drying, survive, and can produce a new crop. Similarly, when particles of solids containing bacteria are dried, it will be found that here also the centre escapes thorough drying, being protected by a superficial crust. Ordinary dust particles, however small, are never so dry that the bacteria contained in them are killed. The proof of this is that numbers of non-spore-bearing bacilli and micrococci can be cultivated from the dust of an ordinary room.*

Dempster has pointed out that cholera vibrios, whilst they can survive in moist soil, quickly die when the land is dry.†

Dr. Buchner ‡ says that in the dust of a room *B. tuberculosis* has been found alive a year after the patient died. But he does not believe that the virus of typhoid or other fevers ever enters the human body through the respiratory tract.

Provisions that have been smoked and dried may yet contain, not only micro-organisms, but also the ova of *Trichina* and worms. Pemmican, the dried and powdered beef of the prairies, has been said to communicate disease. If the meat, however, has been thoroughly soaked in a preservative like pyroligneous acid, and then dried, it is usually free from danger (*Koch*). Dry heat and superheated steam as disinfectants will be further considered in detail in a subsequent Chapter.

* Klein, Stevenson, and Murphy's *Hygiene*, 1893, pp. 11, 81.

† *Brit. Med. Journ.*, March 26, 1894.

‡ *Ohio San. Record*, April, 1894.

CHAPTER III.

DISINFECTION BY HEAT.

Heat as a Disinfectant: Conditions required in a Disinfector—Modes of dealing with Condensation on Goods—Time and Steam Condition required for Disinfection—Experiments on the Penetrating Power of Steam—**Types of Disinfectors:** English, French, Danish, German, American—Public Installations, English and American.

Heat as a Disinfectant.—It has been found in practice that there are cases in which chemical disinfection is not suitable, owing to the fact that many chemical disinfectants are very apt to cause damage to the articles treated, and also that their action frequently involves prolonged exposure, and is even then only superficial in its effect. For instance, the usual mode of disinfecting a room which has been occupied by a person suffering from an infectious disease, is to close all outlets and burn a given weight of sulphur therein for a period of several hours. But if this treatment be applied to such things as heavy woollen clothing its effect is practically *nil*, as may be readily shown by a very simple test. It has been found that a bright shilling, when exposed in a room subjected to fumigation by sulphurous acid, is immediately tarnished, but a similar coin wrapped up in a handkerchief or placed in the pocket is not discoloured in the slightest. It is fair to argue from this that, in the instance cited, the action of the disinfecting gases has only been superficial. The chemical treatment of the room is justifiable on the ground that in all probability surface disinfection only is required in dealing with substances like wood, bricks, and iron, it having been assumed that all permeable articles, such as carpets, curtains, &c., have been previously removed for more complete treatment. It is, however, open to doubt whether, even in this case, chemical treatment would be resorted to were it practicable to apply disinfection by heat.

For the reasons that have just been stated it has become usual not to attempt the disinfection of such articles as clothing, bedding, carpets, &c., by chemical means, however invaluable such means have been proved to be when applied to other cases. It would appear that the introduction of heat in some form or other for purifying purposes would be an obvious step to take, but it must be remembered that nearly two centuries ago, disease germs considered as organisms of any kind, still less as bacteria-bearing spores, were then unknown, and, if their existence had even been suspected, considerable experimental proof would be required to show that a temperature below that at which articles of clothing would be damaged or weakened in their fibre, would be sufficient to destroy all danger of infection. The work of Needham, therefore, during and before 1743, must be looked upon with admiration, since it was he who first recorded experiments in a systematic manner involving the use of heat with the object of sterilising organic substances. His cultivations, as they would be termed to-day, were placed in carefully-closed vessels surrounded by fire, and his experiments led him to conclude that such treatment rendered growth impossible. Curiously enough an after-growth in the sterilised cultivating medium made him a convert to the theory of spontaneous generation, and it was in reference to this theory, the crucial debate of the age among scientific men, that the publication of his experiments was due.* Needham's great opponent, Spallanzani, in reference to the same theory, also took up the question of sterilisation by heat; he even went so far as to detect the difference between dry and moist heat, and showed that in some instances animal life was impossible in water at 45° C., whereas the same cultivations were not destroyed by dry heat at a temperature less than 80° C.

In 1804, Appert discovered that meat, vegetables, &c., when placed in carefully sealed receptacles, and dipped in boiling water for an hour, would keep indefinitely without putrefaction or fermentation. This process was very carefully reported on by Gay Lussac (at the request of the French Government), who, owing to these investigations, expressed the opinion that no oxygen was present in the sealed vessels after the process, and that the absence of this gas was essential to the preservation of animal or vegetable tissue; but it was noteworthy that, although this *brochure* was for long regarded as the standard work dealing with the subject, no mention whatever was made of the destruction of germ life within the vessel.

It is generally believed, however, that the earliest application of heat to disinfection on a large scale, as opposed to the laboratory experiments of Needham, Spallanzani, &c., was not made public until Dr. Henry, F.R.S., of Manchester, gave an account in the *Philosophical Magazine* for 1831 of some experiments he had made on the disinfection of infected clothing by hot air. A steam jacketted copper was used, into the casing of which only steam at 212° F. was admitted; but, apparently, it was found impossible to heat the interior to much more than 200° F. with these appliances. Dr. Henry's results, so far as they went, were encouraging, and tended to show that the clothing of

* See *La génération spontanée*, by I. Strauss; *Arch. de médecine expérimentale*, t. 1er, pp. 139-156 and 329-348.

scarlet fever patients, which had been submitted to a temperature of 200° F. for two to four hours, would not propagate the disease if worn by other healthy persons. Most of Dr. Henry's experiments, and even of those of Dr. Baxter in 1875, were made with vaccine lymph, and it was really not until the experiments of Pasteur, Lister, Burdon Sanderson, Tyndall, and Koch had been published, that sufficient data concerning the reality and nature of bacteria existed to render it possible to test the efficacy of heat, dry or moist, as a destructive agent.

The results of Tyndall's experiments (communicated to the Royal Society in 1876 and 1877, and also contained in his well-known book, entitled *Floating Matter of the Air*) were remarkable, inasmuch as they treated the subject largely from the physicist's standpoint. In this work he proves conclusively how very variable is the treatment, both as regards duration and intensity, of the heat essential for the sterilisation of organic matter. He showed, for example, that hay infusion might be kept continuously boiling for several hours and yet not be sterilised, inasmuch as the spores could resist such treatment and develop subsequently, although the original mature bacilli would have all been destroyed. As a proof of this he boiled similar infusions intermittently for a couple of minutes, twice or three times during a day or so, and found that, although the total period of actual boiling might be less than six minutes, compared with the hours of the previous case, no aftergrowth whatever appeared in the preparation. Tyndall also pointed out, and proved in some cases, that oxygen was an essential to the existence of micro-organisms. He found that 180 minutes continuous boiling failed to sterilise a turnip infusion in the presence of the ordinary supply of air, but that ten minutes at 212° F. sufficed to produce absolute barrenness, when such heating was conducted in absence of air. The production of a vacuum was found to be such an important factor in sterilisation that experiments were made to ascertain whether the total absence of oxygen would in itself be sufficient to effect destruction, and in so many instances was this found to be correct, that the conclusion was arrived at that, with sufficiently perfect exhaustion, all infusions would probably be sterilised.*

The views of Tyndall, in reference to the necessity of oxygen for the propagation of microbes, have since been much modified by the experiments of later observers, who discovered that a small class of bacteria, called "obligatory anærobes," could only exist in the absence of oxygen, and that others, "facultative anærobes," increased most in the presence of free oxygen, although it was possible for them to exist in the absence of this gas. The latter class is the larger of the two, and

* *Comptes Rendus*, vol. lxxx., p. 1579.

includes many pathogenic organisms, such as the *Bacillus anthracis*, and the bacillus of Asiatic cholera. There is also a third class, "obligatory ærobes," to which the presence of oxygen is an absolute necessity. The observations of Tyndall are, in this respect, not perfectly accurate, although it is probable that his conclusions would hold true for the larger number of cases for which disinfection is required, insomuch as clothing is constantly aërated, and, therefore, should, under ordinary conditions, contain no living obligatory anærobes.

The foregoing results are of the greatest importance from the practical standpoint, as will be seen later on. They paved the way for further progress at the hands of Koch, Pasteur, and others.* Koch made his experiments on *pure* cultivations of (1) non-spore-bearing organisms, such as the *Micrococcus prodigiosus;* and (2) of spore-bearing kinds, such as anthrax bacilli, &c. He attempted disinfection by chemical agency, hot dry air, and by steam; moreover, in all these cases the trials were eventually made on a sufficiently large scale, with bedding, &c., to make his results of the greatest value. He confirmed, generally, the result of previous workers that the spores were the most difficult to destroy, and that, therefore, if they be devitalised, all bacteria will also have been rendered harmless. In dealing with hot air he found that spores were only destroyed by being exposed at 284° F. for a period of three hours, but that at this temperature † almost all fabrics which require disinfection are already injured, and that the rise in temperature inside a small roll of blankets so exposed was not sufficient, unless the exposure was continued for a much longer period. When steam at 212° F. was used as a disinfecting agent, Koch found that anthrax spores, when freely exposed, were killed in five minutes, and that even with steam at atmospheric pressure, penetration of heat through blankets took place in about one-quarter of the time necessary to secure a sufficient internal temperature when hot air alone was used. From the medical point of view, these experiments were most satisfactory, although, owing to the crude nature of the apparatus used, it would appear that most, if not all, the articles treated were considerably moistened and in some cases damaged by the action of the steam.

Hoch and Wolfhügel ‡ conclude that "dry heat, even continued for two hours at 150° C., did not always assure disinfection, although nothing resisted, even for a few minutes, boiling water or steam at 100° C." Gaffky and Löffler § summarise their experiments as follows:—

* *Mittheilungen aus dem K. Gesundheitsamte*, vol. i., p. 188.

† See also *Brit. Med. Journ.*, September 6, 1873.

‡ *Mitt. a. d. Kais. Gesundh.*, 1881, p. 301. § *Ibid.*, p. 322.

1. Non-spore-bearing bacteria cannot endure for one and a-half hours an exposure to hot air at 100° C.

2. The spores of mould are not killed by one and a-half hours exposure to hot air at 110° to 115° C.

3. The spores of bacilli are only killed by three hours exposure to hot air at 140° C.

Bonhoff and Foster * state that *Bacillus tuberculosis* at 60° C. dies in one hour, at 90° C. in five minutes, and at 95° C. in one minute.

The experiments of Dr. Klein and Dr. Parsons, as detailed in the *Annual Report to the Local Government Board for* 1884, confirm very largely those of Koch, and they also deal with the question of practical disinfection in a manner that renders this work of very great value. The great advantages of steam over hot air were demonstrated very clearly, and, owing to the number and diversity of their experiments, they were able to show that, in some cases at all events, the action of steam in a suitable apparatus was not in itself injurious to the articles treated.

The work of Pasteur, Tyndall, Lister, Koch, Parsons, and others has, therefore, determined the fundamental conditions for successful disinfection by heat.

Conditions required in a Disinfector.—It remains to be shown that the mechanic can meet the requirements of the bacteriologists, and, at the same time, deal with the practical difficulties that invariably beset him during the introduction of novel machinery. The conditions for dry-heat disinfection, so far as temperature and duration of exposure are concerned, have not been very clearly defined; but from experience gained by Dr. Hopwood at the London Fever Hospital, it may be gathered that an exposure of bedding to hot air at a temperature of 250° F. for a period of nine hours is generally sufficient, and no material damage is caused thereby to the goods.

The great difficulty in designing a stove to fulfil these conditions arises from the fact that it is almost impossible to obtain a uniform equable temperature in a sufficiently large chamber. It is probable that exposure to air at a temperature of 260° F. for nine hours weakens many woollen materials, and a temperature of 280° F. distinctly discolours them, whereas an error of 10° or 20° F. on the lower side of 250° F. renders disinfection by these means more doubtful. The allowable range of temperature in a hot-air disinfector should, therefore, not exceed 20° F., and the mean should be about 250° F., since, according to Drs. Parsons and Klein, the free exposure of anthrax spores to air at 245° F. for one hour suffices for their destruction.

Most engineers are well acquainted with the great difficulty met

* *Hyg. Rundschau*, vol. ii., p. 869.

with in heating air to a uniform temperature, and the problem is not made any the easier by the fact that in such places where hot-air machines are now required, steam is not available for heating the air. If it were available, there can be little doubt but that it would be employed for the actual disinfection without the aid of air. As a rule, coal and gas are the only sources of heat available for the purpose, and even then, seeing that it is merely in the smallest and most out of the way districts that hot-air disinfectors are permissible, the first cost of the apparatus has to be kept so low that adequate temperature regulating becomes almost impossible to provide for in a chamber of the requisite size. It must be remembered that although local conditions may make it excusable to erect hot-air apparatus, the size of the hospital or population of a district does not determine the capacity of the hot chamber, for it must be large enough to contain the largest article that it is likely to have to disinfect (usually a double mattress) without being folded. In dealing with hot-air disinfection it becomes especially important to arrange the articles in such a manner as to reduce to a minimum the distance through which heat has to penetrate, and, therefore, bulky things, such as mattresses, should never be folded, and if several have to be treated at once, each should be separated from its neighbour by wooden strips to allow of 2-inch or 3-inch air space.

Seeing that mattresses should not be folded, owing to the diminution in penetrative effect of the heat, and frequently cannot be folded or bent without damaging their construction, we can at once fix upon a length of 6 feet as a minimum for the chamber, or if this be not practicable, the diagonal should not be less than this, if, as is generally possible in a hot-air chamber, a rectangular section can be used. One dimension being fixed at 6 feet as a minimum, another may be determined in a similar manner by the width of the mattress. In hospitals or public institutions beds do not commonly exceed 3 feet in width, but private household mattresses very commonly exceed 5 feet. It may, however, be assumed that in the future no *public* hot-air disinfectors will be erected, and that their very limited scope will be confined to small workhouses or institutions; hence, after allowing for a small margin, a depth of 4 feet should suffice. The depth and length being fixed respectively at 4 feet and 6 feet, the width may be fixed according to circumstances depending on the number of mattresses or clothes likely to require disinfection at one time. Thus four mattresses each 6 inches thick would require a chamber 3 feet 6 inches wide, after making sufficient provision for air space between each unit. As a matter of fact the smallest really satisfactory hot-air disinfecting chamber usually erected in this country is 4 feet 6 inches long, 4 feet

6 inches high, 4 feet 6 inches wide internally, and in this an ordinary 3 feet × 6 feet mattress must be placed diagonally. This is a very unsatisfactory arrangement, owing to the available space being so much cut up, and also because the ends of the mattress rest actually in the angles of the chamber where it has been ascertained a certain quantity of "dead" air (*i.e.*, unchanged or stationary air) generally remains at a temperature considerably lower than the average throughout the closet. The latter objection is in reality one common to most disinfectors of rectangular section, but if the chamber be of ample size, these dead air spaces need not actually be occupied by portions of the charge.

The question of air circulation through the chamber is probably one of very great importance, for not only does it tend to promote uniformity of temperature by admixture of gases of different temperatures, but also it has been found that gases in motion can be more readily heated by a hot surface owing to their rubbing action, and conversely, that moving heated gases can part with their heat more readily to cold surfaces than when they are at rest. In all hot-air stoves there is, of course, a certain risk of overheating the goods, and in most cases they are temporarily weakened, and perhaps rendered brittle, immediately after their removal, although these latter defects usually disappear after the articles have regained their normal hygrometric moisture; possibly this does not occur in such disinfectors as have water pans exposed in the hot chambers. Precautions have also to be taken to damp a fire in the chamber should it occur, owing to the presence of lucifer matches, in spite of the fact that a careful attendant can always search for and remove all such dangers from the pockets and linings of garments, &c. The danger against fire is very usually guarded against by placing some fusible links in a chain stretched across the interior of the chamber, which chain is so connected to a damper that when broken, the latter closes the exit to the chamber, and thus the fire is automatically gradually quenched through lack of oxygen. The same device is also commonly geared to close the gas supply, if it be a gas-heated machine; but it must be noted the arrangement is one which only comes into action after the evil has arisen, and does not protect clothing from damage, but merely checks the extension of fire. Dry-heat machines are likely to be little used in the future, and it is, therefore, unnecessary to describe them at any length. Dr. Parsons' *Report* of 1884 gives full particulars of the several types then in use. Dr. Parsons found that very few, if any, fulfilled all the conditions required for adequate disinfection, although he mentions Bradford's apparatus as being the best coal-fired disinfector, and the invention of Dr. Ransom as being a very suitable gas-heated machine. The former contained an exposed dish of water during Dr. Parsons' experiments, whereas the latter did not; although there is no apparent reason why such an addition should not be made if found advantageous. In the Bradford apparatus, a range of temperature of 24° F. was found to exist throughout the chamber, the maximum being about 248° F. The moistening of the air was found to have an appreciable effect in aiding the penetration of the heat, and thus diminishing the period of exposure, and in Mr. Bradford's opinion it also tended to preserve fabrics from injury at high temperatures.

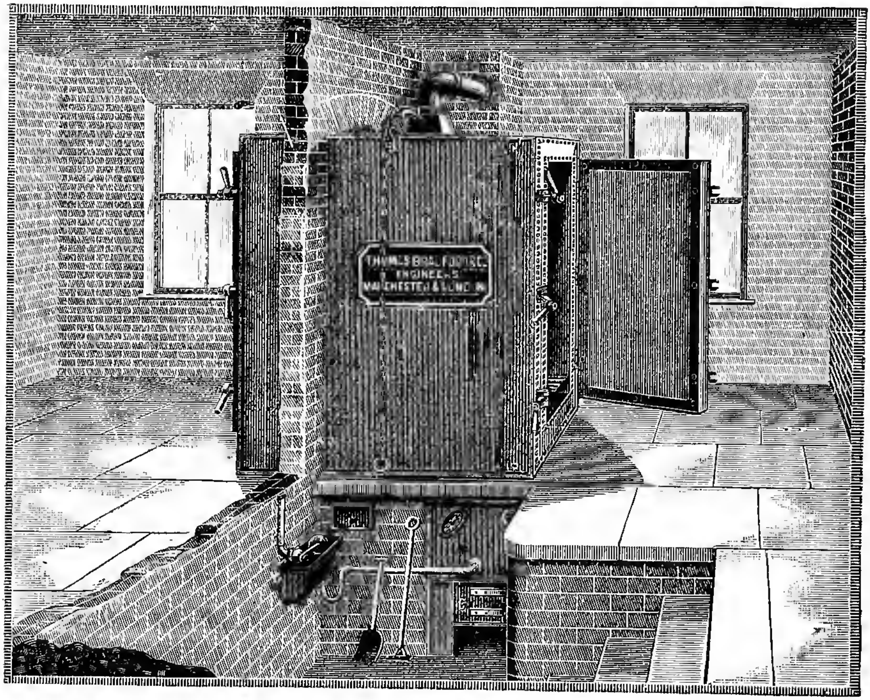


Fig. 1.—Bradford's Hot-Air Disinfecting Apparatus.

On the other hand, it is clearly difficult to so stoke a fire as to produce a nniform temperature in a large chamber (even opening the furnace door caused a drop of temperature in the chamber of 7° F.), and the success, or otherwise, of the process must, therefore, largely depend upon the skill and attention over several hours of the person in charge. No experiments appear to have been made with microbes in either machine, so no definite proof is given that moist air at about 230° F. has absolute germicidal properties, if continued for two hours only. The construction of one form of this plant is given in Fig. 1. In Dr.

Ransom's apparatus, which is heated by gas, the temperature may be automatically governed by means of the now well-known mercurial regulator, and on trial a variation of 9° F. was recorded in the chamber, the minimum being 247° F. Although the time taken to get up the requisite temperature and disinfect is considerable, the apparatus can be left with safety to work without attention owing to the gas regulator, and, in consequence, the drawback is much minimised. In this case also, a constant stream of heated air passes through the machine, which, no doubt, tends to preserve uniformity of temperature, and perhaps accounts to some extent for the better results than can be obtained in a coal-fired apparatus.

The chief drawbacks to hot-air disinfection are, therefore, due to the slowness, and the danger of damaging the goods. It has also been found that the process offers facilities, or even encouragement, to the man in charge to scamp his work, for one can rarely tell by the appearance that articles have been disinfected or not, and so great is the risk of articles firing or being singed, if subject to a temperature of 250° F. for several hours, and thus bringing the attendant into trouble, that, as often as not, he takes the precaution never to allow it to exceed 200° F. In one instance, at a dry-heat disinfecting station in a densely populated London district, the attendant actually prevented the air rising above 190° F. because expenses have been incurred in the past for the replacing of damaged clothing. This farce has been going on for many years, and had not been altered in 1894. Such a state of things would be almost impossible if steam were used, and, moreover, there exists no such temptation, for there is no danger of damaging the clothing by heat in a well-constructed steam apparatus, and the required temperature is obtained independently of the attendant after his steam valve has once been opened. The superior germicidal and penetrative qualities of steam have already been referred to, and the only drawback to its adoption is that, unless proper precautions are taken, the steam may condense on the articles in sufficient quantities to damage them, and to necessitate drying subsequent to their removal from the machine.*

Modes of Dealing with Condensation.—This question of condensation roughly divides the several types of steam disinfecting apparatus into two classes, viz., firstly, those in which provision is made to prevent copious condensation by keeping the walls of the chamber at a higher temperature than the steam inside; and, secondly, those in which no such provision is made, and which frequently necessitate, as a consequence, the subsequent drying of goods. Each of these classes might be

* See v. Esmarch, *Zeitsch. f. Hyg.*, Bd. iv.; Gruber, *Gesundheits ingenieur*, 1888; Budde, *Archiv. f. Hyg.*, Bd. ix.

further subdivided into several others determined by the pressure of the steam admitted to the chamber, by the currency or otherwise of the steam in contact with goods, and by the introduction or addition of apparatus necessary to create a vacuum in the chamber. Special apparatus has also from time to time been made to overcome special difficulties, such as arise when heavy bales of rags or merchandise have to be treated in large quantities. The usual practice at home is to erect a machine in which condensation is prevented by means of a steam jacket or outer casing surrounding the chamber containing the articles to be treated, and into which steam is admitted at a higher temperature than that passing subsequently into the chamber. The walls of the chamber being retained thereby at a higher temperature than the steam admitted, condensation of the latter, due to contact with cold walls, is absolutely prevented; but it must be borne in mind that however valuable Washington Lyon's invention may be, it does not absolutely prevent condensation on the goods themselves, which are cold when first admitted, and only slightly warmed on the surface by radiation from the hot sides and air convection due to the same cause. There is, therefore, an initial condensation on the surface of most goods when first brought into contact with steam, and consequently a rise in temperature owing to the reception of the latent heat of the steam during liquefaction. The fresh steam which next comes into contact with the goods does not condense so largely, because they are at a higher temperature than before; but, nevertheless, liquefaction does occur, and the articles again rise in temperature. This cycle of operations repeats itself again and again rapidly, but finally the whole of the articles are at the same temperature as the surrounding steam and no further condensation occurs. The influence of the jacket then becomes of greater importance, for it heats the steam, and no steam is being condensed. The consequence is that the steam becomes superheated (the safety and reducing valves keep the pressure constant) and is always kept in circulation by the convective effect of the sides; the result is that whatever moisture the goods may hold is re-evaporated, so that they may be taken out substantially dry. It would appear, perhaps, from the foregoing description that many delicate fabrics would be damaged by even the temporary condensation at the commencement of the process; but it is found in practice that surprisingly little injury is done; even the colours in cheap cotton print show no signs of running, while delicately-tinted silk dresses are but little affected by the condensation. Some materials lose their gloss, and certain other woollen goods, such as new blankets, take the slightly yellow tinge that would generally follow a good washing; the only goods which are absolutely damaged are those made of leather, or fur.

These latter should always be treated by dry heat, or other means, and the same remark generally applies to varnished or glued wood-work, although heat of either sort when applied to finished woodwork almost invariably leaves a record of its application of a more or less serious nature.

Time and Steam Conditions required for Disinfection.—The precise time required for disinfection in such a machine as has just been described depends on three main factors—viz., firstly, on the particular disease germ that it is required to kill; secondly, on the nature and bulk of the articles supposed to contain the germs; and lastly, on the steam pressure employed to secure penetration into the goods. It is, of course, impossible to say whether any article contains only one species of microbe, and also it is very frequently found to be practically advantageous to treat at one operation the clothing, &c., of patients suffering from several distinct maladies. As it also simplifies the routine work of the attendant to have only one basis on which he may calculate the total time required for disinfection, the minimum time generally adopted should be that required for the steam to kill the most persistent microbe when unprotected by foreign and artificial surroundings. According to Dr. Klein and others anthrax spores have hitherto been found to be among the more persistent forms of organism affecting human beings, and, judging from their experiments, it may be said that a free exposure to saturated steam, at 212° F. for fifteen minutes, was a period in which sterilisation could be effected with certainty. It was found that five minutes exposure under the same conditions gave doubtful results, and, therefore, it is probable that absolutely safe disinfection cannot be effected with steam under less than ten minutes free exposure. This period was also found just sufficient to kill lice and their eggs, for which purpose these machines are sometimes almost entirely used in such places as workhouses. The germicidal effect of saturated steam at a higher pressure of, say, 15 or 20 lbs. per square inch is usually supposed to be greater than that of steam at atmospheric pressure; in fact, Dr. Klein considered that its efficacy might be taken for granted, and, therefore, made no experiments of a similar nature by its aid. There is, however, one point to which attention should be drawn; steam may be either "saturated" or "superheated," but the germicidal influence of the two is considered by many to be different, although the steam is dry in both conditions, and either form may exist at any pressure or in the absence of water. These two facts are mentioned, because in the minds of some saturated steam is commonly associated with moisture, and superheated steam is confused with steam under pressure. The two forms are distinguished entirely by their temperature—that is to say, steam may just exist at

227·95° F. under an absolute pressure of 20 lbs. per square inch (*i.e.*, including atmospheric pressure), or by adding more heat to it, its temperature will rise, say, to 300° F. at the same pressure although its volume will increase, and in this condition it is said to be superheated. In most, if not all, steam-jacketted machines the earlier portions of the operation must perforce be conducted with saturated steam, and in the better machines, from which the articles come out absolutely dry, it is probable that the steam contained in the chamber becomes slightly superheated towards the end of the process. Hence, it matters but little in a jacketted machine whether saturated or superheated steam be the better disinfecting agent, for steam may be used in both conditions. As a matter of fact, the difficulty has always been to bring the articles out dry, and so long as they come out with even ½ per cent. added moisture, it is certain that the steam has never been entirely superheated.

The question of steam pressure to be employed is one which has been much debated, and at the present time there are machines (mainly on the Continent) which employ steam at 1½ lbs. pressure; and others again working with steam at 20 lbs. pressure. Assuming, for the sake of argument, that the higher pressure steam has no greater germicidal effect than the lower (which is not probable), it still has many important practical advantages which are of great value in most cases. When bulky articles, such as mattresses, rolls of carpets, &c., have to be treated, or when the machine must be filled so entirely that the air space between each article almost disappears, then it is clear that penetration of 20 lbs. steam will take place far more rapidly than if this pressure be only 1 or 2 lbs. Or, again, a machine which uses steam at 20 lbs. pressure may be worked off almost any existing boiler, because almost all steam generators nowadays work at pressures above that required, and, although it is a comparatively simple matter to reduce the pressure automatically to 20 lbs., it is not nearly such an easy problem to reduce the pressure sufficiently so that the steam may be used with safety in apparatus designed to stand 1½ lbs. only. This difficulty may entail the erection of a special boiler of unusual design, and steam is then raised under conditions the reverse of economical. It is also noteworthy that condensation is more likely to take place when low-pressure steam is used than when steam at a higher temperature is admitted. The main objection to high-pressure apparatus is that the machines require not only greater strength, but also more careful design, and are consequently more costly. There are occasions, doubtless, when, on economical grounds only, the low-pressure machine is allowable; but the circumstances, even in these cases, should be such that time for drying articles can always be allowed subsequent to treatment. Although steam can, as has already been shown, penetrate the bulkiest article in a comparatively short time, this period may, by a little manipulation on the part of the attendant, be very materially reduced. In arranging the goods in the chamber, every care should be taken to leave a little space between each of the various rolls or bundles. Often a few pieces of wood or a rough hurdle may come in very useful when articles have to be piled one on the other, or things can be hung up readily so as to allow of circulation. In all cases it is safest not to permit the attendant to handle infected articles more than is absolutely necessary; therefore, bundles or rolls ought not to be themselves unpacked, although such a proceeding would undoubtedly hasten the process. Again, after the chamber has been closed (assuming it to contain bulky articles), penetration may be greatly facilitated by relaxing the pressure and refilling several times during the process. Thus, if the chamber be filled with steam at 20 lbs. pressure in two minutes, this steam may be allowed to remain stagnant for say two minutes, and then allowed to escape. It should immediately be refilled with steam, and perhaps five minutes later again allowed to escape, and so on. It is probable that this procedure is advantageous owing to the large amount of air retained in woollen and other goods, which is compressed by the steam into their centre, and if not allowed to distribute itself throughout the chamber by removal of pressure, would greatly retard penetration. It has been found that rolls of blankets, rolls of carpets, and compressed bales are among the most difficult articles to disinfect, and in such cases the precautions just referred to should most certainly be adopted. Mattresses and pillows can readily be separated one from another, but if this be not done, considerable time may be required for these also. There is still one difficulty which arises when heavy charges are placed in the machine, and that is due to the internal condensation in the centre of the goods. The explanation of the causes promoting condensation will have made it clear that such difficulties will be more difficult to eradicate in large bundles than in small ones; and, as a matter of fact, it is generally the rule that moisture will be perceptible in the centre of a large roll in spite of the steam jacket. It is clear that condensation may be entirely avoided in the first place if the goods be raised to the temperature of the incoming steam prior to its admission; but it has been shown that in dry-heat stoves it is a very lengthy operation if the goods be bulky. The length of time is due very largely to the fact that the hot air is not forced into the centre of the goods; in fact, it has little more than a surface action, and, as a consequence, the goods usually act as a capital non-conductor to protect the interior, and the cold air retained there. But if we assume that this contained cold air could be withdrawn, and the hot air subsequently forced in to take its place, we get a very different state of things, and the heating can obviously be effected far more rapidly. This course is practicable if steam be available, for the removal of air and the compulsory substitution of other heated air absorbs more work than could be expected from an attendant if steam power were not at hand, as is the case when dry-heat disinfectors are employed.

The whole process may be completed by merely creating a vacuum in the chamber and then admitting heated air at atmospheric pressure. It is a very simple matter to withdraw the bulk of the air by a simple steam jet arranged after the fashion of the ordinary spray producer until a vacuum of 20 inches is indicated on the gauge; and then, if the chamber be placed in communication with the atmosphere, air is forced in at a pressure of about 10 lbs. to the square inch, and, in transit, it may be passed through a short coil of pipe surrounded by steam at the required temperature so as to heat it to the most suitable degree. There are many features about this process to recommend it; for, not only is it possible to regulate the temperature of the incoming air to a nicety, but it is also itself easy to heat, because it is constantly in motion, and, for the same reason, the hot air itself heats the goods it comes in contact with the more rapidly. If the air be passed through pipes heated by the direct heat of a fire, it becomes almost impossible to control its temperature, and the same dangers of scorching arise as were found by the use of dry heat stoves. In the class of apparatus described it has been found desirable to keep the temperature of the incoming air to about 220° F., so that, when steam is admitted at 250° F., it does not become superheated, and its germicidal influence is not affected. Supposing, for the sake of argument, that moisture still remains in goods after steaming, the presence of the vacuum and hot-air apparatus is still of great value; for by its aid the articles may be dried to any extent desirable at a far lower temperature than 212° F. The vacuum has several other advantages quite apart from its drying qualities. It enables the operator to remove most of the air from the chamber before the admission of steam; consequently, the ordinary steam pressure gauge may be read accurately as a temperature gauge, seeing that the mixture of steam and air has not to be considered, whereas the temperature of saturated steam varies with its pressure.

Also, the production of a good vacuum * prior to the admission of

* The term *vacuum* is not intended to imply the total absence of gases; a space filled with a gas, and under a pressure equal to that of 20 inches mercury as measured by the vacuum gauge, would be generally referred to as a fairly good vacuum.

steam is equivalent to raising its pressure, so far as its penetrative power is concerned; consequently, the rapidity with which bulky articles are disinfected is very much increased, although the temperature at which they are treated remains unaltered. It thus becomes possible to disinfect goods with steam at only 10 lbs. pressure as rapidly as with steam at 20 lbs. pressure, when no vacuum is created. Both these points are of importance, since of late years the practice has become prevalent to treat very bulky things, such as rolls of carpets, compressed bales, &c., and as the amount of work to be done is thus much increased the disinfecting chamber is commonly packed closely. Moreover, the damage done to delicate fabrics, which sometimes lose their gloss at 250° F., may be entirely avoided by disinfecting at say 220° F., without any increase in the time required to secure penetration. Altogether, the advantages to be gained by the introduction of this inexpensive and simple vacuum apparatus are considerable, and great credit is due to the inventors (Mr. J. B. Alliott and Mr. J. M. C. Paton).

Experiments on the Penetrating Power of Steam.—An idea of its powers may be gathered from a comparison of the following two trials. In p. 296 of Dr. Parson's report it is stated that a cotton rag press-packed bale was tested in a Washington-Lyon machine. The dimensions of the bale were 3 feet 6 inches × 3 feet × 2 feet 3 inches, and its weight was 5 cwts. At the end of four hours a thermometer at its centre registered 258° F., and the increase in weight was 4·8 per cent. Experiments were made in 1893 with a similar machine, but fitted with the vacuum apparatus, on a press-packed bale of cotton rags weighing 5 cwts. 3 qrs. 13 lbs., and measuring 3 feet × 2 feet 4 inches × 4 feet 6 inches. The trial was conducted on similar lines, and every precaution was taken to prevent the passage of steam down the hole through which the thermometer had been admitted by plugging it up with a long conical piece of wood larger in diameter than the hole itself. The thermometer was so arranged that when the mercury column reached a height equivalent to 220° F., an electric bell was rung outside the chamber. The bell rang precisely forty-five minutes after the introduction of the bale to the chamber, and it was removed after a final drying by the vacuum and hot air after a further period of thirty-three minutes. The whole time taken was seventy-eight minutes, and the total increase in weight was less than 2·6 per cent. The bale was again submitted to the air-drying for fifteen minutes, with the result that the moisture was further reduced by 30 per cent.

The accompanying chart shows the mode of working adopted during this trial, although it would probably have hastened the process had the alterations of pressure and vacuum been more frequent, and it was also a mistake to have admitted the steam immediately on obtaining the first vacuum, instead of admitting and extracting hot air prior to the admission of the steam. The particular trials referred to are not such as will have to be frequently repeated in public disinfecting stations, but they have been given merely as indicative of the greater penetrative and drying powers of jacketted disinfectors when fitted with vacuum apparatus. If bedding or clothing has to be treated the

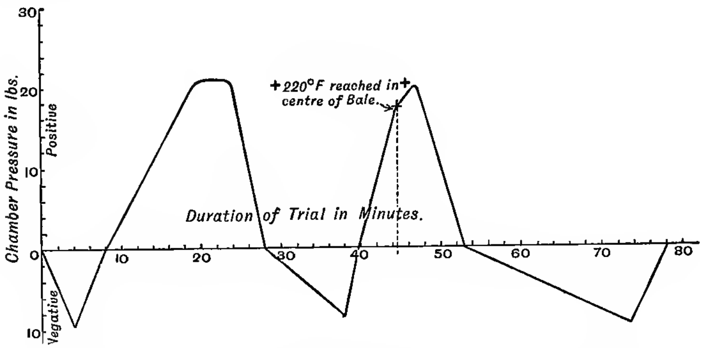


Fig. 2.—Chart showing effect of vacuum of apparatus on the penetrative power of steam.

duration of the process is considerably shorter in either form of apparatus; but there still remains the same advantages in favour of the machine fitted with the vacuum apparatus.

English Apparatus—Washington-Lyon's Patent.—In this country the machines mostly in use are those made under Washington-Lyon's patent. This is largely owing to the far reaching nature of Mr. Lyon's specification, on which much litigation has taken place. Generally speaking, these machines are made in two forms, square and oval in section.

The square form (until recently known as Goddard's patent, made by Goddard, Massey, & Warner, of Nottingham) is jacketted all round the body, in addition to the two doors. The jacket in this case is usually half filled with water, and is used as a boiler. The fire-grate is placed immediately under the body of the machine, and the firebrick flue (see Figs. 3 and 4) is built to traverse the bottom, and thence along other flues, built around the sides of the machine, to the chimney. The steam pressure in the jacket (*i.e.*, the boiler) is usually limited to 20 lbs., and disinfection is carried on by steam at the same and lower pressures. Arrangements are also provided for passing a current of hot air through the chamber before and after disinfection. The air is heated by passing it through a pipe situated in the furnace flue immediately under the disinfector, and thence into the chamber. The air may be circulated and extracted from the chamber by means of a small exhauster. This apparatus has had a considerable sale owing largely to its rectangular form, and there can be little doubt that it disinfects adequately, and also that when properly worked there should be little or no moisture present in the goods subsequent to disinfection. Its apparent first cost is also a factor in its favour, although if the cost of the necessary brickwork setting and side flues be added to the cost of machine and erection, this advantage is more

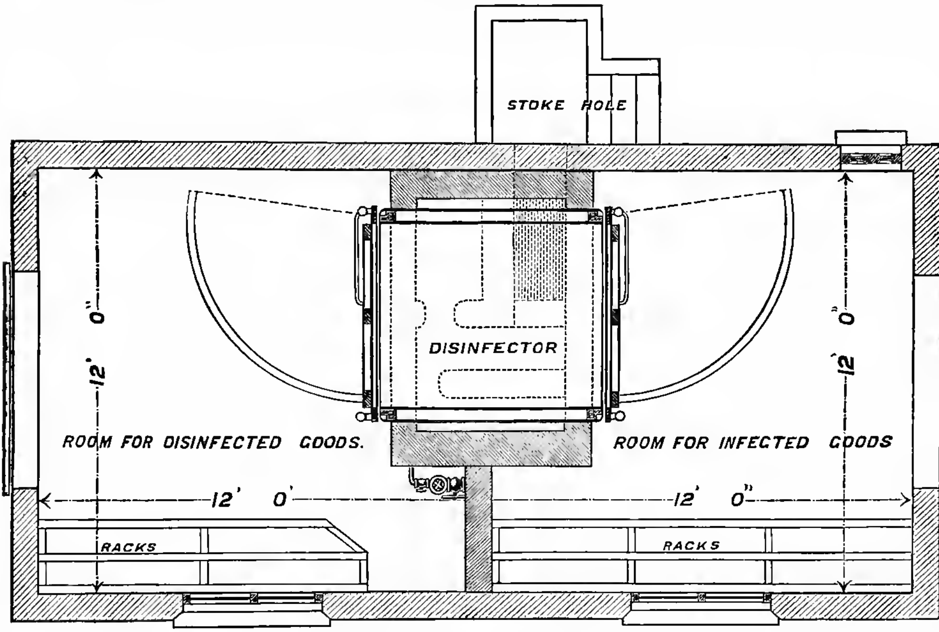


Fig. 3.—Sectional plan of Goddard & Co.'s square form of Washington-Lyon's disinfecting chamber.

apparent than real. Its chief disadvantages are, curiously enough, precisely due to those features which are presumably advantageous. For instance, the square shape is to some an attraction, whereas it is undoubtedly a constructive weakness, and for obvious reasons the most suitable section for a steam chamber to stand a considerable internal pressure would be circular. Thus this advantage has to be paid for in the shape of repairs to leaky joints, insurance, &c., although possibly, in certain cases, it may be worth the risk. Again, the use of the jacket as the boiler is advantageous inasmuch as less space is required; but, on the other hand, it is an imperfect boiler, which cannot be got at properly for cleansing, and is likely to be the cause of mishaps, especially at the bottom (which is not readily accessible for examination), where the fire impinges directly on the flat plate, and gradually burns it away. The presence of jacketted doors is also a feature of this machine, although it is doubtful if this additional complication is necessary when the hot-air apparatus is also supplied. The air is heated by the action of the hot gases of the fire, and the only

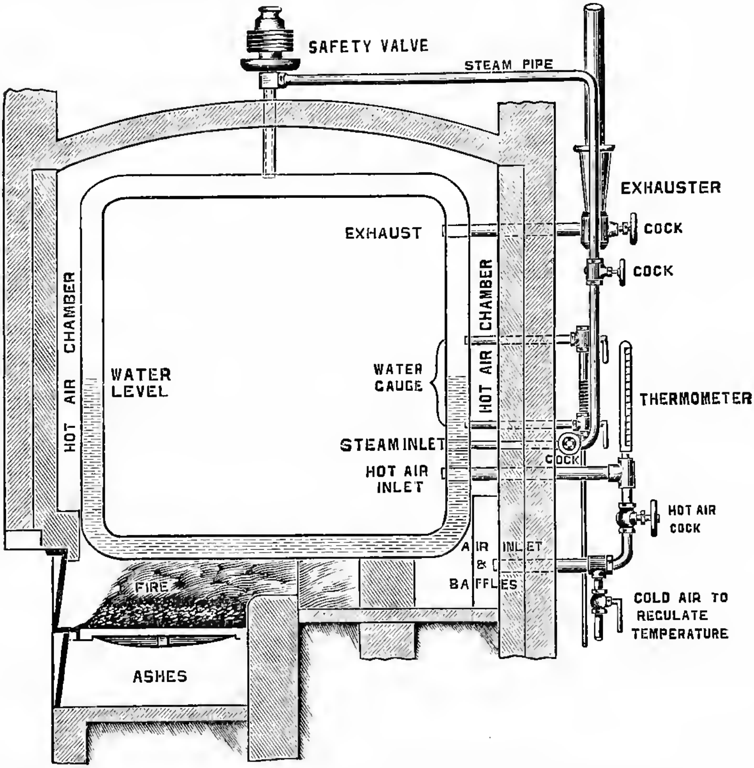


Fig. 4.—Section through Goddard & Co.'s square form of Washington-Lyon's disinfecting chamber.

precaution that has to be taken in reference to this point is to warn the attendant not to raise too large a fire when using the hot-air blast; for, if this point be not considered, the air may attain a scorching temperature, and so damage the contents of the chamber.

The size of this disinfecting chamber is usually 5 feet × 5 feet × 6 feet 6 inches internally, although machines of smaller dimensions are also made. The following experiment, made on a new machine in 1893, gives an idea of the working of this apparatus :—

The fire was lighted at 10.8 a.m., the water in the jacket being cold, although the brickwork was still warm from the previous day's work. At 11.45 a.m. the pressure gauge showed 10 lbs. steam pressure, and at 12.0 noon it indicated 19½ lbs. pressure. The total time occupied for raising steam took one hour fifty-two minutes, and about 1 cwt. 1 qr. of coal had been consumed. The door was then opened for the admission of clothing. Three minutes were occupied in opening and four minutes in closing the door. At 12.10 p.m. the exhauster was set to work, and hot air was drawn through the chamber until 12.20 p.m., ten minutes in all. The chamber pressure gauge reached 5 lbs. at 12.20½ p.m.; 10 lbs. at 12.21½; 15 lbs. at 12.23; 19 lbs. at 12.27; and 20 lbs. at 12.31. During this period, from 12.20 to 12.31 p.m., the jacket pressure fluctuated between 19 and 20 lbs. At 12.23 p.m. the steam escaped freely from one of the doors which had presumably slightly sprung. This happened again subsequently, and had to be remedied by tightening the bolts securing the doors. At 12.31 p.m. the addition of feed-water to the boiler caused the pressure in the chamber to fall to 17½ lbs. Steam to the chamber was shut off at 12.35 p.m., and the chamber was then exhausted. From 12.35½ p.m. to 12.44½ p.m. hot air was again drawn through the chamber, and the door was opened at 12.48 p.m. A certain amount of vapour escaped through the door on opening, and some water was found at the bottom of the chamber. The goods which were hung up, consisting of overalls, were fairly dry and not damaged. A maximum thermometer which had been exposed in the chamber registered 260° F. The total process of steam raising and first disinfection occupied two hours and forty minutes, and the total fuel used amounted to about 1 cwt. 2 qrs. The time for disinfection only after steam has been raised was forty-eight minutes.

Dr. Whitelegge has been good enough to give the following figures relating to some trials made with this apparatus at Leicester in 1889. The process was similar to the foregoing, but the total time occupied was only twenty-seven minutes, which, apparently, was too little to secure penetration. The following are his results:—

When removed after disinfection, a horsehair pillow, weighing originally 2 lbs. 8½ ozs., was increased 1¾ ozs. in weight; it was damp inside but dry on cooling. The thermometer in centre indicated 241° F. A flock pillow was increased only ½ oz., the initial weight being 3 lbs. 8½ ozs. This was also damp inside, but dry on cooling. The thermometer at centre showed 234° F.

Three blankets, each folded into 16, piled one above the other on the floor, were wet at centre and bottom even on cooling, and the thermometer at centre indicated 166° F. Dr. Whitelegge also took the temperature of the chamber at different parts when the hot air only was admitted.

Temperature in hot-air inlet, touching the pipe, was	. . .	289° F.
,, on pillow 1 ft. from inlet,	,, . . .	252° F.
,, on floor near inlet,	,, . . .	247° F.

The temperature in chamber due to radiation and convection only, with and without air current, was as follows:—

The middle of floor	after 15 mins.	=239° F.,	or after 5 mins.	with ejector	only	237° F.
,, roof	,,	=245° F.,	,,	,,	,,	250° F.
The roof near door	,,	=239° F.,	,,	,,	,,	246° F.
The floor ,,	,,	=241° F.,	,,	,,	,,	241° F.

The other form of disinfector generally used in this country is that originally known as Washington-Lyon's, and is made by Manlove, Alliott & Co., Ltd., Nottingham. The leading points of difference between this and that made by Goddard & Massey are (1) that the boiler, except in the locomotive type, is usually kept distinct and separate from the disinfector, and (2) that the section is usually oval or round. As made during the past two years, the vacuum apparatus invented by Messrs. Alliott & Paton has generally been added, which is in itself a distinctive feature, although only of recent introduction. In Fig. 5 we show one of this firm's disinfectors of the old type, and in Fig. 6 the same fitted with Alliott & Paton's patent vacuum apparatus. Fig. 7 shows a portable steam disinfector for purifying wearing apparel and bedding in rural sanitary districts. This machine has a circular chamber 5 feet long and $2\frac{1}{2}$ feet diameter. The larger

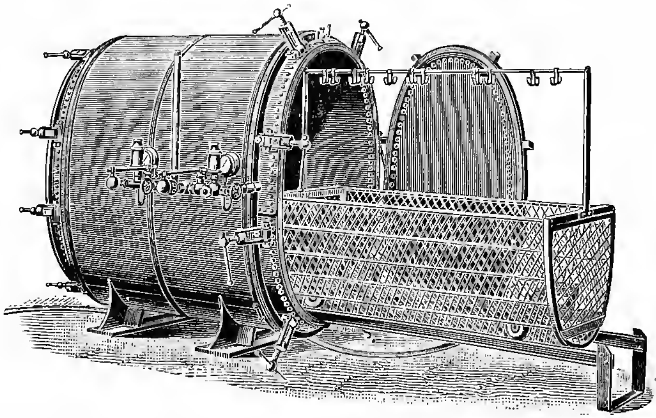


Fig. 5.—Manlove & Co.'s form of Lyon's disinfector (old type).

form shown in Fig. 8 has a chamber 7 feet × 4 feet 2 inches × 2 feet 7 inches, and is fitted with the vacuum apparatus.

With this class of apparatus, a special boiler is, of course, not necessary when steam can otherwise be obtained. The pressure in the steam jacket is maintained at 32 lbs. per square inch, but the boiler pressure may be anything above this, as steam entering the jacket is automatically reduced to the required pressure. In the chamber, the steam pressure is maintained (also automatically) at 22 lbs. In apparatus not fitted with the vacuum arrangement, the pressures in jacket and chamber are usually 25 lbs. and 20 lbs. respectively. The higher pressure in the first case is found more convenient for the double purpose of air heating and extraction. This machine when fitted with the vacuum apparatus, may also be used as an efficient dry heat disinfector, since hot air is admitted into a partial vacuum, which, in other words, is equivalent to working with hot air under pressure. The air is heated by passing it through pipes surrounded by steam at a constant temperature, and the danger of scorching is thereby obviated. The larger sizes of the machine are

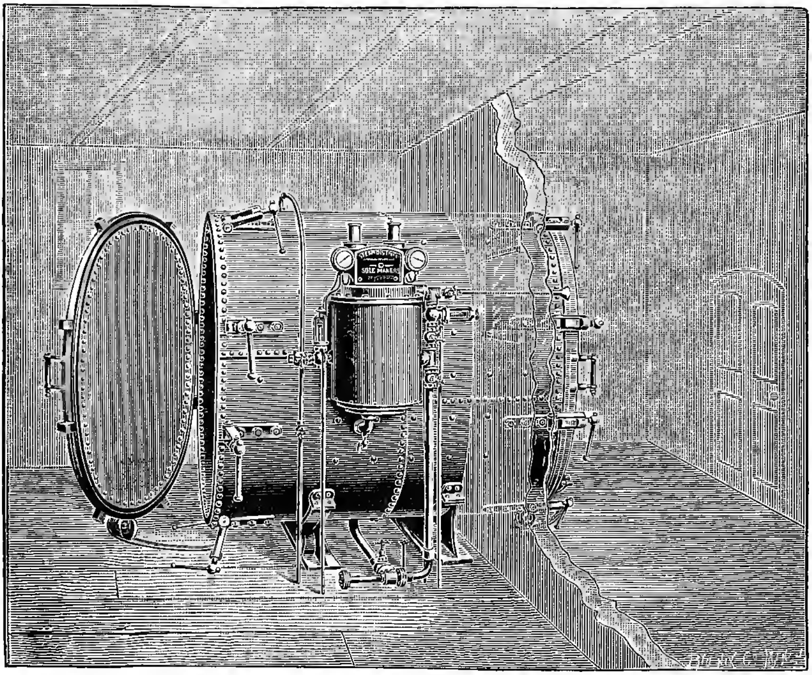


Fig. 6.—Manlove & Co.'s form of Lyon's disinfector fitted with a vacuum apparatus.

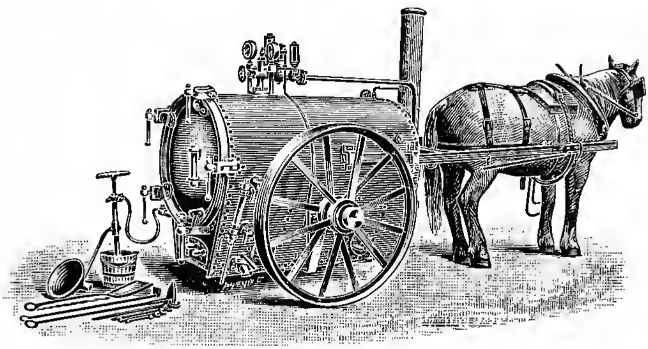


Fig. 7.—Portable steam disinfector (Manlove & Co.).

usually oval in section, and the smaller sizes round. This is presumably with the object of obtaining greater strength and durability, and in the oval form the largest articles can be disinfected without great expenditure of ground space. The separate boiler admits of ample inspection in the ordinary ways, and, if erected at the same time as the disinfector, contains, in the most recent designs, arrangements for burning the whole of the gases exhausted from the disinfection chamber before passing them into the atmosphere. The best mode of working this apparatus under ordinary conditions is to admit a current of hot air for a few minutes, then obtain a vacuum, and break it with steam at 20 lbs. pressure. The steam having done its work of disinfection is discharged, a vacuum is again obtained, and a current of hot air

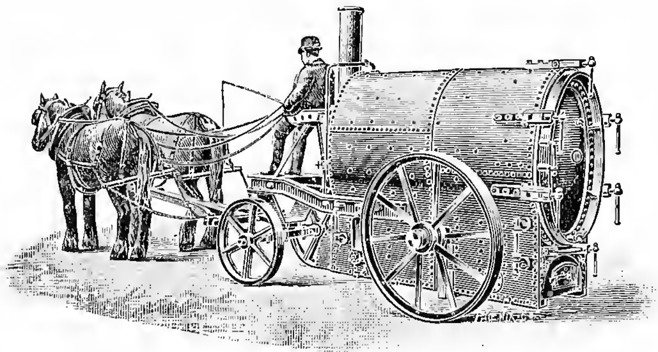


Fig. 8.—Larger form of portable steam disinfector with vacuum apparatus (Manlove & Co.).

completes the process. In the experiments on a medium size machine, details of which are given below, this course was not closely followed, as it is the best only when the machine is very full, or the articles are bulky.

EXPERIMENTS ON A WASHINGTON-LYON'S PATENT STEAM DISINFECTOR WHEN FITTED WITH ALLIOTT & PATON'S PATENT VACUUM APPARATUS.

No. 1.—Charge, 4 mattresses and 4 pillows. Weight before disinfection = 109 lbs. 1 oz.

11.30 a.m.	doors closed.		
11.32 ,,	vacuum	16″	broken by hot air.
11.34½ ,,		0	
11.36½ ,,	,,	15″	,, ,,
11.39 ,,		0	
11.41 ,,	,,	15″	,, steam.
11.43 ,,		0	
11.47 ,,	steam	15″	maintained till 11.50 a.m.
11.52 ,,		0	
11.55 ,,	vacuum	11″	broken by hot air.
11.57 ,,		0	

11.58 a.m.	vacuum	10″	broken by hot air.
12.0 noon		0	
12.2½ p.m.	,,	16″	,, ,,
12.4½ ,,		0	
12.6¾ ,,	,,	16″	circulation by hot air begun.
12.9 ,,	,,	10″	,, ,,
12.12 ,,		0	doors opened.

Total time = 42 minutes.

Total increase in weight = 1 oz., or 0·05 per cent.

No. 2.—Two blankets fresh from the laundry wringing machine were next put in the disinfector. One blanket contained a large amount of soap, and it was noticeable that this one took far longer to dry than the one which was comparatively free from soap.

Before disinfection, the total weight was 15¾ lbs. After 50 minutes one blanket was nearly dry, and weighed 3 lbs. 3 ozs. The soapy blanket weighed 4 lbs. 2 ozs., and was perceptibly moist.

The two, therefore, weighed 7 lbs. 5 ozs., or a *reduction* in weight of 54 per cent.

These blankets were then put back into the machine and completely dried, their total weight in that condition being about 6¾ lbs.

No. 3.—Subsequently, a charge of bedding was treated, consisting of blankets, pillows, sheets, &c.

The total weight before treatment was 29⅜ lbs.

,, after ,, 28 ,,

Total time = 35 minutes.

Diminution in weight = 1 lb. 6 ozs., or 4½ per cent.

In none of the foregoing experiments were the articles in any way damaged.

Dr. Whitelegge also made some experiments on this form of machine in 1889, when it was not fitted with the vacuum apparatus. Permission has kindly been given to refer to them here, but space does not allow of their being dealt with as fully as they deserve :—

Steam was admitted to the jacket at 10 lbs., but the steam entered the chamber at a pressure of 5 lbs. only. A thermometer was placed inside one of the bulky articles to be treated, and so connected as to ring an electric bell outside when a temperature of about 220° F. was reached.

The door was closed at 12.35.

Steam was turned on at 12.37.

5 lbs. pressure in chamber at 12.38.

Bell rang 12.53½ (the bell ceased in 20 seconds upon intermitting the pressure immediately after this).

Steam was shut off at 12.56.

Door slightly opened to facilitate drying at 1.0.

Door opened wide, dry air inside, 1.5.

(*a*) Horse-hair pillow (2 lbs. 7½ ozs.) weighed 2 lbs. 9½ ozs., and was damp in centre, but dry on cooling. The electric thermometer at centre rang in 15 minutes, and corrected reading gave 223° F.

(*b*) A flock pillow (3 lbs. 6¾ ozs.) weighed 3 lbs. 9 ozs. (?), and was damp in centre, but dry on cooling. The corrected temperature was 219° F.

(*c*) Blue Saxony flannel $\frac{21\frac{1}{4}}{21} \times \frac{15}{15}$ afterwards measured $\frac{20\frac{3}{8}}{20\frac{5}{8}} \times \frac{14\frac{1}{2}}{14\frac{1}{2}}$ and was slightly yellow, but not felted.

(*d*) White, unshrinkable flannel $\frac{21\frac{1}{4}}{21} \times \frac{15\frac{13}{16}}{15\frac{14}{16}}$ measured afterwards $\frac{20\frac{7}{8}}{21\frac{1}{8}} \times \frac{15\frac{6}{8}}{15\frac{5}{8}}$. This also was slightly yellow, but was not felted.

(*e*) Six samples of coloured silk, pleated, were unchanged, except that the dark green became wet and black. These had been placed near the door.

(*f*) Thick book (*Churchill's Directory*) on floor was cool inside. Thermometer placed uncovered in other parts of machine showed temperatures varying from 228° F. to 234° F.

A further experiment was then made on following lines :—

Door was shut at 1.21 p.m.

Steam admitted 1.22.

Full steam pressure attained in chamber (5 lbs.) 1.23.

Pressure was intermitted at 1.31.

Bell rang at 1.35.

(*a*) Two blankets, each folded into sixteen layers, laid one above the other on the wooden floor, were damp on removal, and dry on cooling.

The electric thermometer at centre—*i.e.*, with sixteen layers of cover—showed a corrected temperature of 228° F. The bell rang in 12 minutes.

Another experiment was made with low-pressure steam, with ½ lb. pressure in both chamber and jacket.

Door was closed at 2.17.

Steam at ½ lb. pressure in chamber at 2.20.

Bell rang at 2.37.

(*a*) Two blankets arranged as before were wet, but became immediately dry on shaking. The bell rang in 17 minutes, and the thermometer showed a temperature of 214° F.

(*b*) Horse-hair pillow came out steaming, and thermometer indicated 216° F. at centre.

(*c*) A flock pillow came out steaming, and the thermometer at centre indicated 213° F.

It is noteworthy in Dr. Whitelegge's experiments, that when steam at 5 lbs. pressure was used the thermometer at centre of blankets registered 228° F. in twelve minutes, and that when steam at ½ lb. pressure was used the thermometer, under apparently identical conditions, indicated only 214° F. after seventeen minutes, and also in the latter case pillows were taken out steaming. Although the types of disinfecting apparatus described are not absolutely the only ones used in this country, probably more than three-fourths of those erected in the past ten years have been of these types.

TYPES OF DISINFECTORS USED ON THE CONTINENT.

1. **Austria—Thursfield's Apparatus.**—On the Continent, several foreign designs have been extensively used, and some of these are

occasionally to be met with in this country. Fig. 9 represents a portable form of apparatus used to some extent in Austria, and

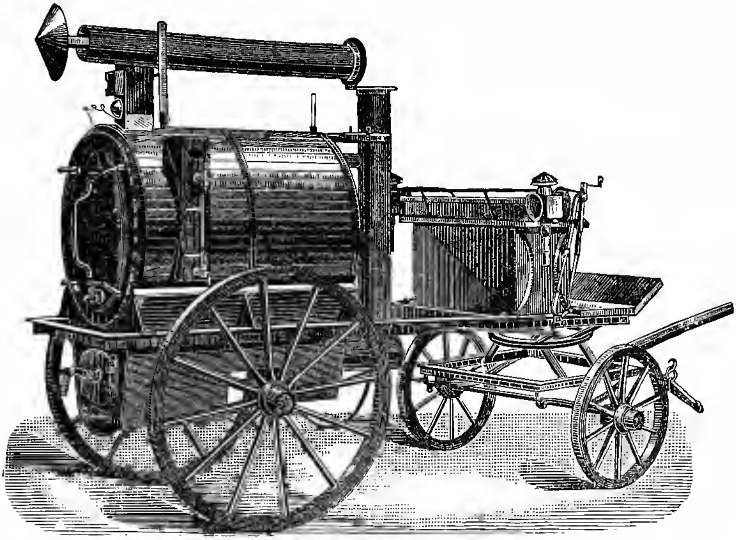


Fig. 9.—Thursfield's portable disinfector (large).

designed by Mr. Thursfield, of Vienna. It is, in the modern patterns, usually circular in section and jacketted; the jacket is partially filled with water, and acts as a boiler with the fire underneath. The boiler is open to the atmosphere, and, therefore, when steam is admitted to the chamber it is only at 212° F. A continuous current of steam is kept passing through the chamber, and as the latter is jacketted by the boiler casing, condensation is largely minimised, and the inventor states that clothing removed after treatment is only slightly damp. After each disinfection the boiler is partially refilled with cold water, and, consequently, ebullition ceases for a time. It is stated that the boiler contains 20 gallons of water, and can generate steam in twenty-five minutes from water at 50° F.; the total time required for one disinfection is said to be sixty-eight minutes.

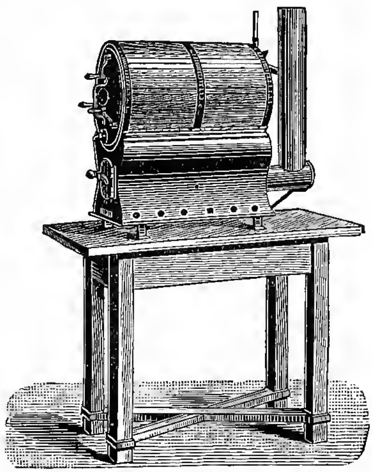


Fig. 10.—Thursfield's portable disinfector (small).

Maximum thermometers placed inside different articles registered 218° F. The consumption of fuel during the above trial was said to have been only 7 lbs. wood and 19 lbs. of coal. A smaller form of the Thursfield disinfector is shown in Fig. 10.

2. France—The Equifex Stove.—A common type of apparatus in France is that made by Geneste, Herscher & Co., of Paris. This machine is externally not unlike those of Washington-Lyon, although its construction is materially different, inasmuch as there exists no steam jacket, and only comparatively low-pressure steam is employed. It is made in several sizes and types, which may be briefly described as follows:—

(1) It is a fixed machine working with steam at from 7 lbs. to 10 lbs. per square inch; consequently the maximum temperature to which the infected articles are exposed is from 230° F. to 240° F. The large size is commonly 6 ft. diameter and 13 ft. 6 in. long, inside of which are two sets of steam-pipe coils. Each set consists of eleven pipes running the whole length of the machine, one being placed at the top, the other at the bottom of the chamber. These coils are so arranged for drying purposes, and to prevent condensation. Arrangements are made to enable the air to escape through a pipe at the bottom of the disinfector pending the admission of steam, with which the disinfecting process is commenced. When the pressure has reached 7 lbs. to 10 lbs., the steam is exhausted and a fresh quantity admitted. In this way the inventors claim that sufficient penetration is secured without the aid of steam at a higher pressure, and also that it is only necessary that steam at 10 lbs. be actually in contact with the goods for not less than fifteen to seventeen minutes, in addition to the time taken in filling and exhausting the chamber, which should be done not less than three times during the operation. Before the goods are taken out it is recommended that they be left in the closed machine for some time to dry, although the precise time taken by this process is not clear.

(2) Messrs. Geneste, Herscher & Co. also make a type to work at from 2 lbs. to 5 lbs. pressure with current steam. In this machine the temperature to which the goods are exposed does not exceed 217° F. to 222° F. The inventors make a point of bringing the steam into the chamber at the top and extracting it at the bottom, and say that the air in the chamber is thereby effectively driven from the chamber. The steam pressure in the case of this machine is too low to make the relaxation and renewal of pressure of any benefit to penetration. The steam is only nominally "current" because the outlet is governed by a modified form of reducing valve. A feature of the apparatus is that the two doors are so interlocked

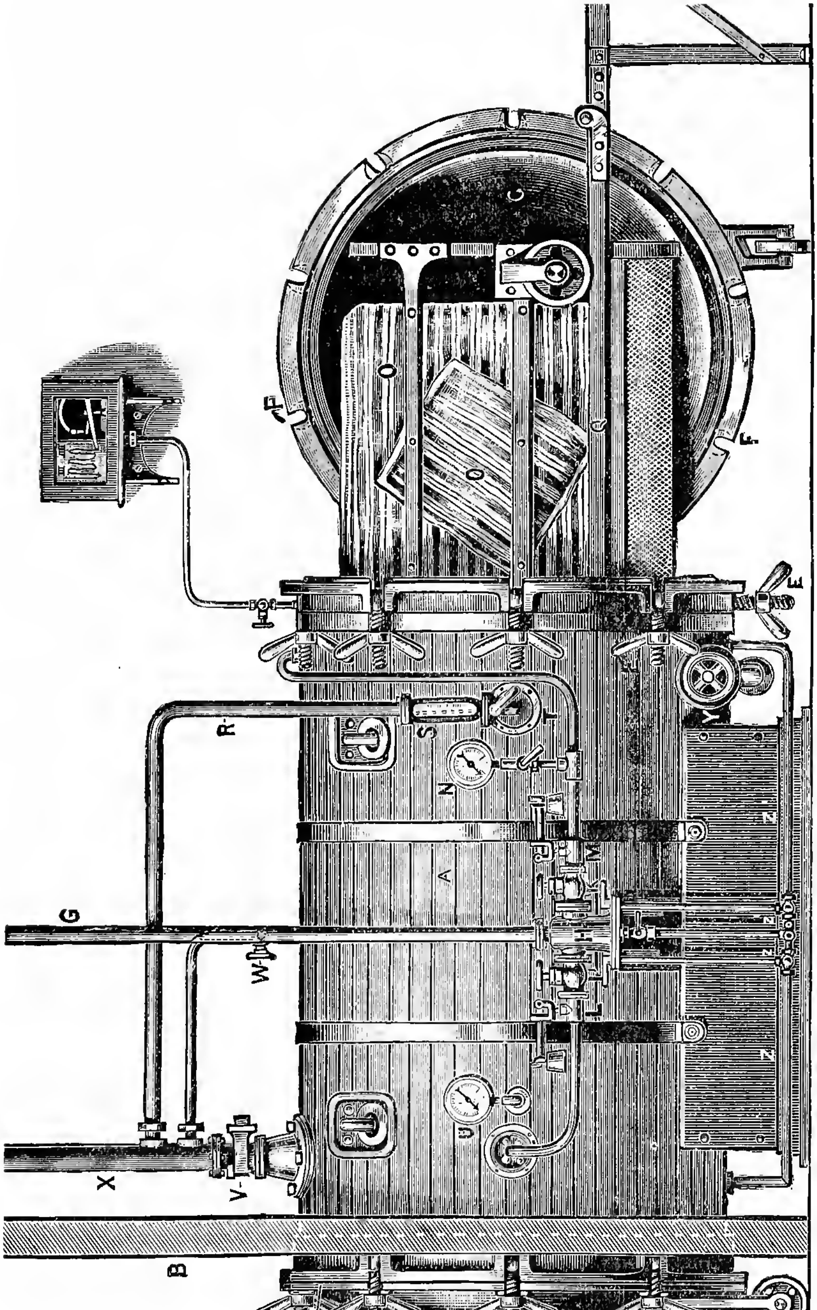


Fig. 11.—The Equifex horizontal steam disinfecting stove.

that it is impossible to have the two doors open at the same time, but otherwise the arrangements of this type are similar to those in the other. In Fig. 11 we give an illustration of an Equifex horizontal stove working with confined steam.

The disinfecting chamber, A, is a wrought-iron cylinder without jacket or other means of superheating the steam, but lagged with wood and coated with a non-conducting composition. The stove usually passes through a partition, B, to separate the infected objects from the disinfected. The doors, C, D, are fitted with an arrangement making it impossible for both to open at the same time, and are secured by nuts, E, locking into solid steel recesses, F, on the door. A row of steam tubes runs longitudinally inside the stove for warming the stove before and during disinfections, and for heating the air which is used in the subsequent drying of thick objects. The steam is led to the stove by a pipe, G, from the boiler, and, after traversing a separator, H, passes through the reducing valves, I, K, and safety valves, L, M, to the stove and tubes respectively. When the desired pressure is reached in the tubes, as shown by the gauge, N, steam begins to escape through the safety valve, M, and the attendant then regulates the pressure by the reducing valve, K. The stove, having thus been warmed, is charged with the objects, O, to be disinfected, which are loaded in the ordinary way on to a wheeled carriage, P, running on rails within the stove, and on hinged rails, Q, outside. The door is then closed, and locked with the safety nuts, E, and the valve, I, is opened, allowing steam to pass through the safety valve, L, into the body of the stove. The steam enters the stove through an internal sparge-pipe fitted longitudinally inside it towards the top, and furnished throughout its length with a screen to assist in the thorough projection of the steam to all parts of the stove. The steam is at first allowed to escape through the air discharge pipe, R, and carries with it the air from the stove. The discharge pipe, R, is fitted with a thermometer, S. When the air is ejected, the mercury will rapidly rise to 195° to 205° F., at which point the valve, T, controlling the pipe, R, is closed. The steam continues to enter the stove through the valve, I, till it reaches a pressure of 10 lbs. per square inch, as marked on the gauge, U, when it escapes through the safety valve, L, until the attendant has regulated the pressure by the reducing valve, I. A film of water is formed throughout the pores of the object under a pressure just sufficient to keep it from evaporating. Advantage is taken of this fact to get rid of the air secreted originally in the pores of the object by shutting off steam occasionally (say every five minutes) by means of the valve, I, and opening the sluice valve, V. The sudden reduction of pressure so effected causes a sudden re-evaporation of the condensed steam in the objects; so what was water in the pores expands into steam of some sixteen hundred times its volume, sweeping out before it the air from the pores. To assist this process the stove is fitted with a pneumatic exhaust, operated without any moving parts by the steam pressure. For this purpose a jet of steam is allowed, by means of the valve, W, to pass up an aspirator or ejector fitted in the steam discharge pipe, X, so automatically sucking out both the steam and the air ejected from the pores, and producing a partial vacuum under which the vaporisation of the steam and the ejection of the air is completed. With objects of ordinary thickness disinfection is complete in fifteen to seventeen minutes. Steam is then let off as before; and ou the door being opened, all objects such as blankets, clothes, &c., are taken out and shaken, when they will be found to be perfectly dry. Mattresses and thicker objects are replaced in the stove for five minutes for the aspirator to withdraw the steam.

3. **Denmark—Reck's Apparatus.**—In Denmark, Mr. A. B. Reck, of Copenhagen, has designed an apparatus which contains some features of novelty; but, like most of the foreign apparatus, it does not aim at so much as those of English design, and he is content to disinfect "in such a manner that things would be spoiled by steam as little as possible." The inventor attributes the presence of moisture in goods almost entirely to the inrush of cold in the presence of vapour, and his improvements are directed towards diminishing this evil. After the goods have been steamed (at about $1\frac{1}{2}$ lbs. pressure), a spray of water is injected at the top of the chamber in such a way as not to impinge on the clothes, and, simultaneously, a large air valve is opened at the

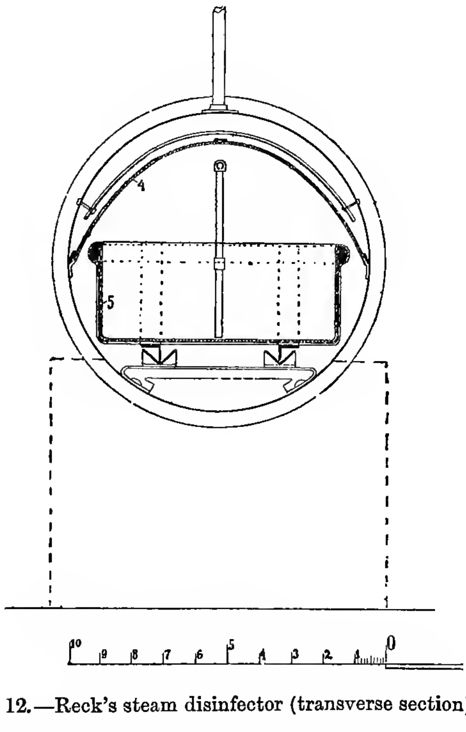


Fig. 12.—Reck's steam disinfector (transverse section).

bottom. It is claimed that the steam contained in the chamber rises to the top, is condensed by the cold water spray, and the momentary partial vacuum so produced is re-occupied by air rushing in at the bottom of the chamber. In this way the whole of the vapour is condensed and carried away with the water, and when the chamber door is opened cold air only is present. The main difficulty of condensation on the clothes during disinfection due to radiation, and their own low temperature, is not dealt with in any way, either by steam jacketting or preliminary heating by hot air.

In Figs. 12 and 13 we show two sectional views of Reck's apparatus. Dr. Reid has lately tested this form of disinfector, and has reported favourably upon it to the Stafford County Council.

4. Germany—Schimmel's and Budenberg's Apparatus.—A disinfecting apparatus largely used in Germany is that made by Oscar Schimmel,

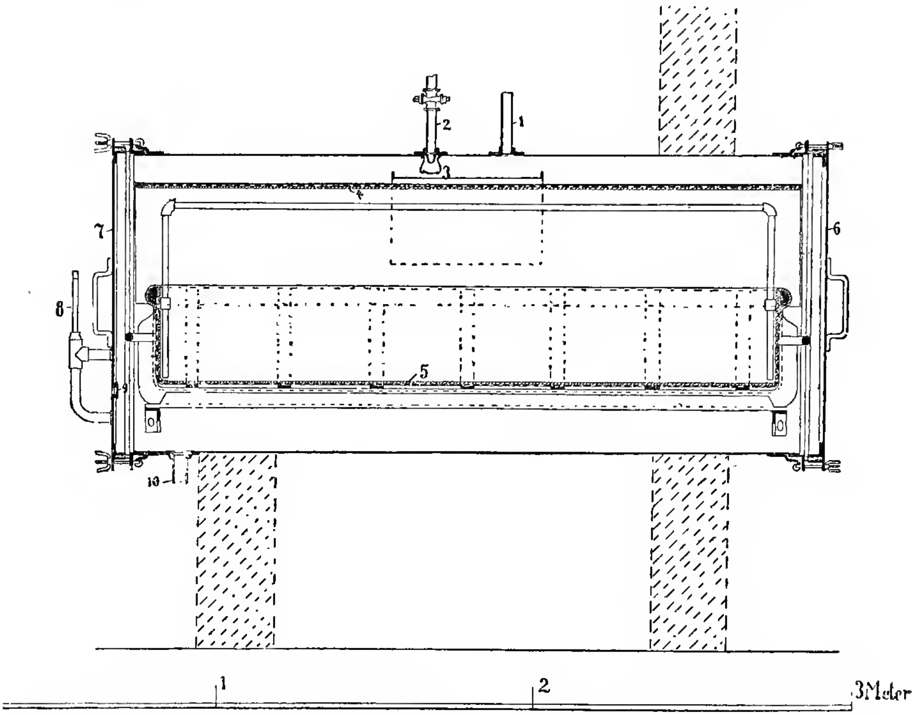


Fig. 13.—Reck's steam disinfector (longitudinal section).

of Chemnitz. There is nothing very striking in its design, and probably the explanation of its extensive use may be found in the fact that it was one of the first to be placed on the market. The claims made are, broadly speaking, three. First the clothes are warmed by hot air to a temperature of 60° C.; secondly, they are steamed by current steam at atmospheric pressure; and lastly, they are partially dried, and aired again by warm air. No pretence is made that the articles come out perfectly dry, or that the process is a rapid one, but it is justifiably claimed that articles which are not too bulky are disinfected, and also that the first cost of the apparatus is moderate.

Fig. 14 shows a small vertical type with steam-generating apparatus and fire beneath. Steam rises round the chamber in which the clothes are situated, and enters at the top and leaves at the bottom, while condensed steam returns to the boiling apparatus. Great care would have to be exercised to see that water never ran short in the domed bottom, for it is very small in quantity, and would need frequent

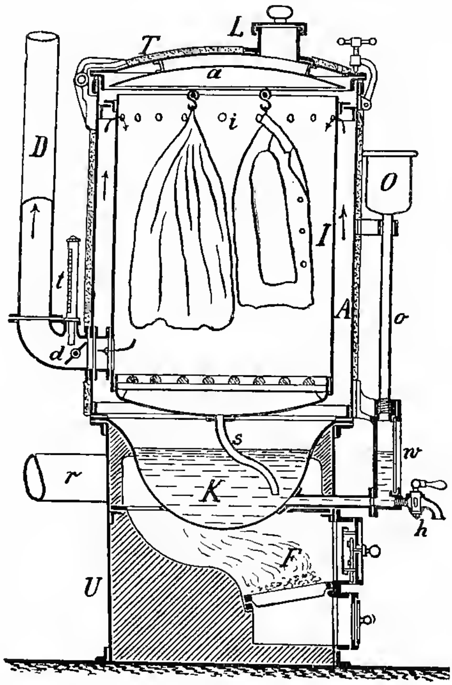


Fig. 14.—Schimmel's vertical steam disinfector.

replenishing by hand through the funnel. When a charge has been disinfected, the fire has to be drawn in order that steam may be prevented from passing into the chamber. To obtain air circulation, a small door is removed in the crown, and, the exhaust pipe being also open, a certain air circulation is obtained owing to the heat retained in the clothing and walls of the chamber.

In the larger size shown in Fig. 15, which is oval in section, more elaborate arrangements are provided for air heating, &c., and steam has to be obtained from a separate boiler. The gilled pipes at the bottom are filled with steam at boiler pressure, and thus to some extent they check condensation in the chamber when steam at atmospheric pressure is admitted. Air circulation is again obtained entirely by the crude method of opening a small door at the bottom of the

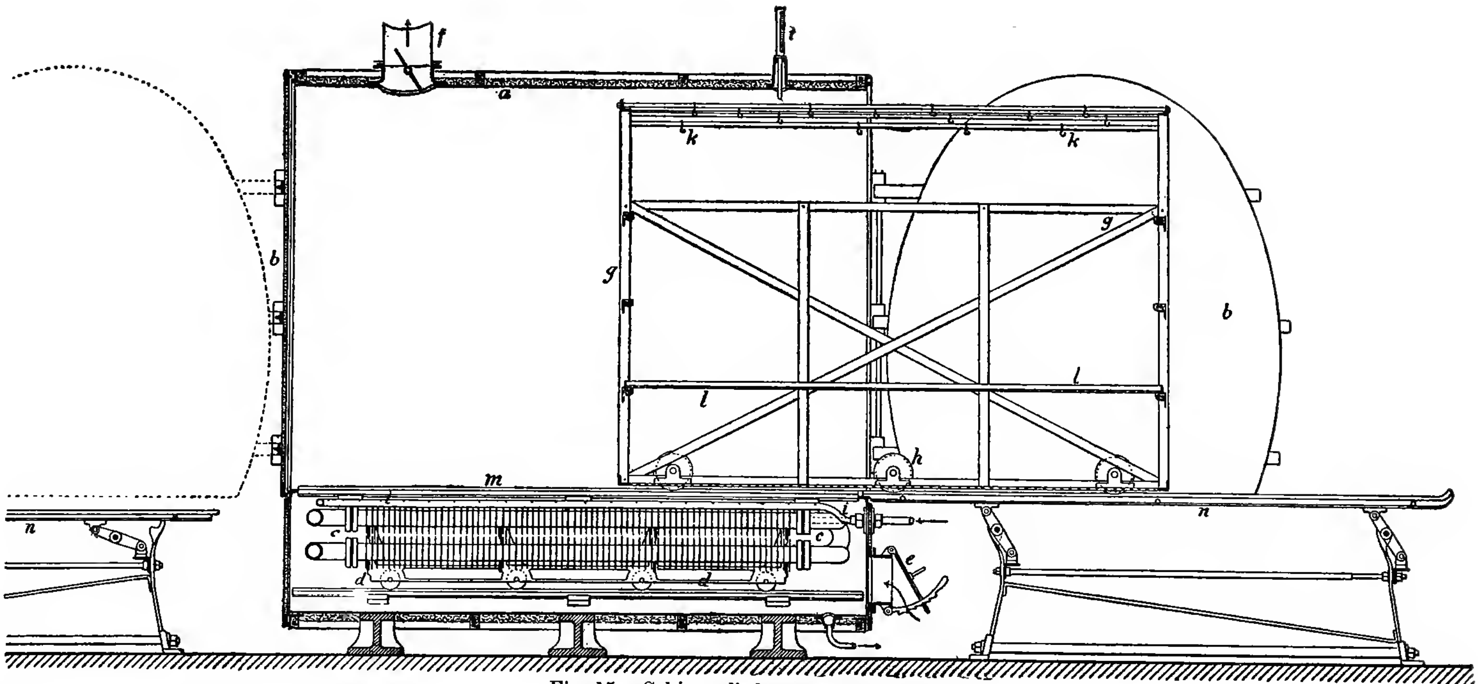


Fig. 15.—Schimmel's large steam disinfector.

chamber close to the gill pipes, and allowing it to rise and escape at the top by the exhaust pipe. Machines of this type have been at work in Berlin for about ten years. In the larger apparatus it is usual to admit current steam to the chamber at about $1\frac{1}{4}$ lbs. pressure. It is necessary when working the apparatus, first to warm it up by hot air for not less than thirty minutes, and then, after putting in the goods, to again warm them for thirty minutes or thereabouts. Steaming is said to take about thirty minutes (although this must surely depend largely on the articles being treated), and the final drying occupies another fifteen minutes. The whole process, including loading and unloading the truck, should, therefore, mean an expenditure of time amounting to nearly two hours; and, even when taken out, the articles are supposed to undergo a further process in an ordinary drying closet.

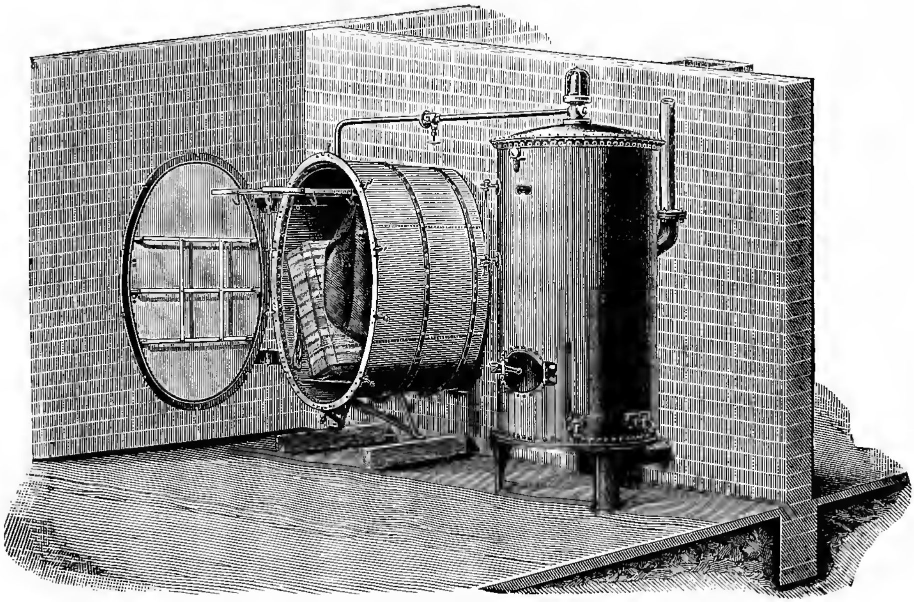


Fig. 16.—Budenberg's steam disinfecting apparatus.

The general arrangements of Schimmel and Geneste Herscher's apparatus all bear a considerable resemblance the one to the other, and it is difficult to see how the actual work done by the various designs should be very different in result. It is, therefore, to the credit of Herr Oscar Schimmel that he should almost alone admit the weaknesses of his apparatus, and at the same time give financial reasons as a valid excuse. The apparatus of W. Budenberg, of Dortmund, works at about 3 lbs. pressure, and is very similar to that of Geneste Herscher's (Fig. 16). It has been carefully studied by Dr. Hahn.*

United States.—In the United States the apparatus of Geo. V. M'Lautlin & Co., of Boston, is used to some extent, as is also that of Washington-Lyons. M'Lautlin's machine bears a very close resemblance to Geneste Herscher's apparatus, the only appreciable difference being that it is built in an apparently more substantial manner to enable it to work with steam at a pressure exceeding 10 lbs. Generally speaking, disinfecting apparatus on the Continent is built with rather a different object in view to that which obtains in this country. It is not regarded as essential for the clothes to come out absolutely dry; and if they have to be dried by some other means after treatment, that is not considered prejudicial to the machine.

Time, also, is not valued to the same extent as in this country, whereas first cost is a matter of the greatest importance. As a consequence, a cheaper machine is produced, which disinfects at the expense of wetting the goods after a more prolonged exposure. These conditions do not obtain generally in this country, for frequently, owing largely to recent regulations, the whole of the clothing and bedding of a family have to be disinfected and returned ready for use within one or two hours, whilst the family is housed at the public expense pending the chemical disinfection of their own room. The public sentiment is also in favour of purchasing things of the most durable nature, in spite of the fact that their first cost may be greater. Lastly, the use of low-pressure steam is not largely favoured, because very bulky articles, such as bales, cannot be disinfected in machines using it; whereas, high-pressure machines can not only deal with the bulkiest articles, but can always, if desirable, be used with low-pressure steam with equal efficiency.

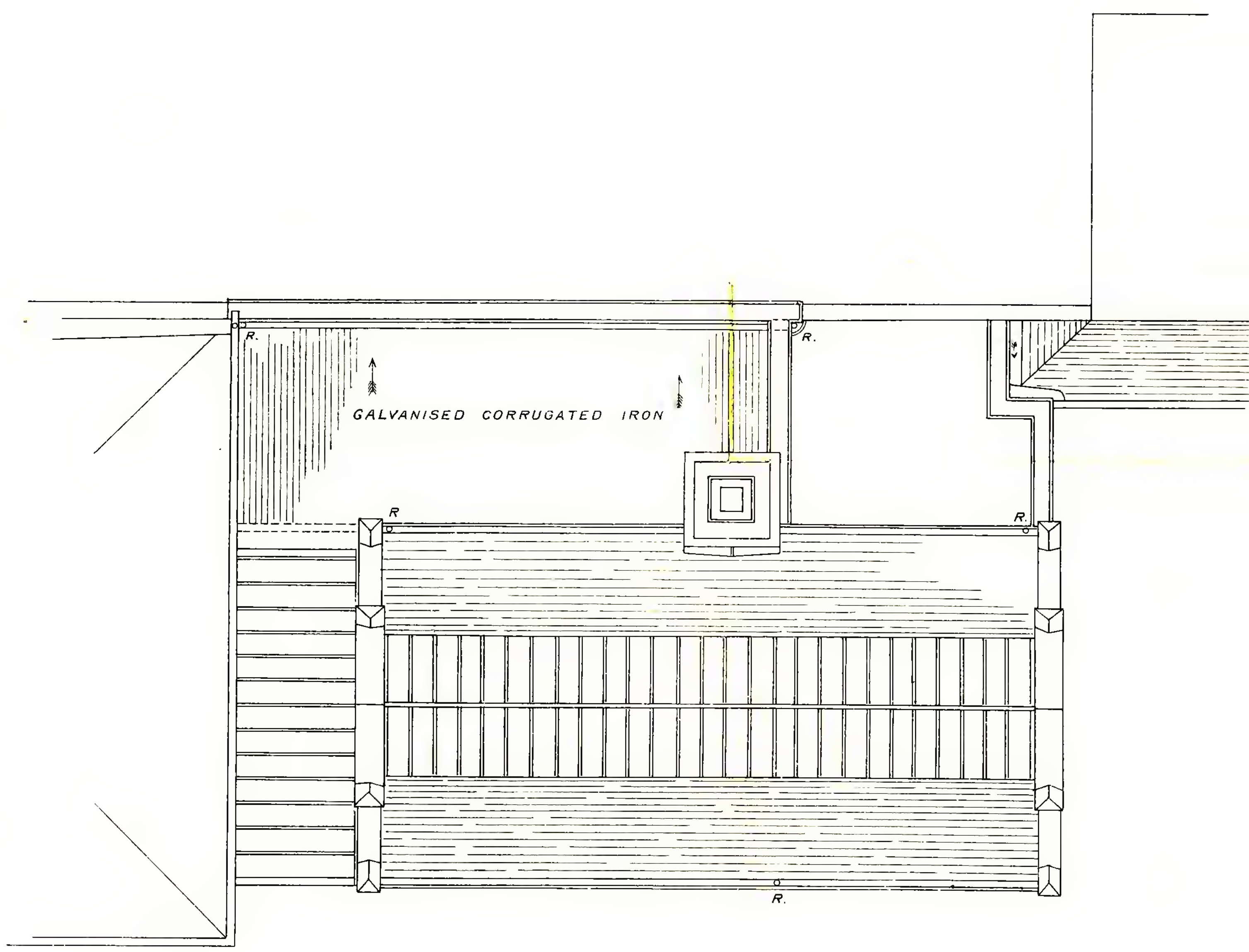
It is probably for these reasons that low-pressure disinfectors have been tried, and very largely abandoned at home.

PUBLIC INSTALLATIONS.

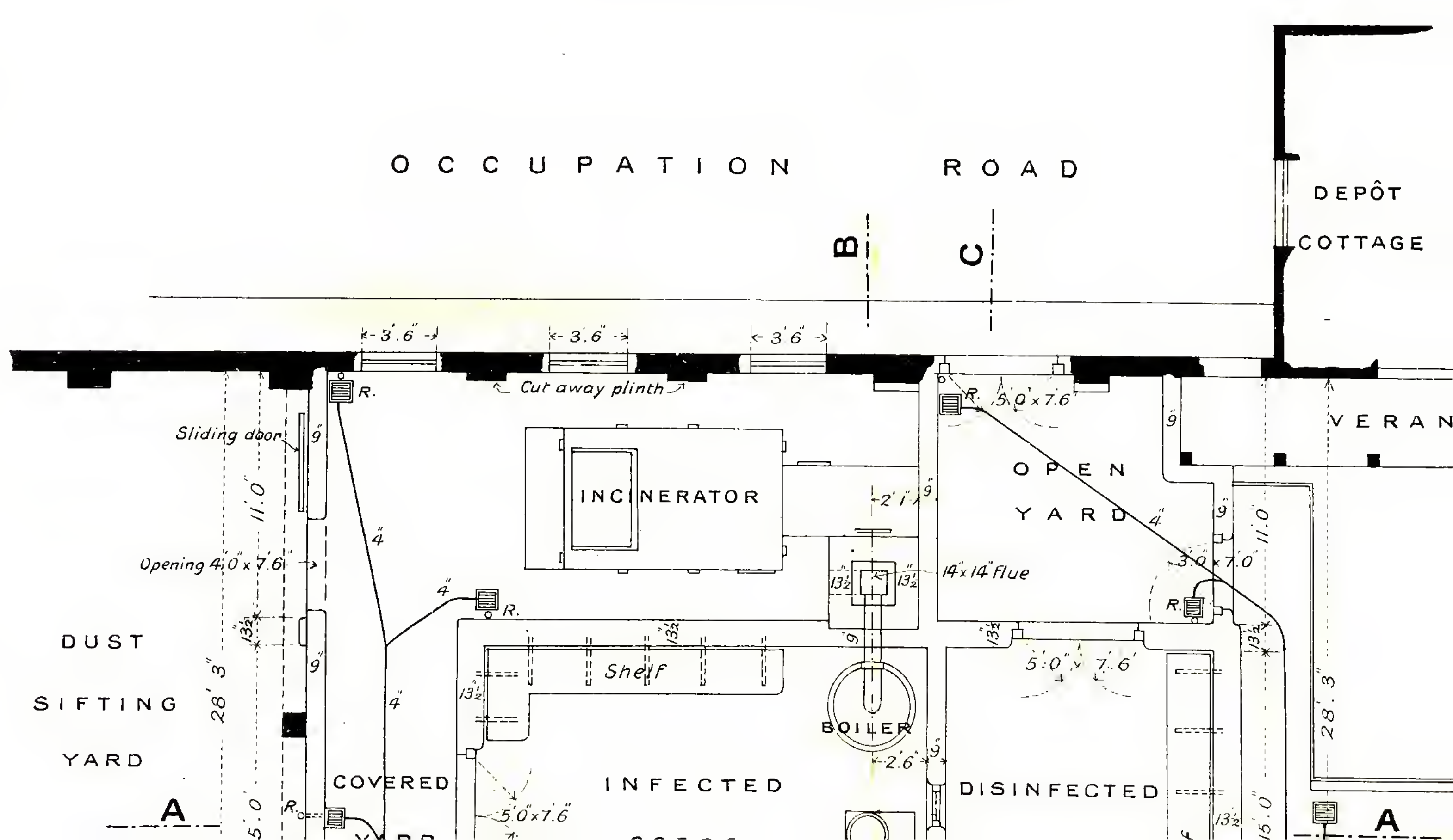
Plan of a Disinfector House.—The main point which has not yet been dealt with in this chapter is the arrangement of building and appurtenances requisite for a public installation. Owing to the courtesy of Mr. Rowland Plumbe, F.R.I.B.A., of London, the drawings of the disinfector house and incinerator at present being erected for the Vestry of St. Mary's, Newington, are shown in the plate opposite. The particular arrangement is not one which must be followed in every instance, for each case has to be treated on its

* *Deutsch. Medic. Wochensch.*, 1890, No. 12.

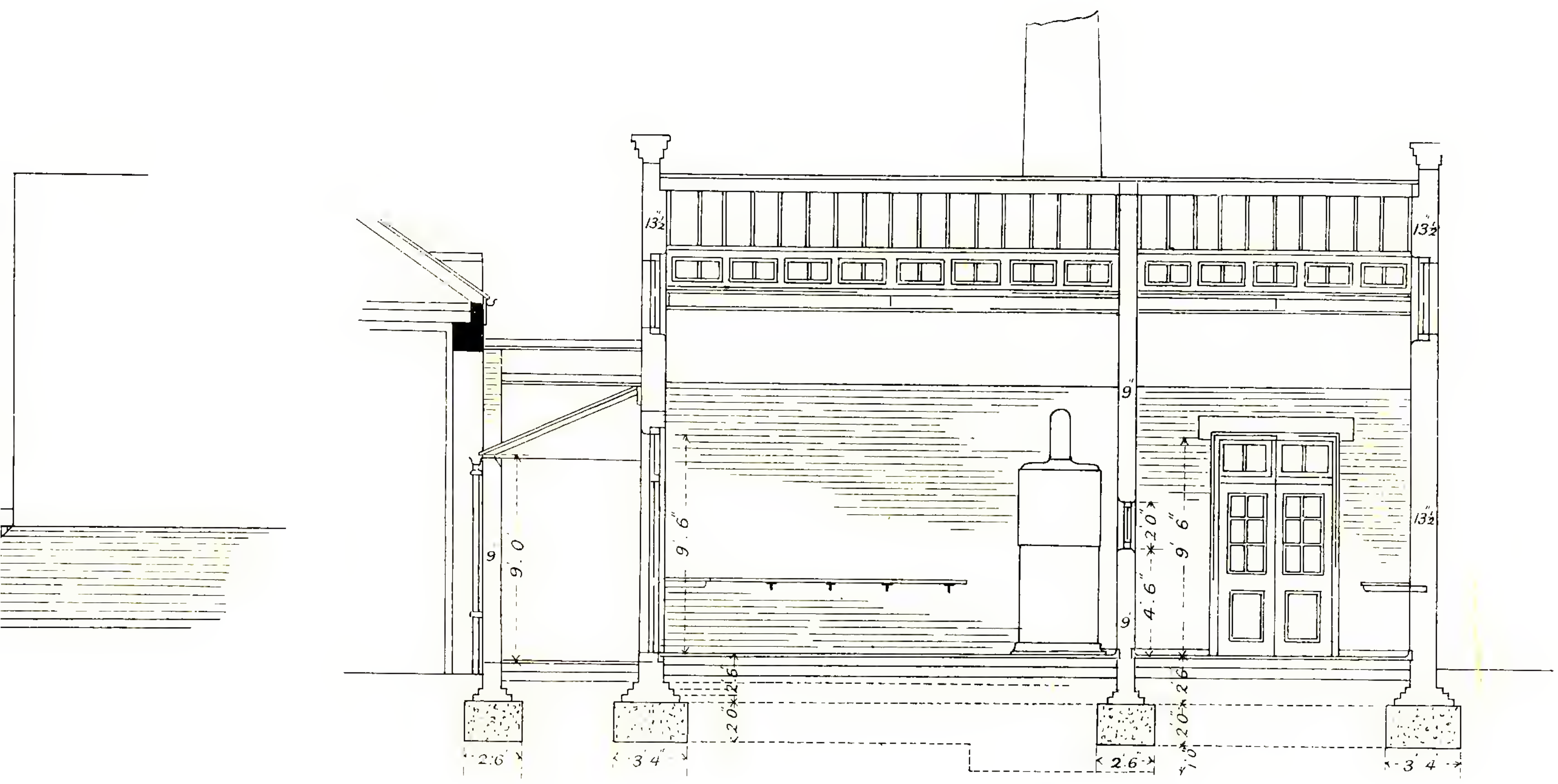
NEWINGTON VESTRY, NEW DIS



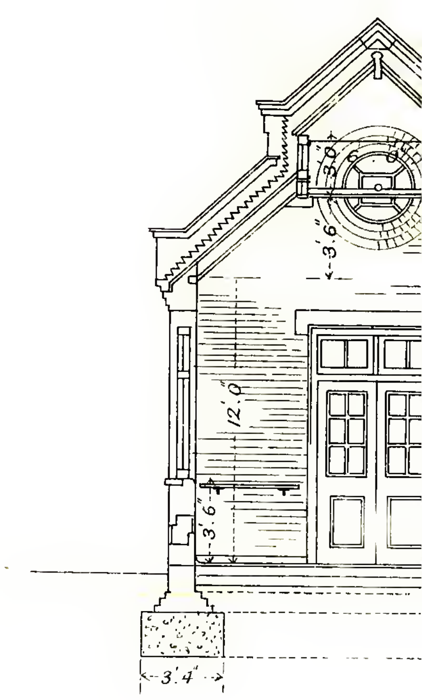
ROOF PLAN.



DISINFECTOR AND INCINERATOR



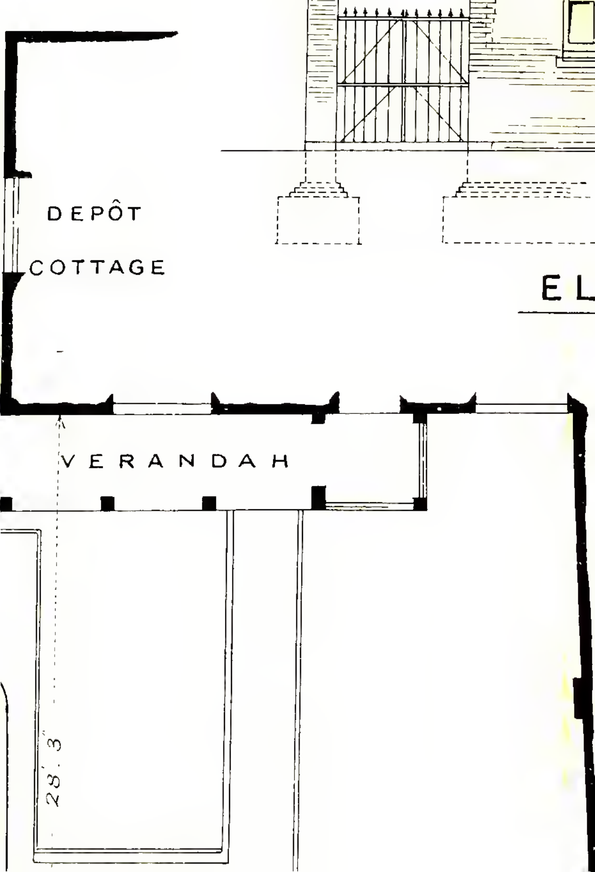
SECTION A. A.

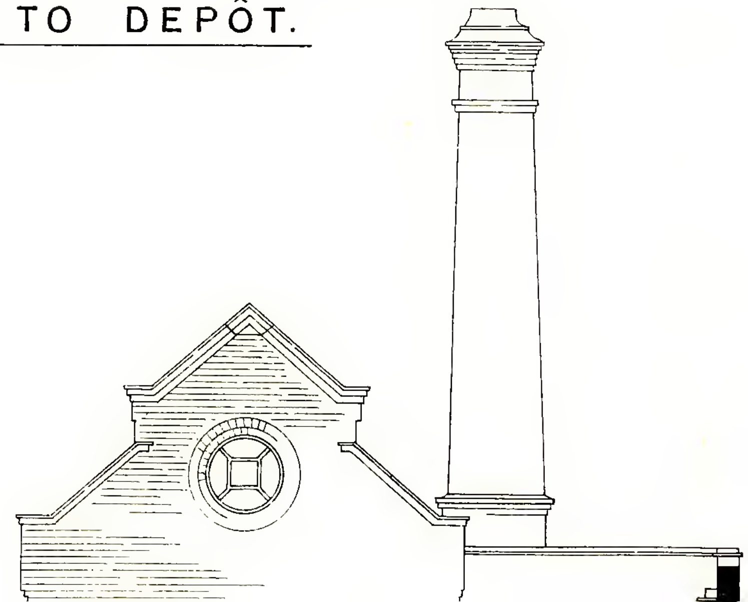


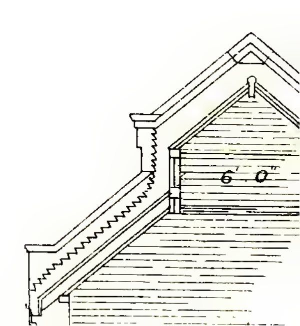
SEC

ELEVATION TO DEPÔT.

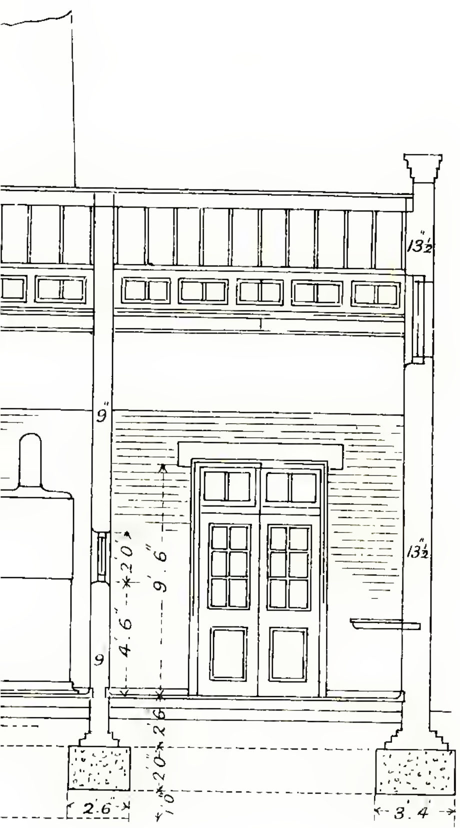
ELEVATION



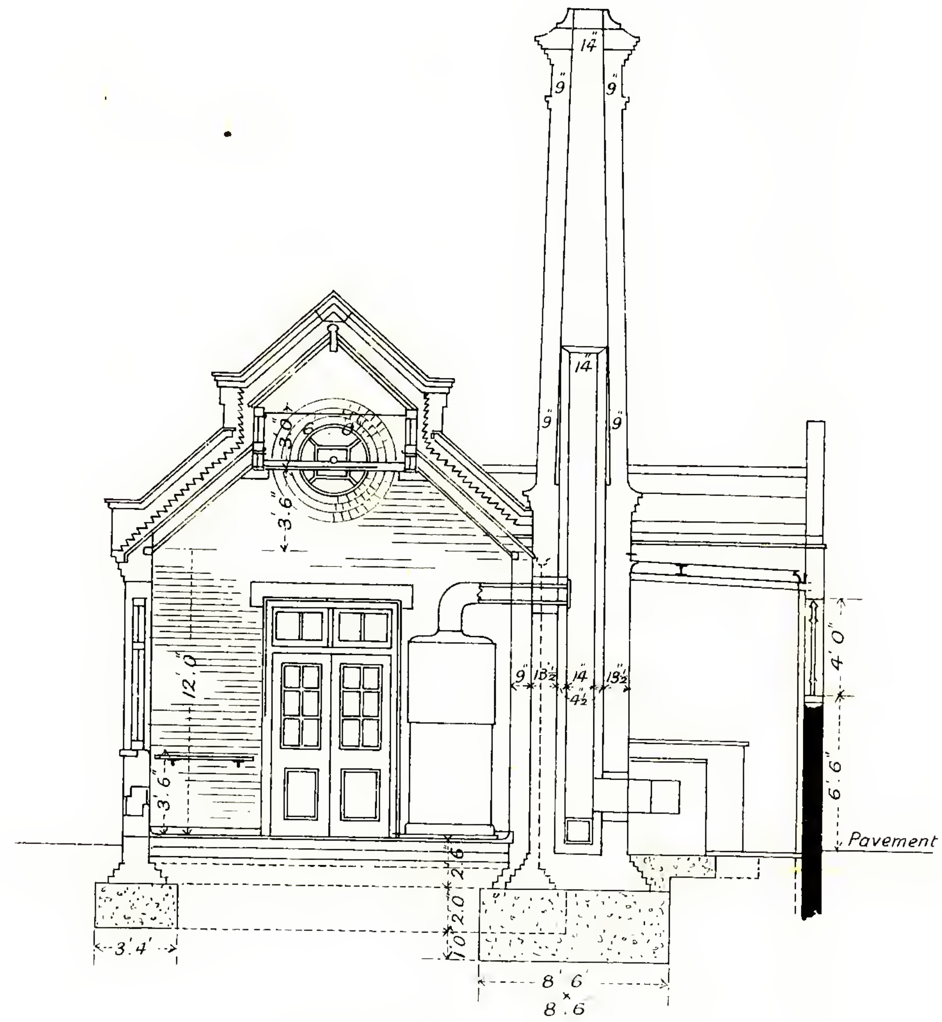




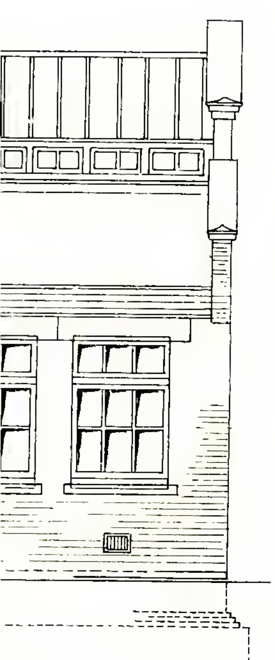
NERATOR.



A. A.



SECTION B. B.



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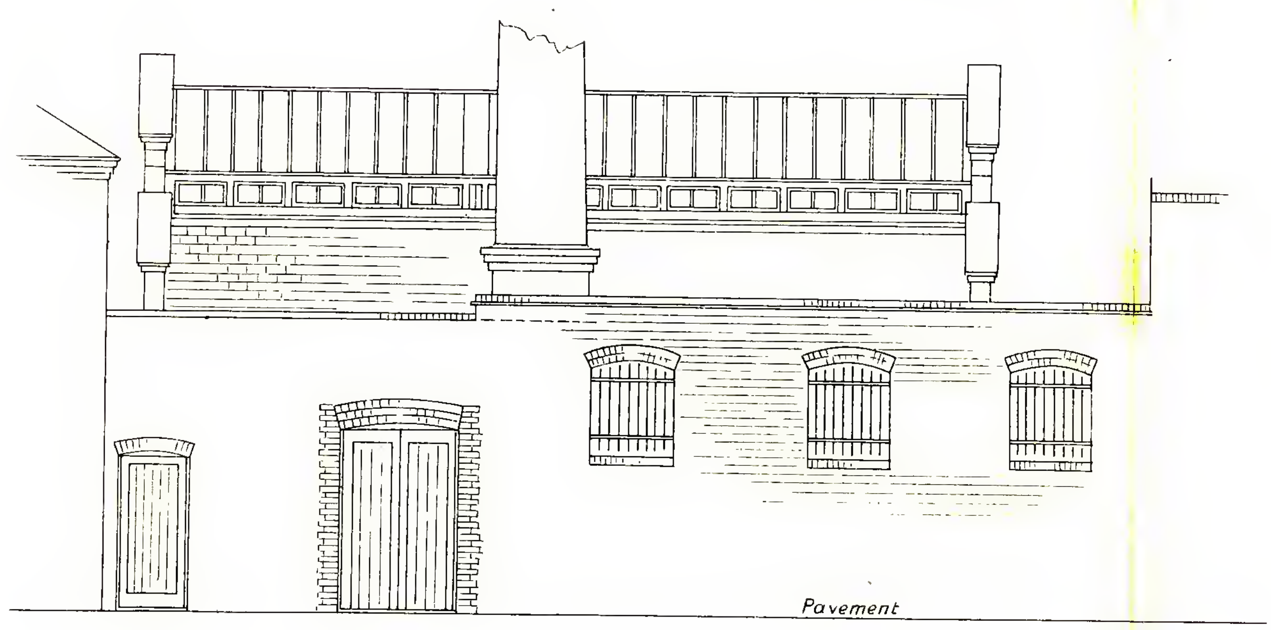
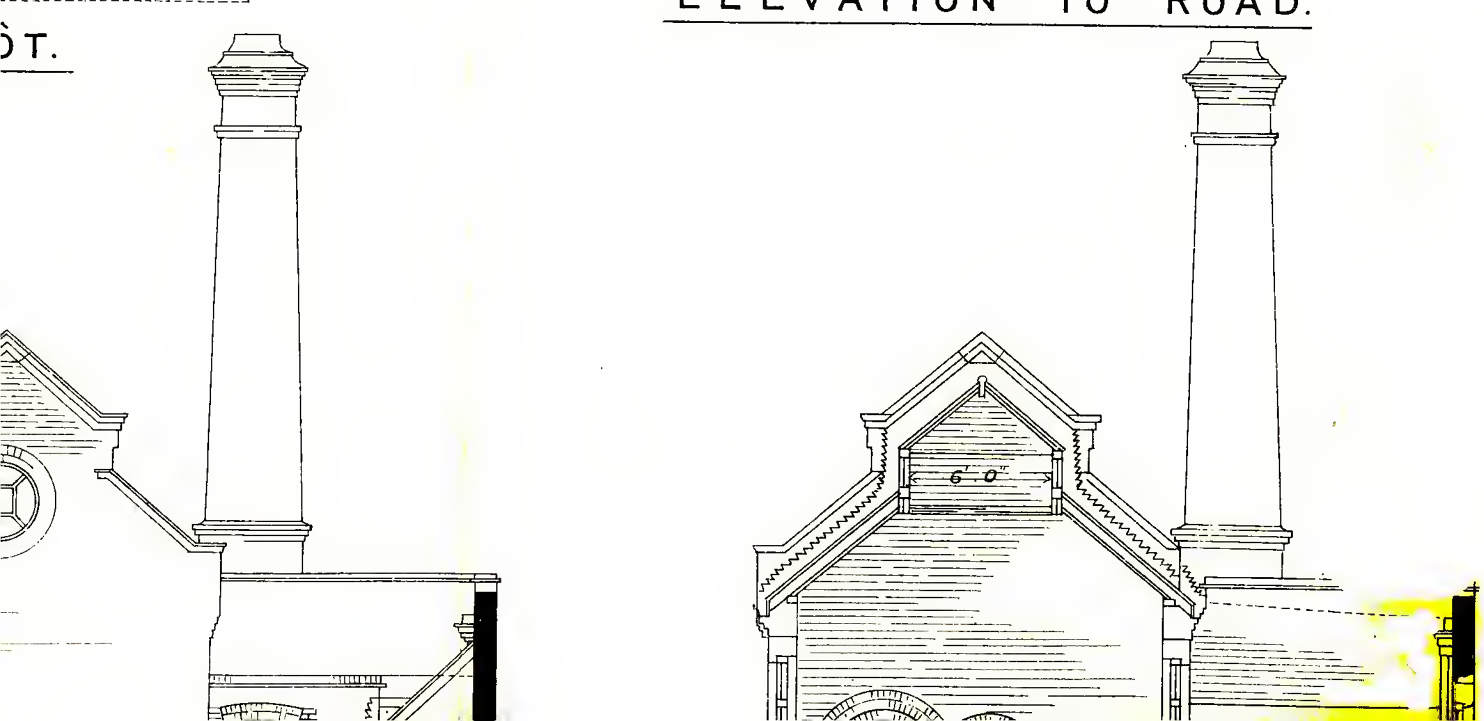
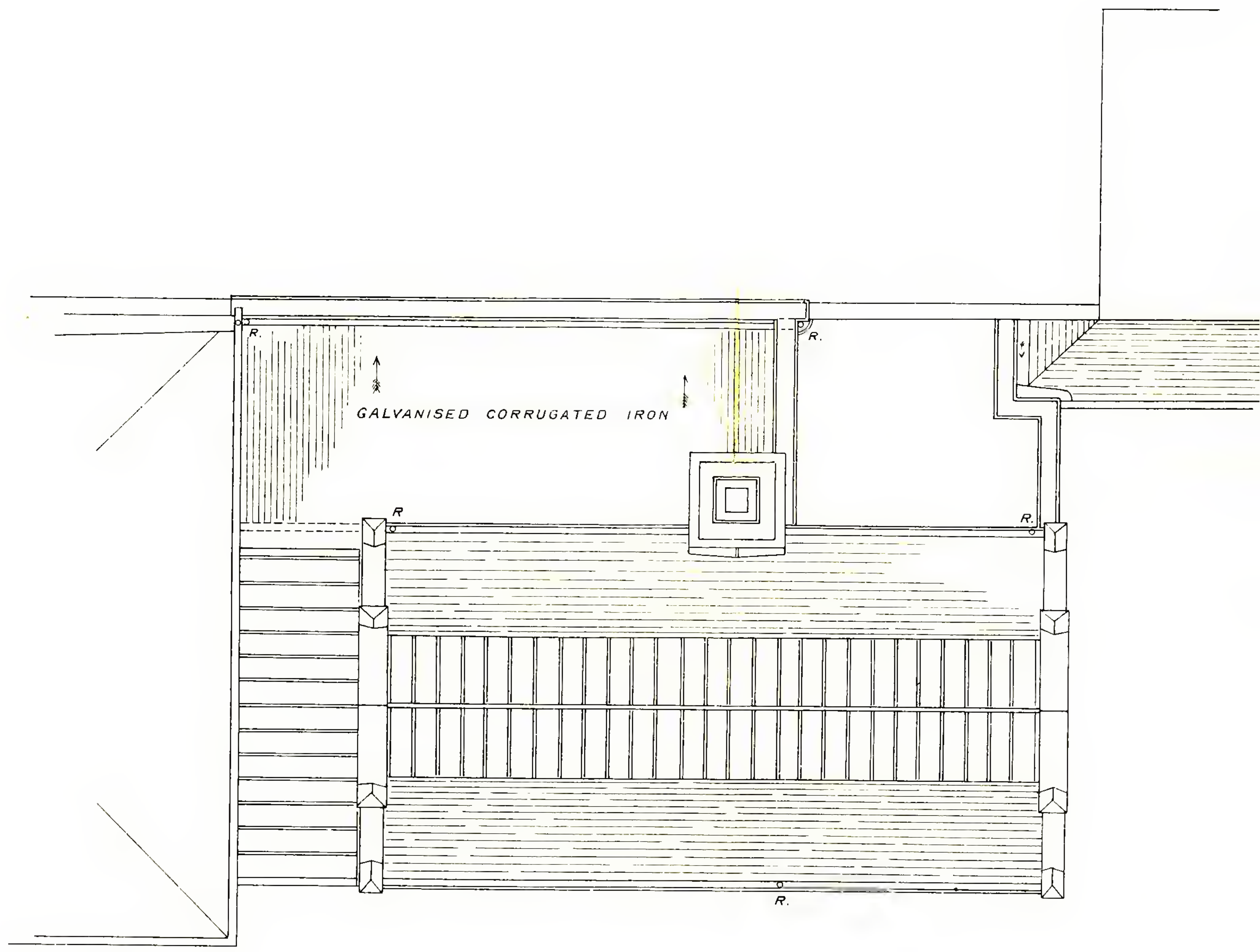
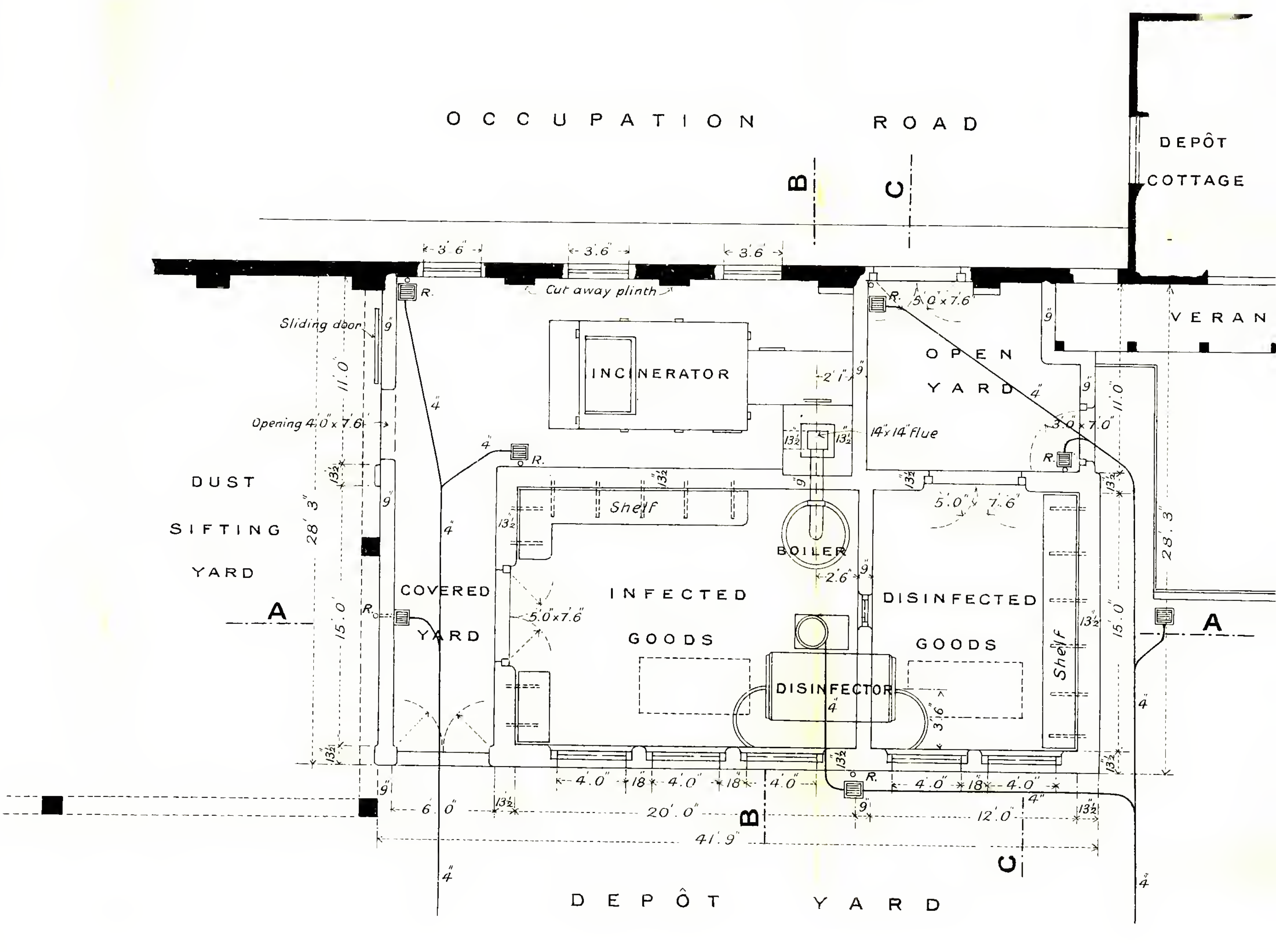


ELEVATION TO ROAD.

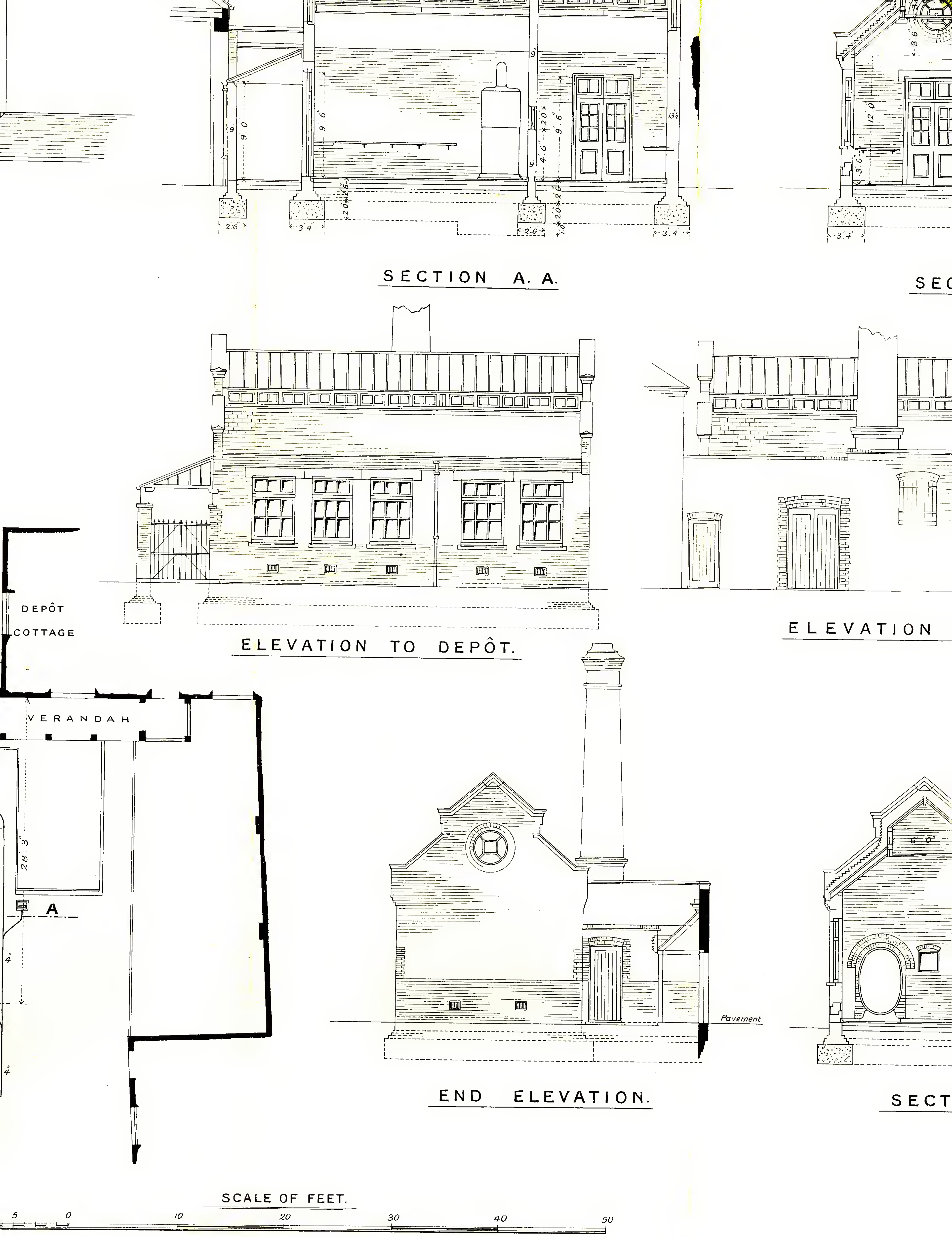




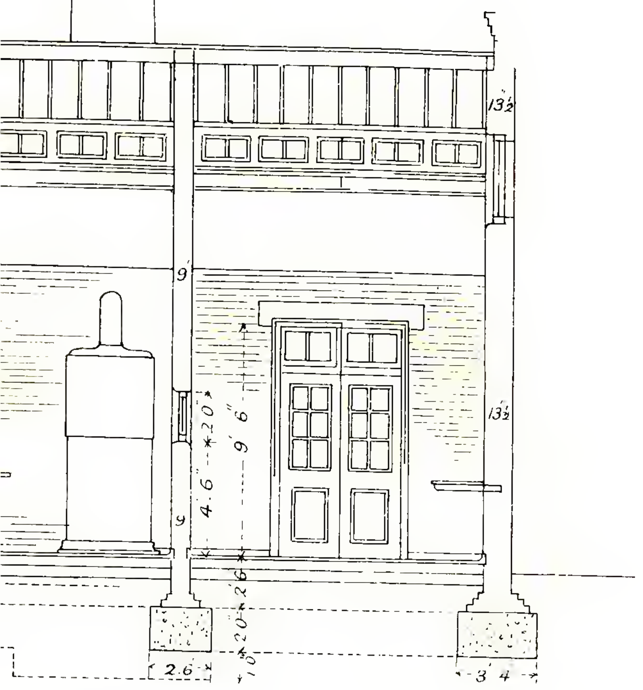
ROOF PLAN.



GROUND FLOOR PLAN.



WATERLOW & SONS LIMITED, LONDON WALL, LONDON.



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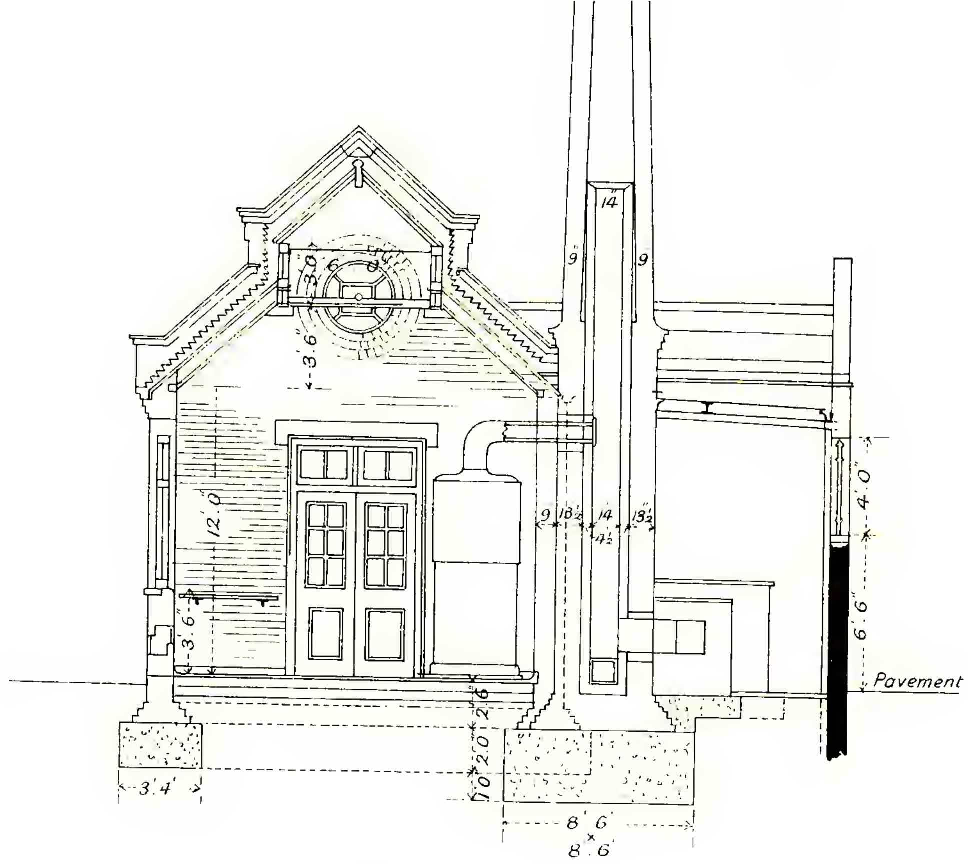
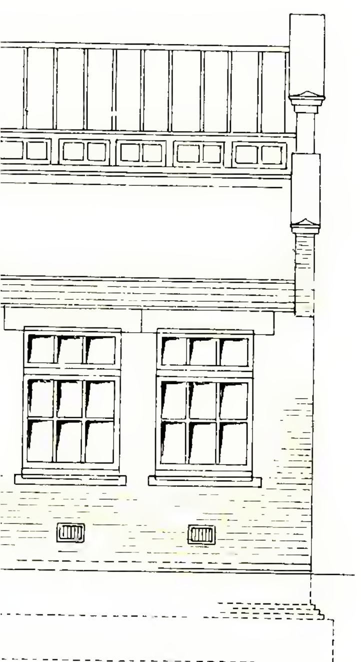


SECTION B. B.



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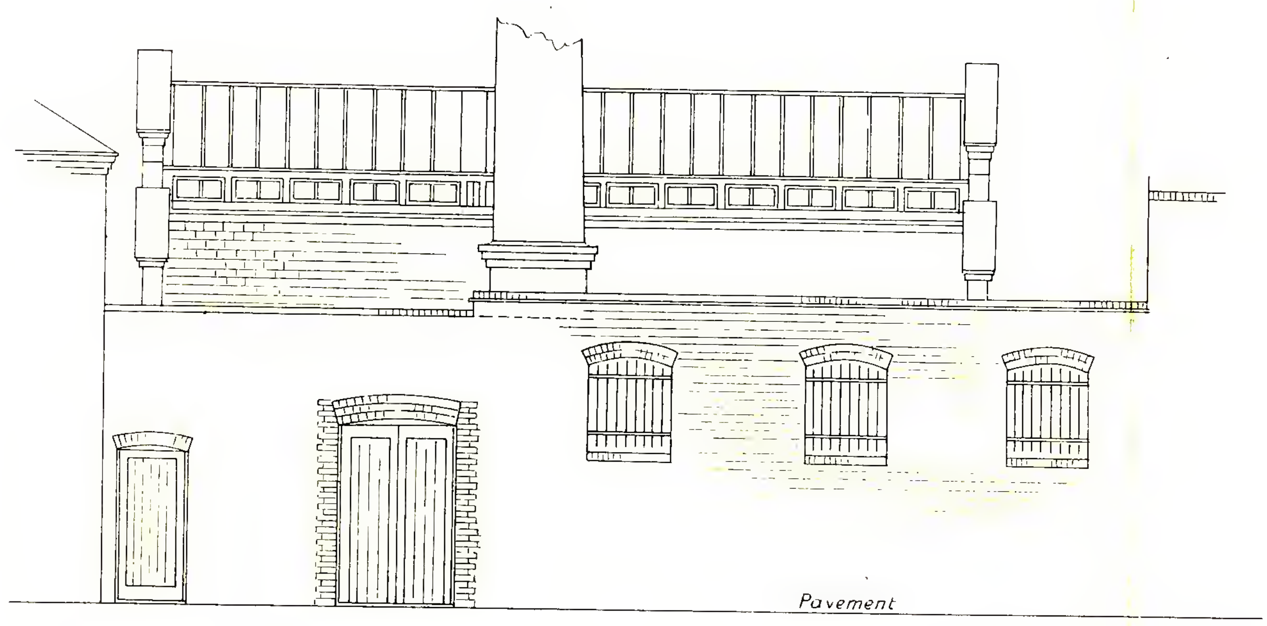
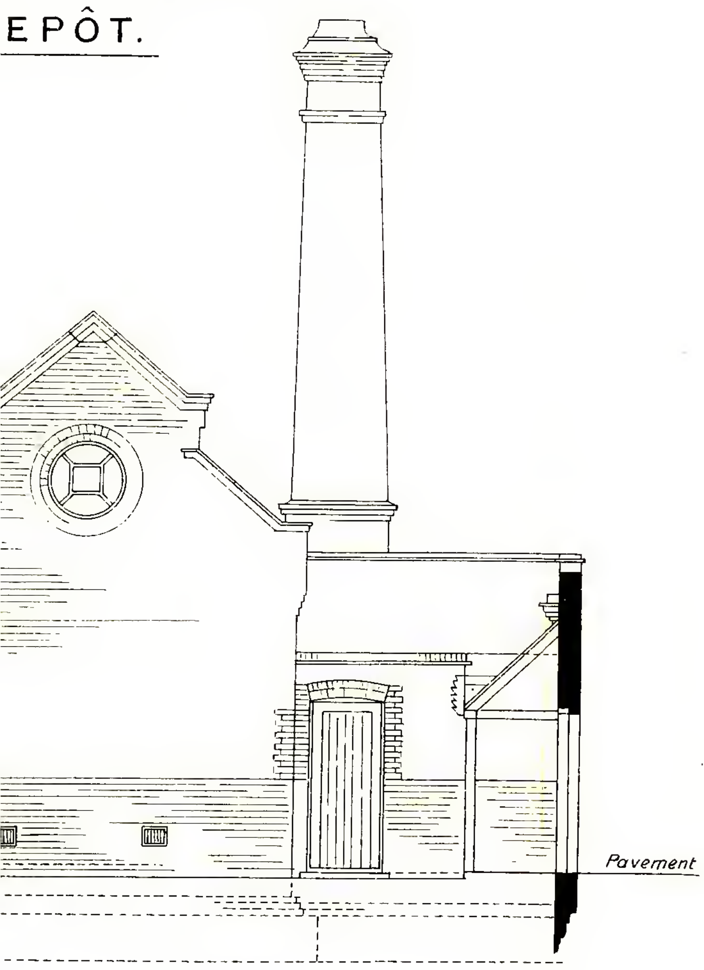


ELEVATION TO ROAD.



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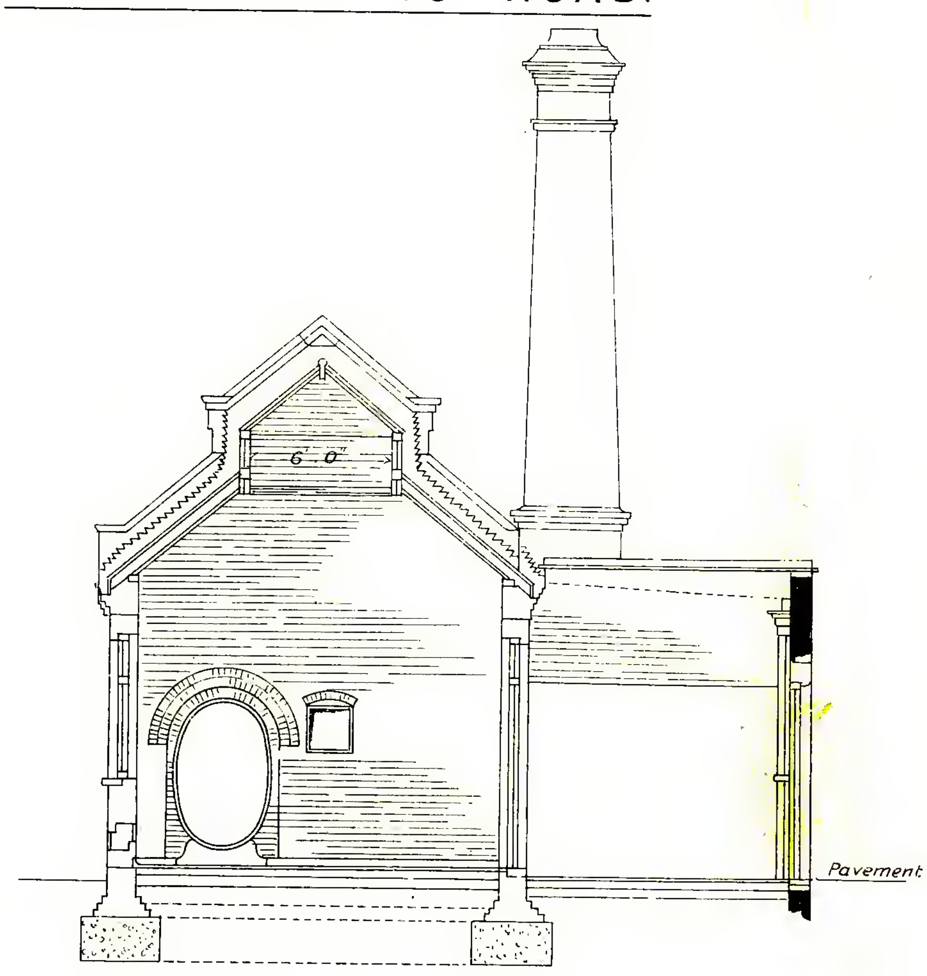


SECTION C. C.

merits, and this building has had to be adapted to its environments. It is, however, a fairly representative installation, arranged with considerable care, and is complete, with the exception that the plan does not show the sheds for the infected and disinfected vans or hand carts, which have been subsequently erected.

The main feature of a disinfector house is that there shall be two rooms; one permanently kept for infected goods, and the other for disinfected goods. The machine is built in the wall dividing the two rooms, and is fitted with two doors, one door opening into each room. These doors should never be open at the same time, and there should be no direct inter-communication whatever. Two men should be provided to work the apparatus, one of whom should have his duties confined to the infected side, and the other to the disinfected side of the apparatus. Generally, one man only is told off to look after the

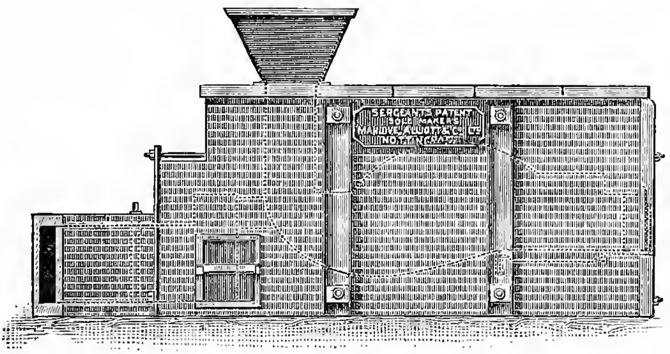
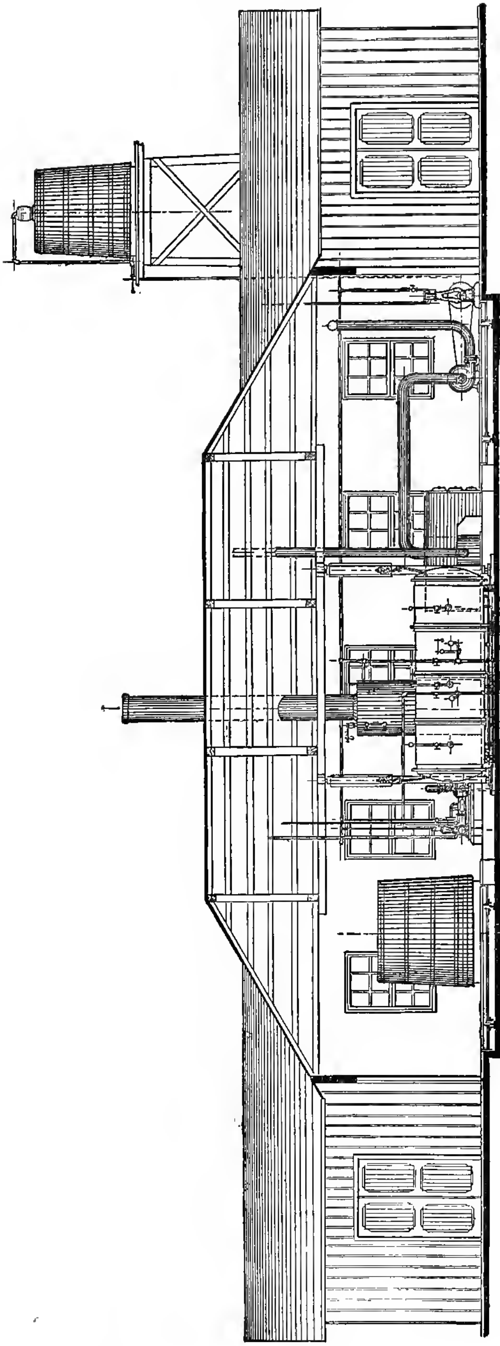


Fig. 17.—Dr. Sergeant's incinerator.

infected side, where the boiler and things that require attention are placed, and he signals or shouts to some man engaged on other work when goods have to be moved from the machine into the disinfected room. The incinerator is no essential part of the disinfection, but is, nevertheless, sometimes put on the same site for the purpose of destroying by fire bedding or clothing that is not worth disinfecting. For instance, it sometimes happens that the mattress of cholera patients are purposely of the commonest description, and only fit to burn. They can only be burned in very carefully constructed furnaces, fitted with a secondary fire to destroy the objectionable products of combustion; otherwise, the process might become a nuisance and danger to the neighbours. They are also useful for getting rid of condemned meat, offal, excreta, &c. A figure of Dr. Sergeant's incinerator, which is the one adopted at Newington, is shown in Fig. 17. At Newington, the same chimney is used for both the disinfector



DISINFECTING PLANT FOR U.S. MARINE HOSPITAL SERVICE.

Fig. 18.—(Section).

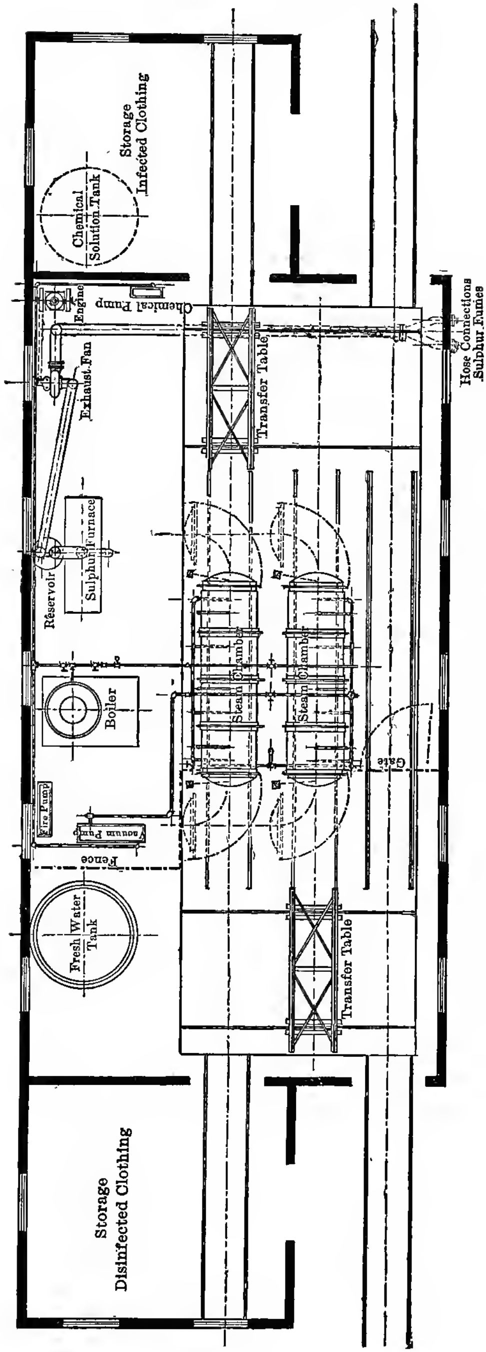


Fig. 19.—Disinfecting plant for U.S. Marine Hospital Service (plan).

boiler and incinerator, but otherwise the two departments are kept distinct. The minor points to be attended to in the building for a disinfector require also some care. The floor should be of some smooth, hard material, such as cement, laid with a fall towards a drain; and arrangements should be provided for swilling out the two rooms very thoroughly by fixing a small hose to taps in either room. All internal angles should be rounded, so as to permit of ready cleansing; and slate and iron should be used where possible in preference to wood for the racks and fittings. Good washing accommodation and w.c. should also be provided for the attendant, and special overalls should be given him for wear whenever at work in the building. These overalls should be disinfected before allowing them to go to the laundry. Considerable attention should be paid to the ventilation of both rooms, as in summer the radiated heat from the boiler and machine is apt to be oppressive. The lighting should also be ample and well diffused, for this encourages cleanliness.

United States.—For the Marine Hospital Service of the U.S. Government at the modern stations plant has been provided for disinfecting by heat, by fumes, and by chemicals. The arrangements have been described by W. H. Francis of Philadelphia,* and are shown in Figs. 18 and 19. The disinfectors are two rectangular steam-jacketted chambers 16 feet long, with steam-tight doors opening at each end. The chambers are constructed of an inner and outer steel shell, $2\frac{1}{2}$ inches apart, cast-iron end frames, intermediate truss bands, and of screw stay-bolt construction. The doors have concave steel plates riveted to cast angle frames fitted with heavy rubber gaskets, they are handled by convenient cranes, and drawn tight by drop-gorged steel eye-bolts, swinging in and out of slots in the door frames. The chambers, therefore, act as drying ovens, the articles being heated before the admission of the steam, and thoroughly dried after the steam has been exhausted. A vacuum of 15–20 inches can be produced in the chamber before the admission of the steam, and any pressures up to 15 lbs. (250° F.) can be obtained.

For fumigating at this station, 3 lbs. of sulphur per 1,000 cubic feet of air space are employed, and for disinfecting with liquids, mercuric chloride (1 : 1,000), carbolic acid, and chloride of lime, are at present used.

* *Proc. Am. Soc. Mech. Engineers,* vol. xv.

CHAPTER IV.

CHEMICAL DISINFECTANTS.

THE NON-METALLIC ELEMENTS AND THEIR DERIVATIVES.

The halogens—Chlorine, chlorides, hypochlorites, chlorates—Bromine, bromides—Iodine, iodine trichloride, iodic and periodic acids and periodates—Fumigation—Fluorine, fluorides, silicofluorides—Chloroform, bromoform, iodoform—Organic haloid compounds.

THE HALOGENS AND THEIR COMPOUNDS.

Chlorine.—About the year 1800, Guyton de Morveau in France, and Cruikshank in England, proposed the use of chlorine as a disinfectant. Cruikshank suggested the following method of procedure :—"2 pts. common salt, and 1 pt. powdered manganese, with 1 pt. water and ½ pt. sulphuric acid gradually added, is sufficient for five or six beds."

A similar method of generating chlorine is to gently warm one part of manganese dioxide in a granular form with four parts of concentrated hydrochloric acid (5 grms. MnO_2 and 20 grms. HCl give 1 litre of Cl; ½ oz. of MnO_2 is abundance for a large room).* Letheby recommended one teaspoonful of powdered manganese and half a cupful of strong crude hydrochloric acid, mixed by degrees by stirring in a saucer set on a hot brick.

It should be remembered that the crude acid contains arsenic, which would be evolved as the intensely poisonous arsenious chloride; hence, at a little additional expense, pure acid only should be employed.

Each of these methods requires heat, which presents great difficulties in application. Usually, therefore, the chlorine is evolved from chloride of lime by the action of moderately diluted sulphuric or hydrochloric acid. It has been stated † that 1 part bleaching powder with 2 parts of sulphuric acid of specific gravity 1·53, and enough water to cover the powder, evolved three times as much chlorine as when hydrochloric is used. This may be due to the heat generated by the sulphuric acid, as the amounts yielded are theoretically the same, as the following equations show :—

$$CaCl_2O + H_2SO_4 = CaSO_4 + H_2O + Cl_2.$$
$$CaCl_2O + 2HCl = CaCl_2 + H_2O + Cl_2.$$

If the insoluble and, therefore, solid sulphate of lime keeps back less chlorine than does the deliquescent calcium chloride, the difference in the yield might be explained.

* Reichardt, *Desinfectionsmittel*, p. 65. † *Lancet*, 1888, p. 110.

Dr. Mehlhausen * of Berlin used 600 grammes of bichromate of potash and 3 kilos. of pure hydrochloric acid, of specific gravity 1·16, for generating chlorine. These weights yield on warming 130·6 litres (405 grms.) of chlorine. He traced a somewhat greater activity to the gas than when prepared by the ordinary processes; this may, perhaps, be due to some chromyl chloride (CrO_2Cl_2) evolved in addition. The cost of this method prevents it from being generally employed.

Chlorine has three possible modes of action:—

1. It may replace hydrogen in the organic substances, forming innocuous compounds and poisoning the bacteria. Such action would be slow, would scarcely occur at all except in sunlight, but yet would be the only possible action on dry matter. It may account for the antiseptic action of chlorine, as distinguished from its disinfecting power; the latter has been questioned, but the experiments of Baxter and Sternberg on dried vaccine lymph seem to be conclusive.

2. The offensive gases of putrefaction are decomposed by chlorine; sulphuretted hydrogen, which is always present, being resolved into sulphur and hydrochloric acid—

$$H_2S + Cl_2 = 2HCl + S.$$

Phosphoretted hydrogen from animal matter would be also decomposed. Ammonia (and compound ammonias) would give first of all ammonium chloride and nitrogen—

$$8NH_3 + 3Cl_2 = 6NH_4Cl + N_2,$$

hence the copious white fumes frequently noticed when a chlorine mixture is thrown into a dung pit. More chlorine decomposes the ammonium chloride first formed; when this takes place there is always a formation of intensely acrid vapours which attack the eyes, owing, no doubt, to the production of chloride of nitrogen. Hydrocarbons would in most cases be little affected by chlorine, but they, as a rule, are not so offensive as the other gases mentioned.

3. The common and most important action of chlorine is as an oxidising agent. In the presence of water, more especially in light, it combines with hydrogen to form hydrochloric acid, and liberates oxygen—

$$H_2O + Cl_2 = 2HCl + O.$$

The oxygen so formed is far more active than atmospheric oxygen, and is in a condition to burn up the putrescent matters and kill the organisms which accompany the putrefaction. But there are several conditions indispensable to thorough disinfection, and amongst these (*a*) *the presence of moisture* is absolutely essential when chlorine fumigation is resorted to.

* *Bericht der Cholera Commission*, 1879, vol. vi., p. 335.

(*b*) *Quantity.*—Baxter says that the disinfecting action of chlorine and of potassium permanganate depend much more upon the nature of the liquid than upon the specific organism present. Kuhn, Bucholtz, and Haberkorn have confirmed this view. For example, in a liquid like urine, which requires large quantities of chlorine, before the liquid be deodorised, the action on germs does not begin before the chlorine is in excess, and it must be maintained in excess until the last germ is destroyed, otherwise the fermentation will recommence. But if the action has been completed, germs that may afterwards enter from the atmosphere find it an unsuitable medium for growth. From this it follows that the smell of chlorine must be perceptible and persistent for some time, or no good result will have been obtained. Excess of chlorine may be chemically tested for by a paper dipped in a solution of iodide of potassium and starch paste, which is turned blue by free chlorine, or the bleaching of litmus paper may be used as an indication.

Baxter in his experiments mixed chlorine with vaccine lymph, and found that its activity was not destroyed till the liquid had become acid from the presence of free hydrochloric acid. Most putrefactive organisms thrive best in alkaline solution; hence the antiseptic power of all free acids in varying degrees.

To kill pure vaccine, Baxter found the minimum proportion of chlorine to be 0·2 per cent. (*i.e.*, soda chlorinata solution, B.P. 1 in 10: chloride of lime, 1 in 100, both acidified). Hofmann * gives 0·15 per cent. as sufficient for septic virus.

(*c*) *Time.*—The vitality of the organisms considerably influence the length of time required for sterilisation. Sternberg † found that 1 per cent. of chlorine in air in six hours made dry vaccine inert. This is a very large quantity, for a room of 50 cubic metres would require at this rate 5 kilos. of bleaching powder, even if all the chlorine were evolved, which is generally impossible. Baxter states ‡ that air saturated with chlorine by standing over the aqueous solution took thirty minutes to sterilise needles charged with dry vaccine.

These are impossible conditions in practice. Living organisms themselves contain 90 to 95 per cent. of water, hence the disinfectant entering them would be greatly diluted. Moreover, their envelopes are often tough and resisting, especially those of germs. Therefore, more time must be given.

Fischer and Proskauer,§ from laboratory experiments on spores of

* *Vierteljahrsschrift für gerichtliche Medicin*, April, 1878.

† *Bulletin of the U.S. Board of Health*, Washington, 1881.

‡ *Report of Med. Off. of Privy Council on Disinfectants*, 1875.

§ *Mitt. aus d. Kaiserl. Gesundheitsamte*, Berlin, 1884.

anthrax and various bacteria, conclude that for air fumigation at least 0·54 per cent. of chlorine must be present, and consider it more efficacious than sulphurous acid. The experiments of Jalan de la Croix,* on the putrefying bacteria of beef tea, give a surprisingly favourable account of the power of chlorine among the agents which are fatal to low organisms, and place it next to corrosive sublimate as an "antivirulent."

The substances tried, arranged nearly in their order of efficiency as determined by him, were as follows:—Mercuric chloride, chlorine, chloride of lime, sulphurous acid, bromine, sulphuric acid, iodine, aluminium acetate, mustard oil, benzoic acid, sodium salicylate, potassium permanganate, phenol, chloroform, borax, alcohol, oil of eucalyptus, potassium chlorate. The methods used were first that of Bucholtz, then those of Salkowski, Wernicke, and Wernitz, and other specially devised "bacterioscopic" processes.† He concluded that "besides chlorine, bromine, and iodine, we have only sublimate and osmic acid that will kill the bacteria of splenic fever within twenty-four hours."

Given the above time, he states as to quantity that "in beef tea all growth is stopped by 1 in 30,208—*i.e.*, 1 gramme of chlorine in 30 litres (chloride of lime, 1 in 11,135 has the same effect); 1 in 22,768 kills bacteria in full growth, and prevents their spontaneous development in cooked beef tea exposed freely to air; that of 1 in 15,606 in raw beef tea.. Chloride of lime is required in stronger doses, of 1 in 3,700 in cooked, and, contrary to what one would expect, 1 in 286 in raw beef tea."

To destroy the germs it requires yet larger amounts, varying between 1 in 431 and 1 in 4,911 for chlorine, and 1 in 100 to 1 in 500 for chloride of lime.

Vallin ‡ throws some doubt on the above researches, and asserts that the antivirulent action of chlorine is relatively restricted, and is notably inferior to what would be presumed by the above figures.

Dr. Mehlhausen § made a number of experiments, of which the following is an abstract:—

I. In a room of 37 cubic metres with door and window sealed, he placed a number of insects in gauze enclosures, and two vessels of water teeming with vibrios, rotifers, and infusoria. An earthen pot containing 740 grammes (20 grammes per cubic metre) of bleaching

* *Arch. für experiment. Pathologie*, 1881.

† Wernitz, *Grundriss der Desinfectionslehre*, pp. 166 to 178, and Virchow's *Archiv.*, vol. lxxviii., pp. 53 to 60.

‡ *Traité des Désinfectants*, 1882, p. 118.

§ *Bericht der Cholera Commission*, 1879, vi., p. 335.

powder with a little water, to which he added 1,100 grammes of hydrochloric acid, was also introduced and the door sealed. After nine hours the room was opened and ventilated. The animals were all living; the flies only were insensible, but recovered on the next day. The water in the vessels, originally neutral, had become acid, and gave with nitrate of silver a copious precipitate of chloride. All the bacteria were dead. The 740 grammes of chloride of lime had given 59·7 litres of chlorine—*i.e.*, 1·613 litre per cubic metre, or *0·1613 per cent.* in the air (about the amount mentioned by Hofmann, as above given), whilst some had been undoubtedly wasted by non-evolution and by leakage.

II. With the same conditions as before, but with double the amount of chlorine. The vessel contained fermenting urine. In eight hours there was much residual chlorine. Most of the higher organisms were killed; the urine had become acid, but the bacteria and spirilla were still moving.

III. Equal parts of common salt and manganese dioxide, with 2 parts of sulphuric acid and 1 part of water, were warmed together, whilst putrid urine and dysenteric stools in wide flat dishes were exposed for twenty hours to the gas. On opening, only a feeble odour of chlorine was noticed, as it was masked by the effluvia from the stools and urine. Some of the organisms were only benumbed, and recovered their activity in fresh air. The liquids were very acid, and had not entirely lost their fetid odour.

IV. In another room of 48 cubic metres a glass balloon was placed containing 600 grammes of bichromate of potash and 3 kilos. of hydrochloric acid of specific gravity 1·16; by warming, 405 grammes of chlorine were evolved, equal to 2·7 litres per cubic metre, or *0·27 per cent.* Under these conditions all the organisms were killed, but the time required was not stated. The process is, however, long, expensive, and somewhat difficult, costing about 4 centimes per cubic metre, or about 1s. 6d. for disinfecting a room 11 feet square.

Vallin points out that fumigations with chlorine are of little advantage, and are decidedly inferior to those with sulphurous acid. The disengagement of chlorine is incomplete, unless stirred and heated constantly, which is almost impossible in ordinary practice. The facility of "sulphuring" is, on the other hand, of the greatest value, and the expense is about four or five times less.*

Jeannel † noticed that chlorine seemed to have only a temporary action on certain vibrios, as he was able by means of ammonia to restore them to activity after they had been subjected to the influence of chlorine for a long period.

* See *Sulphurous acid*, later. † *Union Médicale*, Sept. 28, 1871.

The experiments of Sternberg* concerning the action of chlorine on infusoria and micro-organisms show that the resistance of the latter is considerable. In an experimental room of 10 litres capacity, he placed 28 grammes of chloride of lime. It was an hour and a half before the movements of the bacteria contained in a drop of putrid meat infusion ceased, although the watch glass holding the liquid was directly exposed to the gas. (If he did not acidify, the only chlorine evolved would be that liberated by the small quantity of carbonic acid in the air present—namely, about 0·071 per cent.—which is too small a proportion, if we take Hofmann's minimum of 0·16 per cent., or Baxter's 0·2 per cent. be admitted.† But the total amount would still be immense if it could be absorbed by the drop of fluid, as it would reach 7 grammes of chlorine in the 10 litres of air.) Sternberg did not consider the movements definitely destroyed until after an hour's exposure to fresh air, they had not reappeared.

Dr. Cash ‡ subsequently studied the action of chlorine, and endeavoured to determine the comparative value of the halogens and of sulphurous acid in destroying the virus of anthrax and tubercle; he concluded that the halogens do not present any great differences when employed in solutions, the strengths of which are proportional to their atomic weights, though chlorine was the least active and iodine the most. This would oblige us to use 127 parts of iodine for 80 of bromine and 35·4 of chlorine. He found that when employed in dilute solutions they did not disinfect. (That is, below Baxter's limit of 0·2 per cent.) He prefers sulphurous acid if the disinfecting agent be employed as a gas, but considers it better to employ a solution of the gas if possible.§

(*d*) *Contact.*—Intimate contact between the gas and the centre of infection must be assured. If large masses of putrescible matter like fæces are present, chlorine gas fails in its action, and must be supplemented by the addition of metallic salts, &c. For if all easily decomposable organic matter be not destroyed, a recommencement of putrefaction is not prevented.||

Klein ¶ used chlorine fumigations in stables for disinfection from swine plague with success.

When in great mass—*e.g.*, dung and straw in typhus—care must be taken not to give a false security by illusory means. Probably in many cases it is better to rely on purification being accomplished naturally

* *Bulletin of National Board of Health*, Washington, July 23, 1881.

† See later, under *Chloride of lime.*

‡ *Pharm. Journ.*, 1887, p. 485; *L. G. B. Sixteenth Annual Report.*

§ See later, *Sulphurous Acid.*

|| Reichardt, *Desinfectionsmittel*, p. 57.

¶ *L. G. B. Thirteenth Annual Report.*

by air and moisture than run the risk of natural decomposition being retarded by the employment of inefficient quantities of antiseptics. It must be remembered that manure that has been treated with chlorine or chloride of lime loses all its agricultural value on account of the destruction of its ammonium salts. On the other hand, if chloride of lime is sprinkled over fæcal matter before removal, it destroys any offensive gases that may be evolved.

It cannot be too strongly emphasised that air cannot be disinfected and still remain fit to breathe. Wernitz * condemns all fumigations as useless, classing all methods as "illusory specifics," since "we require a body which shall come in intimate contact with atmospheric dust, and act for a long time on it." Vallin says "disinfection of air is useless and gives a deceitful security. To make a strong odour of phenol, or put a basin of chlorine in a corner, is, with regard to destruction of virus, an operation quite futile, as the virulent particles in air are probably protected by an envelope of dried albuminous matter."

Chloride of Lime and Hypochlorites.—By treating the alkalies and alkaline earths in solution with chlorine in the cold, mixtures of chloride and hypochlorite are formed which have been long known as useful disinfectants.

Liquor sodæ chlorinatæ, B.P., chlorinated soda, or "Eau de Labarraque" has a strength of $2\frac{1}{2}$ per cent. of available chlorine. It is used in surgery diluted with 10 parts of water (equal to Baxter's effective strength of 0·2 per cent. Cl) as an antiseptic lotion, and is refreshing and non-irritant. By its decomposition it produces a small quantity of common salt. It has also been employed as a mouth wash.

"Eau de Javelle," introduced by Percy in 1793, is similarly made, but with potash instead of soda, and is said to keep longer than the soda compound. The orders of the French Prefecture recommended 1 part of Eau de Javelle of 18° Baume to 100 parts of water for flushing closets and washing walls, &c. It has the advantage over "chloride of lime" that it does not leave behind a deliquescent body like calcium chloride. It acts similarly to chlorine.

"Chloride of lime" or bleaching powder, obtained by passing chlorine over moist slaked lime, has the advantage of being a dry powder, which is more easy of transport and keeps better than the soda and potash preparations. It is a mixed chloride and hypochlorite of the formula $CaCl_2O$, and breaks up into chloride and hypochlorite on solution in water. The latter is strongly alkaline, and is acted on by the carbonic acid of the air giving carbonate of lime and hypochlorous acid.

$$2CaCl_2O = CaCl_2 + Ca(ClO)_2$$
$$Ca(ClO)_2 + CO_2 + H_2O = CaCO_3 + 2HClO$$

* *Desinfectionslehre*, 1882.

In contact with organic matter the hypochlorous acid splits up into hydrochloric acid and oxygen, and it is on this liberated oxygen that its value as a disinfectant depends. The calcium chloride remains behind as a deliquescent salt, and this is an objection to bleaching powder being mixed with lime for white washing, as the surface remains damp. It is important to remember that chloride of lime must be acidified, either slowly and spontaneously by the carbonic acid, or by the addition of hydrochloric or sulphuric acid or even vinegar, for any chlorine to be liberated. Weak acids only decompose the hypochlorite, leaving the chloride untouched, and evolve hypochlorous acid. Strong mineral acids, on the other hand, evolve chlorine.

To prove the necessity of acidification, D'Arcet and Gaultier de Claubry showed that air deprived of carbonic acid by a potash wash-bottle, and then passed over chloride of lime, was not disinfected.

Good bleaching powder contains 34 per cent. of available chlorine. It is best used in the proportion of 1 part to 10 or 12 parts of water. It should be freshly prepared, and kept from light and air. When old it becomes damp and is then of inferior value.

Similar preparations of aluminium and magnesium hypochlorites have been made by precipitating a solution of chloride of lime by sulphates of aluminium or magnesium. The latter has no special advantage, but the former has in addition the mordanting and clarifying and antiseptic properties of other aluminium salts (see *Chloralum*, p. 131), and might deserve more extended use. It is commercially used for bleaching paper pulp, under the name of Anderson's solution. The American "standard solution of chloride of lime" is thus described:— "Dissolve chloride of lime containing not less than 25 per cent. of available chlorine, 6 ounces to 1 gallon of water ($4\frac{1}{2}$ per cent.). Use 1 quart for each discharge in cholera, typhoid, &c. Mix well, and leave in the vessel at least one hour before being thrown away." *

For disinfecting clothes, the diluted Eaux de Javelle or Labarraque are better than chloride of lime. The fabrics must be washed soon after, or the fibres will be rotted. Of course the colours will be more or less affected. Jaeger used a paste of equal parts of water and bleaching powder for disinfecting tuberculous sputa. †

It must be remembered that chlorine and the hypochlorites also act energetically on other substances, so that any mixture of them with other disinfectants can only be endorsed by an experienced chemist, for, as a rule, these are only to be used apart.

* *Report of Committee on Disinfectants of American Public Health Association*, p. 235.

† *Arb. a. d. Kais. Gesundh.*, 1889.

One part of chloride of lime to 100 of water forms a liquid for washing the person in infectious diseases. The odour is most persistent, and may even convey a false sense of safety when the effective limit has long been passed. Semmelweis, however, in 1846 succeeded in stamping out of Vienna endemic puerperal fever by its use, and Sir Spencer Wells has advocated its use in this country. *

Liebig contended that the continued action of chlorine or hypochlorites, as in the wards of hospitals, leads to lung diseases in the patients and attendants. Pettenkofer and Lehmann † say that 0·001 to 0·005 per cent. of chlorine affects the respiratory organs; 0·04 to 0·06 per cent. produces dangerous symptoms; and over 0·06 per cent. soon proves fatal. Undoubtedly chlorine will cause chronic bronchitis if in quantity, and disinfection with chlorine involves such a percentage of the gas as absolutely necessitates the removal of animals and plants from its vicinity.

The *Berichte der Choleracommission des Deutschen Reiches*, 1879, condemns the use of chlorine as being dangerous, and Koch obtained unsatisfactory results with chloride of lime. ‡

The same, however, is the case with sulphurous acid, nitrous gases, and still more with bromine and iodine, which are all intensely poisonous. § This action, coupled with the fact that the gas corrodes metal fittings and rots fabrics, has led in great part to its disuse for this purpose, and to its utility being confined to the disinfection of sewers and closets. Angus Smith, ‖ on the other hand, points to the healthy appearance of men employed in bleaching factories; he attributes this to the purification of the air. Notwithstanding these objections to its use, chlorine must be regarded as the most powerful of the disinfectants, being the only convenient gaseous body that can quickly destroy organic matter and consequently ensure perfect disinfection.

"Chlorozone," a mixture of hypochlorites and permanganates, was formerly advocated. It was probably made by passing a current of chlorine through milk of lime, or a solution of soda or potash, in which finely ground manganese dioxide was suspended, or to which the manganous residues from the manufacture of chlorine were added. The chlorine oxidised the manganese compounds to permanganate, and at the same time formed hypochlorite. Such a solution would be attractive from its crimson colour, and would at the same time combine the oxidising properties of both these agents.

* *B. M. J.*, 1892. † Munich Acad., 1887.

‡ *Mitt. a. d. Kais. Gesundh.*, vol. i., 1881.

§ *Wirkung der verdunnten Luft a. d. Organ.* Fränkel & Goppert, Berlin, 1883.

‖ *Disinfectants and Disinfection*, 1869, p. 49.

Chamberland and Fernbach, in a paper on the "Disinfection of Public Places and Dwelling Rooms,"* state that eau de Javelle, bleaching powder of a concentration of 1 in 120, and commercial peroxide of hydrogen, are found to be stronger disinfecting agents towards pathogenic microbes than a 1 per cent. solution of mercuric chloride. These antiseptics, however, at the ordinary temperature, do not act at all on moist germs, or only do so after several hours. When heated to 40° or 50° C., or higher, moist germs are destroyed in a few minutes. Therefore, for rooms they must be heated. Dry germs can resist their action for several hours at 40° or 50° C., but if then moistened with water they are destroyed. It is noteworthy that a 0·8 per cent. solution of bleaching powder is far more active than 1 in 120, whether for moist or dry germs, or whether hot or cold. Thymol, lysol, oil of turpentine, are, in comparison, bad antiseptics. In their experiments 100 grammes of bleaching powder were triturated with 1,200 of water, allowed to stand one hour, filtered, and diluted with 10 litres of water.

This paper requires a few observations. Warming very easily converts "chloride of lime" into chloride and chlorate, and renders it almost inert as a disinfectant; it decomposes peroxide of hydrogen into water and oxygen, so rendering it useless; eau de Javelle (potassium hypochlorite) similarly suffers; hence great judgment would be required in the operation. It must be remembered that the alkaline hypochlorites do not evolve chlorine until after they are acidified, so that a strong alkaline solution may be less efficient than a weaker one in water, since the carbonic acid of the large quantity of water liberates a greater amount of hypochlorous acid. With reference to the prescription for chloride solution for practical purposes, an hour is not necessary if well agitated, and filtration is superfluous.

Sheridan Delépine † uses chlorinated lime for disinfecting rooms which have been contaminated by tuberculous patients, as follows:—(1) A solution of chlorinated lime (1 in 100) should be prepared; (2) the walls, ceiling, and floor should be washed with this solution in the same way as lime or whitewash is usually applied; (3) this process should, for safety, be repeated three or four times in succession; (4) the room should then be closed, a small safe petroleum stove being first placed in the middle of the room, and precautions taken to prevent any chance of fire; over this stove, a large tin basin full of water or bleaching powder solution should be placed. To secure acidity to the air, he further suggests suspending in the water bath a capsule containing hydrochloric or acetic acid. Three hours is sufficient time

* *Ann. de l'Institut Pasteur*, 1893, vol. vii., p. 433. † *Med. Chron.*, May, 1894.

for an ordinary room, and 6 ozs. of bleaching powder, using 3 pints of water for each washing, is the quantity he recommends.

W. E. Crow and Frank Browne, at Hong Kong, during the plague in 1894, used free chlorine generated from ½ lb. chlorinated lime, mixed with 1 quart of water and 1 quart of dilute sulphuric acid (1 in 5). This quantity was used for each room.

The "Hermite" or Electrolytic Process.—About 1859, Charles Watt discovered that when a solution of a chloride of the alkalies or alkaline earths was electrolysed, a solution similar to bleaching liquid was formed. It presumably contained chlorides and hypochlorites, but apparently was more active than a solution prepared in the ordinary way. Magnesium chloride was said to be preferable. Such a solution, originally intended for bleaching paper-pulp, has recently been advocated by M. Hermite for sanitation, and sea-water, containing as it does the chlorides of sodium, calcium, magnesium, and potassium, is proposed as a cheap and suitable material. He uses a special form of "electrolyseur" for affecting the electrolysis, and proposes to pump the solution through a system of pipes to the place of use, and thus render it available for domestic use, and for local flushing of sewers, latrines, &c. Dr. Piton's report to the Mayor and Corporation of Brest, referring to experiments on this system at Nice, states that the Hermite solution, diluted to a strength of about ¼ gramme of free chlorine per litre, does sterilise the fæcal matter in the sewers, but that, in spite of the rapid absorption of chlorine, the disintegration of paper and fæcal matter is no more rapid than when ordinary water is employed. The system was tried at Worthing in the early part of 1894, and Dr. C. Kelly, the medical officer of health for Worthing, in a report incorporating the chemical and bacteriological analyses by Dupré and Klein, "dismisses the experiences of the trials made by the Worthing Corporation as having failed to realise the claims of the inventor, besides involving serious considerations of expense, both in the production of the fluid and the method of applying it to houses." This report was questioned by the English agents, Messrs. Paterson & Cooper, who have formally protested. Dr. Rüffer and Sir H. Roscoe have reported more favourably on the process, and it has been further tried at Havre, l'Oriente, and Nice.

In the patent of Hermite, Paterson & Cooper, No. 22,279, 1893, the apparatus is described, and the strength of the fluid obtained is stated to be 2 grammes of free chlorine per litre, and for use it is recommended to be diluted six or seven times. A current of 300 amperes at a pressure of 6 volts is required to decompose the sea water in the electrolyseur. In patent No. 6,495, March 31, 1894, a method of protecting the iron pipes from corrosion by the chlorine is covered.

The *Lancet* Report on the Hermite process and the experiments at Worthing * comes to the following conclusions :—

By electrolysis of the magnesium chloride in the sea water, magnesia and chlorine are liberated, which subsequently combine to form magnesium hypochlorite $Mg(OCl)_2$ and magnesium chloride. This liquid may be regarded as the magnesian equivalent of bleaching powder solution. The magnesium hypochlorite dissociates into magnesia, which deposits on the walls and floor of the electrolyser, and free hypochlorous acid, which remains in solution.

$$Mg(OCl)_2 + 2H_2O = Mg(OH)_2 + 2HOCl.$$

The Hermite solution then practically resolves itself into a dilute solution of hypochlorous acid, and may be cheaply imitated by passing carbonic acid through a solution of ordinary bleaching powder. It is admitted, however, that this "artificial Hermite" gave in bacteriological examination "varying results, and could not be depended on to exert constantly an equivalent action to the Hermite solution." Chemically, however, the two solutions exhibited very close resemblance.

The strength of the electrolysed sea water in chlorine, or its equivalent, as determined by the arsenious acid process † is 0·5 gramme Cl per litre. Urine at once acts on it, depriving it of about half its chlorine strength.

In comparative experiments on the action on ordinary stools of Hermite fluid, bleaching powder solution, and milk of lime 2½ and 1 per cent., it was observed that, as expected, the bleaching powder was not so immediate in its effect, but in a longer period the final result was similar. "Although in consequence of this the bleaching powder does not exert so rapid and immediate effect as the more unstable Hermite solution, yet the weaker solutions of the former, owing to their stability, in the end produce a much more complete process of sterilisation than in the case of Hermite solutions of similar dilution." The action of the *full-strength* Hermite fluid on the pathogenic organisms of diphtheria and of cholera, and the *Staphylococcus pyogenes aureus* were very satisfactory; but in the case of anthrax it was less conclusive, as the cultures used were proved to be somewhat feeble. Both gelatine plate and broth cultivation were tried. It was far more efficacious than even strong solutions of phenol. As compared with mercuric chloride, the report gives the preference to the Hermite fluid as a practical disinfectant. It sees, however, no advantage in the Hermite solution over the product obtained by treating chloride of lime in solution with carbonic acid.

* *Lancet*, May 26, 1894.

† *Methods of Analysis*, Chap. xv.

Sir Henry Roscoe and Lunt have also criticised the Hermite process unfavourably.*

Chlorates.—Being more stable than the hypochlorites, the chlorates, although they contain more oxygen, give off neither oxygen nor chlorine unless a strong acid be added. Such a mixture is a very strong oxidant, but it evolves besides chlorine, more or less of the explosive and poisonous chlorine oxides known as "euchlorine."

Wiederhold recommends cholera excreta to be treated with potassium chlorate and hydrochloric acid. The odour of the gases evolved is very unpleasant, and powerfully attacks the eyes. The action is very rapid, but is soon exhausted; an objection which, independent of cost and unpleasantness, renders other preventives preferable.†

By themselves, chlorates are mildly antiseptic. Dr. O'Neill found‡ that the chlorates of potassium and sodium had no preservative action on beef tea. Perchlorates are similar.§

Hydrochloric Acid.—Since almost all bacteria grow best in neutral or alkaline solutions, and many are killed by even weak acidity, the mineral acids are valuable disinfectants. Davaine|| states that the virus of anthrax or septic fever is definitely destroyed by the following proportions of acids:—

	Anthrax.	Septicæmia.
Hydrochloric,	1 in 3000	
Sulphuric,	1 ,, 5000	1 in 1500
Chromic,	1 ,, 6000	1 ,, 3000

Vallin, from his own experiments, thinks that a larger amount is required.

Acid fumigations for disinfection, especially with hydrochloric acid, were introduced by Guyton de Morveau in 1805. Previously, in 1773, the stench from the catacombs under the church of St. Etienne at Dijon (which, of course, would be very ammoniacal) was entirely removed in twenty-four hours by pouring 2 lbs. of sulphuric acid on 6 lbs. of salt in a vessel heated by a brazier of hot cinders.

$$NaCl + H_2SO_4 = NaHSO_4 + HCl.$$

The next year the hospital at Dijon, where typhus was raging, was successfully disinfected by the same means. After several other trials, this process was strongly approved by the Academy of Sciences. For 350 cubic metres of space, 200 grms. of salt and 240 grms. of sulphuric acid of 60° B. were recommended.

* *Journn. Soc. Chem. Ind.*, 1895.

† Reichardt, *Desinfectionsmittel*, p. 95.

‡ *Army Medical Report*, 1872, p. 202.

§ Compare *Periodates*, p. 76.

|| "Virus de Septicémie," *Gaz. Med.*, Jan. 10th, 1874.

Its penetrating power and solubility, combined with cheapness and facility of employment, are its chief merits. The gas is less irritant than chlorine, but has a powerful pungent odour. Although it is now seldom used, it is well worth further experiment. Guyton de Morveau* states that "Dr. Cabanellas, in the terrible epidemic in Andalusia in 1780, having exposed to the simple vapour of hydrochloric acid for 16 days, pieces of very fetid flesh, there remained not the slightest odour of putrefaction."

Against its employment are the experiments of Pettenkofer and Lehmann,† in which animals exposed to 3·4 per cent. of the acid in air for one and a-half hours were seriously affected, and many died. Strong men can only stand 0·5 per cent. for a short time, and the limit for workmen used to it is 0·1 per cent. Recent experiments have shown that less than this is destructive of a large number of pathogenic bacteria.

Chlorides.—Many of the chlorides have marked antiseptic properties. Those of the heavy metals, such as iron, aluminium, and zinc, will be noticed under the respective metals.

Sodium chloride, common salt, is generally employed for the preservation of meats, butter, &c. This it does less by its own antiseptic power than by removing in the brine the soluble and more putrescible organic constituents, and by hardening the remaining insoluble fibres. The brine becomes sometimes contaminated with ptomaines, and parasitic low organisms are produced. M. Goubaux has shown that it can sometimes acquire a high degree of toxicity. However, it is generally thrown away and the meat washed before use.

Sodium chloride is not a disinfectant. Pringle, who was one of the first to introduce direct experimental methods in the study of disinfectants, in his *Mémoire sur les Substances septiques et antiseptiques*, ‡ which is of classical interest, and contains details of a series of most carefully devised experiments, found sodium chloride so weak an antiseptic that he placed it the lowest in his scale of bodies investigated. In further experiments he proves that sodium chloride more frequently hastens putrefaction, for, in the proportion of 10 to 20 grains to 2 grains of beef and 2 ounces of water, the salt softens and dissolves the meat, and "by a septic virtue favours its digestion." He cites other authors who have admitted the "putrefiant" nature of sodium chloride.

Bouley,§ and Arloing, Cornevin & Thomas || find that even a saturated solution of salt is without action on the virus of anthrax.

Bromine.—Bromine, formerly employed by Ozanam to combat the development of false membrane in diphtheria, is likely to be more

* *Traité*, 1805. † Munich Acad., 1887, 179. ‡ *Acad. des Sciences*, 1750.
§ *Médicine Vétérinaire*, p. 467. || *Lyon Médical*, June, 1882.

generally used as a substitute for chlorine in the event of an increase in the demand for a volatile liquid which easily gives off, when exposed, large quantities of potent gas. It is now made in large quantities and comparatively cheap. Its odour and action on the mucous membranes are worse than those of chlorine. According to Pettenkofer and Lehmann, men cannot stand more than ·002 to ·004 per cent. unless habituated to it; if so, not more than 0·01 per cent. This shows that fumigation with chlorine or bromine in presence of men or animals is of no value, since bacteria require 3 per cent. Cl for three hours, or 0·4 per cent. for twenty-four hours; hence it can only be used under the direction of experts. It is also intensely corrosive. The chemical action is similar to that of chlorine, but slower. It is much more soluble, bromine water containing 3 per cent. of the element, and possessing greater stability than chlorine water. Bromine stands intermediate in power between chlorine and iodine, as its atomic weight would indicate. Wernitz * finds its efficiency against different known organisms varies between 1 in 1,000, and 1 in 2,840, and 1 in 31,100, iodine lying between 1 in 1,000 and 1 in 24,000. Jalan de la Croix,† to kill bacteria in beef tea, required of bromine, 1 in 2,550, of iodine 1 in 2,000; to sterilise the germs required, bromine 1 in 336, iodine 1 in 410. To prevent growth in raw beef tea exposed to air, 1 in 5,600 of bromine, 1 in 2,010 of iodine. Wilson ‡ states that bromine water of 2 per cent. strength destroyed *Bacillus anthracis* in one day.

Bucholtz § finds the growth suppressed by chlorine, 1 in 25,000; iodine, 1 in 5,000; bromine, 1 in 3,333, as compared with sulphur dioxide, 1 in 666. Arloing,‖ confirmed by Koch, finds that bromine is the most powerful of all destructives to the virus of anthrax and tubercle; even killing the dried virus, upon which chlorine does not act. To summarise, 4 parts of bromine appear to be about equal to 5 parts of iodine, and a safe minimum is about 1 in 2,000, or comparatively—

Cl 0·02 per cent. Br 0·05 per cent. I 0·062 per cent.

The Prussian Government ordered (March 13, 1879) that when strong disinfection of stables was necessary, after removal of the animals, for every 18 cubic metres of space a flask of 250 grammes of bromine should be planted in shell-sand, iron articles being as far as possible removed, and doors and windows closed. The flask is upset, and the operative quickly retires.

After twenty-four hours the place is opened, and ventilated for

* *Wirkung der Antiseptica*, Inaug. Dissert., Dorpat, 1880.

† *Verhalten des Bakterien*, *Archiv. f. exp. Pathol.*, 1881. ‡ *Hygiene*, 1892, p. 525.

§ *Archiv. f. exp. Pathol.*, vol. iv., pp. 1 to 80. ‖ *Lyon Médical*, 1882.

twelve hours before the stable is again used. Its cost was then about 2½d. per cubic metre, but since that date the price of bromine has been much reduced.* All the bromine would be used without attention, and the method seems to have the merit of neatness and efficiency.

Dr. Franck, to whom many of the improvements in the manufacture of bromine are due, has introduced under the name of *bromum solidificatum*, a very convenient form.† This is made by first forming porous rods of kieselguhr (infusorial sand), and molasses baked until hard, and then saturating them with liquid bromine. Each stick contains about 75 per cent. Br by weight, so that a given weight of disinfectant can be obtained by using the necessary number of sticks. At present, however, they cost much more than ordinary liquid bromine.

Fischer and Proskauer‡ have made a number of experiments with the halogens. For bromine, a stoppered bottle was filled with siliceous earth saturated with bromine; when required the stopper was removed, the bottle placed near the ceiling of the room, and the vapour allowed to diffuse. They prefer chlorine, on the ground that bromine is dearer and more destructive to cotton and wool.

They also draw attention to the importance of the presence of moisture when the halogens are used as disinfectants.

A mixture is made by Messrs. May & Baker, of Battersea, London, consisting of a soluble bromide and bromate (preferably of sodium or potassium) mixed with an alkaline bisulphate, such as $NaHSO_4$. The addition of a small quantity of a terpene, essential oil, camphor, or hydrocarbon increases the keeping power of the disinfectant. This mixture, when moisture from the air is absorbed, liberates the halogen thus:—

$$5NaBr + NaBrO_3 + 6NaHSO_4 = 6Na_2SO_4 + 3H_2O + 3Br_2.$$

It is known under the name of "Bromidine."§

The bromonaphthalene night-lights, which owe their efficiency to the liberation of this element, give off the bromine only when burning.|| Dr. C. R. A. Wright has patented the use of monochlor- or bromnaphthalene dissolved or suspended in solution of resin soap. He also proposed using these compounds in powders by mixing them with sawdust or plaster of Paris, &c.¶

* Compare Mehlhausen's experiments with chlorine, *ante*, p. 61.

† Patent No. 254, 1883.

‡ *Mittheilungen aus dem Kaiserlichen Gesundheitsamte*, Berlin, 1884.

§ *Journ. Soc. Chem. Industry*, 1887, p. 378; W. D. Borland, patent No. 6191, 1886.

|| *Journ. Soc. Chem. Industry*, 1890, vol. ix., p. 407. ¶ Patent No. 4,950, 1893.

Iodine is a less powerful disinfectant, according to Koch, than chlorine or bromine. His experiments have the objection of having been performed with an alcoholic solution of iodine, while both bromine and chlorine were used in aqueous solutions. Cash's more recent work shows that when used in rates proportional to the atomic weights, iodine is more energetic than chlorine, bromine being intermediate in its character.

Iodine water is practically stable, but is much weaker than bromine water. Its vapour is eight and a-half times heavier than air, and, therefore, difficult to diffuse.

Iodine does not act by oxidation like chlorine and bromine, but directly combines with the protoplasmic matters of organisms, thereby poisoning them. It is not a good deodorant, and has the disadvantage of producing brown or blue stains when organic materials come into contact with it. Its high atomic weight (127) adds to its cost, but, being a solid, it is convenient, safe, and portable. Lamps of various kinds have been devised for vaporising and diffusing it in a finely divided state.

Messrs. Casson and Brown proposed using candles containing iodine and salicylic acid incorporated with the wax. These, when burnt, give off vapours of iodine and phenol. If the combustion is too free, iodine alone is volatilised, the phenol being decomposed. These candles are said to remove all odour of sulphuretted hydrogen and tobacco smoke, and are recommended for asthma, hay fever, &c.

Better than these are the "Sussex patent night-lights," in which iodoform is mixed with the wax. In burning, hydriodic acid is probably liberated first, and then decomposed by the heat into hydrogen and iodine.

Watson & Fulton* have proposed candles containing iodine and sulphur, which profess to give off the vapour of iodine and sulphur dioxide gas, with no hydriodic acid.

A. J. Shilton † has taken out a patent ‡ for a solution of iodine dissolved in an alkaline iodide in the proportion of 1 oz. of iodine and 2 ozs. of potassium iodide to 1 gallon of water; also § a mixture of 2 ozs. potassium iodide, 1 oz. iodine, and 16 ozs. ammonium chloride; these in strong solution are diluted with 15 to 20 parts of water, and diffused into the room by a spray producer. Davaine and Marchal de Calvi were the first to propose iodine as an antiseptic. The former found that 7 milligrammes of iodine sufficed to kill anthrax bacilli in 1,000 of liquid.|| Griffiths ¶ states that 1 milligramme of iodine in

* Patent No. 10,876, 1885.

† *Journ. Soc. Chem. Industry*, 1890.

‡ Patent No. 2,537, 1889.

§ *Ibid.*, 1885, p. 239.

|| *Bul. de l'Acad. de Médecine*, July 27, 1880.

¶ *Proc. Roy. Soc. of Edin.*, vol. xv., p. 37.

100 c.c. of nutrient broth (1 part in 100,000) destroyed the vitality of *Sarcina lutea*, a chromogenous coccus, in half an hour.

Dr. Williams asserts that iodine greatly reduces the number of tubercle bacilli and prevents spore-formation. "We can inject with impunity into the blood of a dog, for each kilogramme of body weight ·02 or ·03 gramme of free iodine dissolved in 2 parts of sodium iodide. This for an ordinary man would be 1·4 to 2·1 grammes. Beyond this it is poisonous, and death occurs in twenty-four hours. Potassium iodide has an injurious action on the heart." * The importance of these results is shown by the consideration that disinfectants externally applied cannot arrest the progress of disease germs already established in the body, since, as Koch says, "before they destroy the parasite, they kill the host." The choice lies between real though dangerous disinfectants like chlorine, and antiseptics like carbolic acid which require to be of such strength as to be expensive and almost inapplicable. Prophylactic treatment, like injection, or Pasteur's and Koch's inoculation, would have to supplement effective disinfection externally. Koch states that to check *Bacillus anthracis* in man, by internal treatment, 12 grammes of iodine must be constantly in circulation.

Iodine inhalation has proved valuable in phthisis and other lung diseases. Of course, it is very irritant if too strong, but a diluted vapour is tolerated.†

Iodine Trichloride, ICl_3, was proposed as a disinfectant by von Langenbach. It occurs in orange-yellow needles, easily soluble in a moderate quantity of water to a colourless acid solution of extremely irritant odour, affecting the eyes. It is best kept as a 5 per cent. solution. A solution of 1 in 1,000 keeps for several days; after a time it decomposes in the presence of water into hydrochloric and iodic acids, and loses much of its power. It is easily made by passing a current of chlorine through water in which iodine is suspended with constant agitation. It is well known in organic chemistry that the presence of a trace of iodine favours greatly the action of chlorine on organic bodies, hence it is not improbable that a small quantity of iodine, or of its chloride, might be a valuable adjunct to chlorine disinfection. Von Langenbach pronounced iodine trichloride to be one of the most powerful disinfectants known, an aqueous solution containing from 0·67 to 1 gramme per litre, being as powerful as a 4 per cent. solution of phenol. It can be used for cleaning the hands and instruments, and ranks next to mercuric chloride as a germicide.

Traugott ‡ finds by experiments on hospital patients that it is not poisonous, that its effect on germs is very marked, the bacteria of

* *Proc. Roy. Soc.*, 1884. † *Proc. Roy. Soc. Edin.*, vol. xv., p. 54.

‡ *Zeits. für Hyg.*, 1893, p. 427.

typhoid, cholera, and diphtheria being destroyed by 1 per cent. in one minute, the two latter by 1 per 1000 in the same time, while typhoid with 1 per mille required five minutes. It was very successful when tried on the dejecta of cholera. The price of a 1 per 1000 solution is about one-quarter that of 3 per cent. carbolic acid, which it excels in efficiency. Dr. Otto Riedel * had previously in a number of experiments established its value, pronouncing it not very poisonous, and as having about three times the power of phenol. Webb states that chloride of iodine, mixed with talc and stearin or petroleum and burnt, gives an active vapour.†

Iodates are disinfectant, easily giving off oxygen and even iodine. Iodine dissolves at once in an alkali, producing a mixture of iodide and iodate, which, on the addition of an acid, liberates hydriodic and iodic acids. These acids interact on one another, setting free iodine as a precipitate if strong, or in solution if weak.

$$HIO_3 + 5HI = 3I_2 + 3H_2O.$$

Sonstadt has proposed ‡ a mixture of calcium iodate and an alkaline salicylate for destroying the disease-bacteria of pleuro-pneumonia, &c., by spray or vapour. Stronger solutions are made by adding sodium or potassium citrate, which increases the solubility of the iodate. "It may be used as a lotion for sores, bites, or wounds, by injections for cholera or typhoid, or internally." Griffiths states § that a solution containing 0·5 per cent. of potassium iodate destroys several microbes.

Periodates.—Salts of periodic acid, HIO_4, have been recently much extolled as disinfectants. Weaver asserts that "all putrefactive microbes and the poisonous ptomaines they create are destroyed by 1 in 250,000 of 'periodate,' although singularly the aërial moulds are not much affected by it." ‖ One of the salts has been investigated by Klein, who states that "it is a very powerful disinfectant, instantly killing cholera comma bacilli, and typhus bacillus when used 1 in 5,000 of water."

Periodic acid is made by treating perchloric acid with iodine.

$$2HClO_4 + I_2 = 2HIO_4 + Cl_2.$$

The periodates are formed by treating an iodate and an alkali with chlorine, or treating a mixture of iodine and an alkali with excess of chlorine:

$$NaIO_3 + 2NaOH + Cl_2 = 2NaCl + H_2O + NaIO_4.$$

A great number of periodate preparations have been introduced. "Creo" is a disinfecting powder containing tar, alkali, and periodate,

* *Arb. a. d. Kais. Gesundheitsamte*, 1887.

† Reichardt, *Desinfectionsmittel*, 1881, p. 68. ‡ Patent No. 4,920, Oct., 1883.

§ *Proc. Roy. Soc. Edin.*, March, 1889. ‖ *Builder*, Sept. 11, 1889.

for drains, &c. Klein states that a 1 per cent. solution kills cholera and typhoid bacilli in five minutes. Another disinfecting powder contains periodate with eucalyptol. Iodate soaps are made.

Griffiths has given a very favourable report on ferric periodate, 1 in 250, as destroying *Bacillus anthracis* and its spores.

The constitution of these various mixtures seems not to be clearly defined, and further experience is necessary before their very wide claims can be admitted. Their expense and possible instability have been adduced as an objection for public and extended use. It is notable that the higher oxygen compounds of iodine in the chemically pure state are known to be very stable and do not easily give up their oxygen. The activity of these "periodate" preparations cannot therefore be attributed to liberation of oxygen. They present some analogies with the "Hermite" fluid.

ORGANIC COMPOUNDS CONTAINING THE HALOGENS.

Nearly all halogenated organic compounds have antiseptic and anæsthetic properties. The aromatic compounds are more antiseptic and less anæsthetic than derivatives of the hydrocarbons which have not a closed chain. They are, therefore, to be preferred, although chloroform and especially iodoform are still largely used.

Chloroform, $CHCl_3$, is a strong antiseptic, and prevents putrefaction so long as it is present. It is very volatile, boiling at 61° C., has a high specific gravity (1·497), and is almost insoluble in water. These properties, its cost, and its poisonous action on animals, render it of very limited application, almost confined, indeed, to preserving medicinal infusions.

A solution of 5 per cent. chloroform in spirit is sold in small bottles as a preservative, but is not patented. Its peculiar sweet taste and odour are instantly recognised, even in presence of sugar.

Vallin states * that to kill already-grown bacteria requires the relatively large dose of 1 per cent. of chloroform, and that it does not sterilise except when equal parts of chloroform and water are used.

F. Bouillat † has also obtained unsatisfactory results with the chlorides of carbon, CCl_4, C_2Cl_4, and C_2Cl_6.

Bromoform, $CHBr_3$, is similar, but more expensive, less volatile, equally insoluble, and less stable.

Iodoform, CHI_3, a yellow crystalline powder of persistent and disagreeable odour, volatile, soluble in alcohol, but almost insoluble in water, is a powerful antiseptic (proposed by Von Moorhof, of Vienna,

* *Traité des Désinfectants*, p. 206.

† *Zeitsch. f. praktisch. Chem.*, vol. xxv., p. 300.

in 1881), and is much used in hospitals for dressings, &c., in the form of iodoform gauze. A liquid containing iodoform in solution or suspension is readily made by adding to tincture of iodine strong liquor potassæ or liquor sodæ until the colour is destroyed, and pouring this solution into a large bulk of water.

Iodoform night-lights have been already mentioned (p. 73).

To prevent the putrefaction of bronchial mucus in pulmonary diseases, Chiaramelli recommends the internal administration of iodoform. The medicine is eliminated by the lungs, hence its action would be less irritant than in direct inhalation.*

The United States Pharmacopœia gives the following formula for iodoform gauze:—

Iodoform, ...	10 parts.
Ether, sp. gr. ·725, ...	40 ,,
Alcohol, ,, ·820, ...	40 ,,
Tincture of benzoin (1 in 5), ...	5 ,,
Glycerine, ...	5 ,,
Gauze muslin, ...	A sufficient quantity.

"Dissolve the iodoform in the ether, then add the alcohol, benzoin, and glycerine; immerse in a weighed quantity of this solution the exact amount of muslin required to absorb it all, so as to make a product of the required strength in iodoform (generally 30 to 50 per cent.), dry it horizontally in a dark place. Preserve it in air-tight receptacles."

Bisulphide of carbon has been suggested as a solvent, but its odour and inflammability render it objectionable.

Iodoform is also used in fine powder for dusting wounds, in bougies with cacao butter, in emulsion of 10 to 50 per cent. with glycerine, water, and tragacanth, and in solution of 1 part iodoform with 11 of vaseline to 9 of benzene with 2 drops of oil of wintergreen for injections.

The antiseptic power of iodoform has recently been much disputed. While the *Lancet* asserts † that it is a much better antiseptic than most other substances which are used for the same purpose, and is of much more value than carbolic solution, and while Sir Joseph Lister found it of the highest value for wounds, Messrs. Hehn and Rosvinj maintain ‡ that in a long series of experiments they have proved that it is not antiseptic at all, but only a desiccant. "Sterilised iodoform jelly, when inoculated with micro-organisms, was found to be full of them, all growing freely, on the third day." Riedlin asserts § that "as a parasiticide it is feeble and inert, but it dries the surface of

* *Lyon Médical*, 1882, p. 362.
† *Lancet*, 1887, p. 595.
‡ *Chem. News*, vol. lv., 1887.
§ Arnould's *Hygiene*, p. 498, 1889.

wounds." Miguel in his table marks it as very strongly antiseptic;* but Bouillat † found that 10 per cent. of iodoform did not arrest putrefaction change in extract of pancreas. The truth is, as pointed out by Behring, that it produces its undoubtedly beneficial effects, not by acting directly on bacteria, but by inducing chemical changes in their toxic products. He has ascertained that some of these toxines are altered chemically by iodoform and rendered harmless.

Drs. Forster and Marchand ‡ are in favour of iodoform. Dr. W. D. Miller does not recommend it for dental purposes.

Its utility must be limited to surgery, and perhaps also to fumigation in the candles already described (p. 73).

Ethyl iodide is unstable and easily gives off iodine, of which it contains 81 per cent. It has proved useful in phthisis and asthma, in doses of 10 to 15 drops inhaled several times a day. Iodine may be detected in the urine and saliva soon after inhalation. It possesses germicidal powers, and readily destroys *Bacillus tuberculosis.*§ Ethyl bromide has also been suggested.|| Their cost and low volatility would negative them as disinfectants.

Organic Compounds containing Iodine.—The halogens can only exert their disinfectant action in the free state; in combination they may modify the properties of the compound, and make it possibly more antiseptic, but they cannot be disinfectant in the sense of burning up the organisms as chlorine, bromine, and iodine in the free state do. It is true that some of these bodies are decomposed more or less slowly by light setting free some of the halogen, but this would be a protracted, expensive, and wasteful process.

Europhen (isobutyl-cresol hydriodide); iodol (tetra-iodo-pyrroline); aristol (di-iodo-di-thymol); and sozo-iodol (sodium-di-iodo-paraphenol sulphonate) have been proposed as iodoform substitutes, and will be further described among the aromatic antiseptics.

The periodides of the phenols have been patented for antiseptic use.¶

Fluorine itself is more energetic than chlorine, but on account of the intensity of its action and the difficulty of its preparation, is not likely to be made available.

Many years ago William Thompson found that hydrofluoric acid, fluorides (acid or neutral), and silicofluorides (fluosilicates) were antiseptic. He patented their use under the name of "Salufer." Sodium

* *Les Organismes Vivants de l'Atmosphère*, 1883, p. 289.

† *Zeitsch. f. praktisch. Chem.*, vol. xxv., p. 300.

‡ *Archiv. Path. Anat.*, vol. xciii., 1883. § Griffith's *Micro-organisms*, p. 208.

|| Sormani, *Atti dell'Inst. Lombardo*, 1887.

¶ Bayer of Elberfield, and Willcox, Patent No. 7,782, 1892.

silicofluoride is a powder possessing no smell and only a slight saline taste, and is sparingly soluble in water. A saturated solution contains 0·61 per cent. of the salt, and is not irritating to wounds. Thompson states that it is stronger than a 1 per 1000 solution of mercuric chloride, and not poisonous. It is commonly sold in cubes of a definite weight, being thus more easily carried. One cube dissolved in a quart of water is suitable for washing the hands. It is highly spoken of as a non-toxic antiseptic and deodorant.

A "Salufer" wool is also made.*

The recent work of Dr. Effront on the use of mineral acids for the suppression of undesirable fermentations in breweries and distilleries, has demonstrated that hydrofluoric acid has a powerful antiseptic action, and protects the wort from lactic and butyric fermentations. The ammonium and potassium salts have also been used successfully in this way. All the fluorides appear to possess the further remarkable property of increasing the diastatic power of malt.†

Dr. Griffiths in several experiments has found that a 0·4 per cent. solution of sodium silicofluoride was fatal to the bacteria tried—viz., *Micrococcus prodigiosus* and *Bacillus œdematis maligni.*‡

CHAPTER V.

THE NON-METALLIC ELEMENTS AND THEIR DERIVATIVES (*Continued*).

Oxygen and Ozone: Ozonizers—Peroxide of Hydrogen—Carbon Dioxide—**Nitric Acids and Oxides of Nitrogen**: Nitrous Ether—**Sulphur and its Compounds**: Sulphuretted Hydrogen—Sulphurous Acid—Sulphites and Bisulphites—Thiocamf—Sulphites in Food—Sulphuric Acid—Sulphates—Bisulphide of Carbon—**Boric Acid**: Borax and other Borates—Boroglyceride—Boric Acid in Food—Physiological Effects—Influence of Gases on Putrefaction.

OXYGEN, OZONE, AND PEROXIDE OF HYDROGEN.

Oxygen is the chief and natural disinfectant, burning up gradually all organic substances into carbonic acid and water. This process, called decay, affects the various bodies very differently; the more putrescent compounds are generally the most rapidly destroyed, so that fresh air would be all that is needed to keep our surroundings healthy, if it

* *Chem. News*, vol. lvi., p. 132. † *Monit. Scient.*, vol. vi., 1892, p. 81.
‡ *Proc. Roy. Soc. Edin.*, vol. xv., p. 37.

were possible to ensure that all matter likely to be a source of contagion were liberally supplied with the oxygen of the air. The oxidation of the products of those micro-organisms which are poisonous to man, such as the "ptomaines" and "toxines," which Selmi was the first to investigate, is no easy task. The bacteria which produce these toxic compounds have a higher vitality than man, and most strong chemical agents which can kill bacteria have also a toxic effect upon more complex organisms. No man can endure an atmosphere that will kill these bacteria. Only the halogens, chlorine, bromine, and iodine can penetrate their envelopes, and these cannot be given in sufficient quantity when man is present. It is, therefore, absolutely necessary to remove patients and seal rooms in order that disinfection may be successfully accomplished.

The importance of the distinction between an antiseptic, which simply stupefies the germs of disease for a time, and a disinfectant, which kills them and leaves the room sterile, cannot be too strongly insisted upon. The use of antiseptics merely puts off the era of putrefaction, and while arresting temporarily the evil, does not eradicate it.

The "molecular" or ordinary oxygen of the air acts slowly. When liberated from various chemical compounds like permanganate and peroxide of hydrogen it is said to be in a "nascent" or atomic condition, and is then far more active.

A number of inventions attempt to increase the power of atmospheric oxygen by mechanical means. Thus it has been proposed to compress the oxygen into water, increasing the solubility, and therefore presumably the activity.* Similarly J. Konig, with a view to increase the rate of atmospheric oxidation of the waste water of tanneries and slaughter-houses, produces a flow over a tinned iron net 4·5 metres high, with a breadth of 1 metre for every 12 litres per minute, giving as the result of an experiment :—

	Per Litre.	
	Before.	After.
Oxygen,	3 c.c.	9 c.c.
Sulphuretted Hydrogen,	20·4 milligrms.	0·9 milligrms.
Sulphuric Acid,	48·6 ,,	72 ,,

proving that strong oxidation had taken place.† On the same principle polluted water flowing over weirs and waterfalls is oxidised and becomes clear and brilliant. Pathogenic organisms may not, however, be entirely removed by such aëration, and may set up changes again lower down.

* E. Scruby, Patent No. 5330, 1891. † *Chem. Zeitung*, vol. viii., pp. 56, 1008.

The self-purification of rivers in this way is now accepted by most chemists, the natural aëration being aided by infusoria and vegetation in removing most of the dead organic matter and in reducing the number of micro-organisms present.*

Ozone, O_3, is present in country air, but absent in towns, being quickly consumed by the organic matter present in the air. It is an allotropic modification of oxygen produced by atmospheric electrical disturbances, but owing to its energetic oxidising, it is soon destroyed. It closely resembles chlorine in its chemical activity. Its energy has led several inventors to propose electrical means for disinfection, as ordinary oxygen becomes ozonised when subjected to an electric current.

Hagen† proposes to ozonise oxygen by the usual silent discharge method, then to pass it over the articles to be disinfected, or introduce it into sewage, when the ozone, O_3, decomposes into O_2 (ordinary or "molecular" oxygen), and the atom of "nascent" oxygen, which acts upon the organic matter more rapidly than when in the ordinary molecular condition. The remaining ordinary oxygen, mixed with a little carbonic acid, derived from the oxidation of organic matters, is carried back and ozonised again. The process can, therefore, be made a continuous one, the carbonic acid being absorbed by lime. It must however, be borne in mind that:—

1. *No ozoniser yet invented raises the ozone to more than* 10 *per cent.*, and generally not over 1 or 2 per cent., and this strength is hardly sufficient for sewage. It is well known that, owing to diffusion laws, a gas acts far less actively when mixed with a large quantity of another inert gas.

2. *A large volume of gas would be required.* If the sewage contained 1 per cent. of organic matter, 1 gallon would contain about 50 grammes, which would require about 10 grms. of "nascent" oxygen, or 30 grms. of ozone. Assuming the ozonised oxygen to contain 5 per cent. of ozone, 300 litres of ozonised oxygen would be required to disinfect 1 gallon of sewage if the ozone all acted. But as, owing to diffusion, it is reasonable to assume that only part of the ozone would act, a very much larger amount of gas would be required to effect the purpose.

3. *It comes in competition with chlorine,* which is more soluble, and therefore, more rapidly absorbed, and as it can be easily produced in a pure state (100 per cent. as against 5 per cent.), a quicker and more certain action from its use can be relied on.

4. *The question of cost.* With equal efficiency, this would of course decide.

* *Journ. Soc. Chem. Industry*, 1891, p. 720; *Report of State B. of Health, Mass., U.S.A.*, p. 783; *Proc. Inst. Civ. Engineers*, 105, vol. iii., p. 9.

† Brin, October, 1881, patent void.

J. T. Wood* converts sewage or other polluted liquid into spray by the action of a blast of "air, oxygen, ozone, or other suitable gas" under pressure, by which it takes up more than it would under ordinary circumstances. "Any chemical precipitant" is projected into the spray, the sewage allowed to settle in tanks, and the clear liquid further purified by passing it over "oxidising stairs," the "risers" being provided with openings which communicate with tubes containing the ozonised air under pressure. Modifications of the air-blast are described applicable to filter-beds and the weirs of rivers. It is to be feared that the expense would be prohibitive. It does not seem to have been tried on the large scale.

In the dry state, ozone has very little action on micro-organisms, but when moist is a very powerful bactericide. Ohlmuller † found that when bubbled through water in which bacteria were suspended, the strength being 15 milligrammes of ozone in 1 litre of air, anthrax spores (the most difficult of all to destroy) were killed in ten minutes by not less than 90 milligrammes of ozone to the litre of water, anthrax bacilli by 58 mgms., typhoid by 19·5 mgms., and cholera by about 18 mgms. A most important factor to be taken into account is that, when the water contains organic matter the action is much diminished, since the ozone attacks the unorganised matters first, and in so doing is destroyed. It must not be forgotten that the oxidation of organic matter purifies the water, and would apparently render it less liable to subsequent infection, as the pabulum for the bacteria is diminished. Recent researches seem to show, however, that the pathogenic organisms actually multiply with much greater rapidity in pure waters than in ordinary river waters, although they subsequently decline equally rapidly. No process, therefore, that is simply founded on diminishing the organic matter in water, can be regarded as trustworthy.

It will be noticed from the above experiments that a very large volume of air must be driven through the liquid, amounting for anthrax spores to six times the volume of the water treated before sterilisation can be assured. Since no materials, except glass or stoneware, resist the action of ozone, metals, wood, grease, indiarubber, &c., must be avoided in the construction of any apparatus employed.

In generating ozone, the temperature is of importance. At 6° C. no ozone appears to be formed; from this point the yield increases up to 24° C., then declines.

When permanganates are treated with strong sulphuric acid, ozone is evolved. Meyer ‡ makes an intimate mixture of barium perman-

* Patent No. 22,747, 1891. † *Arbeiten a. d. Kais. Gesund.*, 1892, vol. viii., p. 229.
‡ Patent No. 16,463, 1888.

ganate and sodium bisulphate in the proportion of 25 per cent. of the former and 16 per cent. of the latter. "If sufficient water be added to such a mixture so as to form a thick syrup, ozonised oxygen will be evolved."

The cheapest way of obtaining ozonised air is by means of the silent electric discharge. A convenient method, however, for generating it in small quantities is by means of moist phosphorus, keeping it constantly cool to avoid inflammation.

A. Riche first proposed moistening the phosphorus with a solution of potassium bichromate and sulphuric acid, instead of water, and aspirating or, better, driving a slow current of air over it. He mentions a form of "kerite" as the best material for the tubes.

Kattenhoy* places the sticks of phosphorus in glass-capped holders, just projecting from a solution of potassium permanganate in 10 per cent. sulphuric acid. The whole is enclosed under a bell-jar pierced with holes for the outlet of ozonised air, with a locked cover to prevent tampering. There is a funnel to add more liquid when required, and a sliding glass-rod support to adjust the level of the phosphorus. Such an apparatus might be of service for inlet ventilators, but its use would not be advisable in a room, since even a trace of ozone in excess would be irritating to the lungs.

At Berlin the electrical manufacture of ozone on a large scale has been attempted for sanitary purposes.

Andreoli's apparatus, at present in operation at Allen & Hanbury's works at Bethnal Green, is based upon the silent discharge of electricity from points in the well-known "brush" or glow, as distinguished from the spark. The former generates ozone, whereas the latter, by its high temperature, destroys it. A large number of serrated strips of tinned iron are arranged parallel to one another so as to form gratings on opposite sides of plates of glass. The gratings are connected with the poles of a dynamo-transformer, giving a high-tension current of 10,000 volts. The apparatus gives a larger surface and a more uniform distribution of the current than other ozonisers of the Siemens' type. Air is driven by a fan through a cotton wool filter at a rate of 160 cubic feet per minute, then, after cooling, and drying by sulphuric acid on pumice, it passes over the gratings by which about 6 per cent. is calculated to be ozonised.

The same inventor has smaller open ozonisers intended for domestic use, which can be worked by an electric supply current.†

Dr. Forster, of Berlin, proposes the supply of a small quantity of ozone to the air of towns, stating that many epidemics, such as influenza, arise at times when the atmospheric ozone is at its

* Patent No. 24,709, 1893. † *Industries and Iron*, Aug. 18, 1893.

lowest, and that an artificial supply might prevent or modify the outbreaks.

Many years ago an attempt was made to supplement the advantages to be derived from a winter's sojourn in the High Alps by supplying the air of the hotel at Maloja with ozone from powerful induction coils, but it seems that no special benefit from its use was felt by the patients. Dr. Hassall's experience at his sanatorium at San Remo was also disappointing. There are, however, many cases in which it is stated to have proved beneficial in phthisis, and late experiments in the Berlin hospitals have shown results in its favour.

Peroxide of Hydrogen, H_2O_2, is prepared by acting on a peroxide of an alkaline earth by an acid, *e.g.* :—

$$BaO_2 + CO_2 + H_2O = BaCO_3 + H_2O_2$$
$$BaO_2 + H_2SO_4 \text{ (dilute)} = BaSO_4 + H_2O_2$$

It is a syrupy, inodorous, and neutral liquid, which easily decomposes into water and nascent oxygen, hence bleaches and acts as a powerful oxidising agent. In the dilute state it is neither irritant nor poisonous. Its instability is lessened by the addition of a small quantity of acid. Two forms occur in commerce—"ten volumes" and "twenty volumes"—indicating nominally the number of times its volume of oxygen it gives off when treated with peroxide of manganese, according to the following equation—

$$H_2O_2 = H_2O + O$$

The commercial peroxide should always be tested as its quality is often very inferior.*

When an electric current is passed through water, whether the gases oxygen and hydrogen be evolved, or whether the current be so weak that the oxygen remains dissolved, the latter is ozonised, and the water acquires oxidising properties, and behaves as if it contained peroxide of hydrogen. Such a solution has been patented, but the product is too weak to be of use. "Ozonised water" has been introduced under the name of "antibacterikon."

Peroxide of hydrogen is probably present in the "Hermite" solution already described (p. 67).

As a disinfectant hydrogen peroxide would be excellent if it were quicker in its action. Angus Smith in 1869 called it "the disinfectant of the future." It oxidises such bodies as sulphuretted hydrogen readily, it has no smell of its own, and is not poisonous. Metals and fabrics are not attacked; it has not, like permanganate, the tendency to act on inert matter, though it possesses the true characters of a disinfectant. Its action has been recently studied

* For a simple method of measuring the gas evolved, see *Methods of Analysis*, Chap. xv.

in some detail by MM. Paul Bert and Reynard.* They found that all fermentations caused by bacteria are at once stopped by peroxide of hydrogen, and the ferment killed; while no effect is produced on enzymes, such as diastase and those of saliva, gastric juice, and the pancreas. When fibrin has been dissolved in dilute hydrochloric acid, or changed into fibrin-peptone by artificial digestion, hydrogen peroxide is without action on it. It has no effect on foods, like albumen, casein, milk, eggs, fats, sugar, starch, and juice of fruits. So that it is practically one of the few disinfectants which have no effect on digestion, and yet prevent the interfering action of organisms.

Van Tromp† asserted that 1 part of peroxide of hydrogen in 10,000 of polluted water, when shaken up and allowed to stand for twenty-four hours, was usually sufficient to sterilise a water. Altehoefer, however, found,‡ that to ensure sterility, it was advisable to use larger quantities, namely 1 part in 1,000 parts of water. "Experiments made with waters purposely infected with cholera and typhoid bacilli, showed that both these were destroyed in twenty-four hours by 1 per mille of hydrogen peroxide." Altehoefer, beyond a slight taste, which disappeared after twenty-four hours, found no detriment to the water for drinking or domestic purposes, and recommends its application for household use as a protective measure during any epidemics of typhoid fever or cholera. He suggests that 10 c.c. of a 10 per cent. solution should be added to a litre of water, or 70 grms. to the gallon. Traugott also testifies to its innocuous character, even when swallowed in large doses.§

Guttmann injected peroxide of hydrogen hypodermically, but the oxygen was liberated as gas in the circulation, and the animals died of asphyxia.

Miquel places it at the head of his list of antiseptics, making 0·05 grm. sufficient to sterilise 1 litre of beef tea, as against 0·07 grm. of mercuric chloride. Later observers give it much lower potency, averaging about 0·1 per cent.

The class of oxides known as peroxides, which contain more oxygen than the ordinary bases, resemble hydrogen peroxide, and are capable of the following reactions:—

1. When heated they give off oxygen—

$$H_2O_2 = H_2O + O.$$
$$BaO_2 = BaO + O.$$

2. With hydrochloric acid they generate chlorine—

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

* *Berlin Ber.*, vol. xv., p. 1,585.

† *Apoth. Zeitung*, 1890, p. 485.

‡ *Centr. f. Bakteriol.*, 1890, vol. viii, p. 129.

§ See under *Light*, p. 10.

3. With sulphuric acid they give (ozonised) oxygen or hydrogen peroxide—

(i.) Strong acid: $BaO_2 + H_2SO_4 = BaSO_4 + H_2O + O$.
(ii.) Dilute acid: $BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2$.

Many of the peroxides have consequently received attention in the search for disinfectants.

Sodium Peroxide, Na_2O_2, manufactured by the Aluminium Company at Oldbury, near Manchester, is a white powder which on exposure to air becomes damp and spoils, therefore must be kept in tightly closed tins. It is easily soluble in water, and acts like a solution of hydrogen peroxide *plus* caustic soda.

$$Na_2O_2 + 2H_2O = 2NaOH + H_2O_2.$$

If acid be added to the powder, hydrogen dioxide or ozonised oxygen is produced, according as the acid is weak or strong.

Jacobsen* mixes "dioxide of barium, strontium, or calcium with any desired metallic salt." Peroxide of barium is cheaply obtained in Brin's oxygen process. Carbonic acid of the air, in the presence of water, causes it to yield peroxide of hydrogen.

Schone is of opinion that peroxide of hydrogen exists naturally in the atmosphere and in waters. The point is not yet proved.†

Dr. Richardson proposes to saturate peroxide of hydrogen with iodine (very little dissolves), then to add $2\frac{1}{2}$ per cent. of sea salt, and to use the mixture as an antiseptic spray in an "atomiser."

Peroxide of hydrogen and ozone with other products are formed by the slow oxidation of essential oils in presence of air and water, especially if warmed. Such a product, consisting of turpentine oil, water, and air, was patented ‡ under the name of "Sanitas;" more recently § resin, resin oil, camphor, and thymol have been added. These antiseptics would supplement the action of the peroxide of hydrogen or ozone that might be present (see p. 215).

J. Y. Johnson || causes air or oxygen to pass through a mixture of 9 parts of water and 1 part of spirit of turpentine, maintained at the ordinary temperature. When sufficiently saturated with ozone, it is used as a disinfectant for washing wounds.

A convenient test for the presence of peroxide of hydrogen is to add a drop of potassium bichromate solution and a little dilute sulphuric acid to the disinfectant. A blue colour is produced on shaking with ether. "Sanitas" answers to this test when freshly prepared.

* Patent No. 1,711, 1882.
† *Chem. News*, April 27, 1894.
‡ Patent No. 274, 1878.
§ Patent No. 1,172, 1882.
|| Patent No. 14,864, 1884.

NITRIC ACID AND OXIDES OF NITROGEN.

Nitric Acid, HNO_3, when pure is colourless, and has a not very powerful nitrous odour, as compared with the lower oxides which give the colour and suffocating smell to the impure acid. Its specific gravity is 1·52, and boiling point 113° C. As one of the strongest of oxidising agents, it is actively disinfectant, but also very corrosive and poisonous. It oxidises organic matters to such compounds as oxalic acid, and then finally to carbonic acid and water, being itself reduced successively to the lower oxides of nitrogen, which in turn combine with the organic substances to form nitro-derivatives like pyroxylin, nitroglycerin, and picric acid. The latter class of bodies, when soluble or volatile, are themselves poisonous and disinfectant.

Nearly all metals are attacked by nitric acid, giving nitrates and oxides of nitrogen, for instance—

$$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 2NO + 4H_2O.$$

If sulphuric acid be added at the same time, the whole of the nitric acid is driven off as nitric oxide.

Nitric acid vapours are white, and are much less injurious than the red vapours of the oxides. Nitric oxide, NO, is colourless, but turns red in air, forming higher oxides according to the quantity of oxygen; all these are exceedingly poisonous, since they form compounds with the colouring matter of the blood. They may be described as irritant, depressant, and narcotic.

Dr. Calvert (1872) ranks the antiseptic power of nitric acid in dilute solution as about equal to that of hydrochloric.

Nitric acid fumigation was introduced in 1780 by Dr. J. C. Smith for a violent outbreak of typhoid in the British Fleet. For his success he was voted £5,000. On a large iron sand-bath over a brazier were placed a number of stoneware capsules, each containing 12 grammes of oil of vitriol; when hot enough, powdered nitre was added little by little. On stirring with a glass rod, the nitric vapours were evolved in abundance as a thick white mist. The apparatus was carried about among the patients, who unfortunately were affected with violent coughing. Severe bronchial irritation followed, and some destructive action of the surroundings. 350 grammes of nitre in 27 capsules were used for the one hospital ship. The fumigation was daily repeated for a week. The heat should not be too great, and the disengagement should be gradual.

The horrible stench at once disappeared, and the epidemic was conquered in three weeks, the deaths falling on the first day from 31 to 9, and then steadily to the end.*

* Vallin, *Désinfectants*, 1882, p. 265.

Nitrogen Trioxide, N_2O_3, is a red gas of suffocating odour, combining with water to form nitrous acid, HNO_2. Girard and Pabst * describe N_2O_3 as a very strong disinfectant in doses so weak as to be not dangerous, the odour being rather aromatic and etherial. Unfortunately, nitrogen trioxide is a very unstable substance, and is almost always accompanied by the other oxides of nitrogen. The above-named authors patented the use of "chamber-crystals," or nitro-sulphuric acid, in a tower filled with coke. The putrid emanations from closets or sewers are caused to pass up this tower, and, being moist, they dilute and decompose the chamber-crystals, which evolve this gas—

$$2SO_2(NO_2)OH + H_2O = 2H_2SO_4 + N_2O_3.$$

The gases on passing out are quite innocuous. †

Haddan ‡ mixes an aqueous solution of sodium or other soluble nitrite with sulphuric acid (5 parts of acid in 1,000 parts of water), and adds the resulting dilute nitrous acid to sewage. The nitrogen trioxide transfers oxygen to the organic matter, and is re-oxidised by the air, so acting in the well-known way as a carrier from the atmosphere to the sewage, so that "all organisms are destroyed." Although theoretically this action enables a small quantity of oxide of nitrogen to do an unlimited amount of work, yet in practice the disinfection by nitrous compounds has proved expensive, and has no advantages over other methods.

Nitrites are somewhat antiseptic; internally they are dangerous (*Lauder Brunton*).

Nitric Peroxide, NO_2, is a red irritant gas, easily condensed to a brown liquid. If it were desirable, the latter would be the most convenient form for use, and could be obtained in sealed tubes or syphons like sulphurous acid. It is made by heating nitrate of lead.

$$Pb(NO_3)_2 = PbO + 2NO_2 + O.$$

Guyton de Morveau, in his classical work, found that this gas was a feeble disinfectant, but irrespirable and dangerous. Payen § places NO_2 in the front rank among disinfectants. He uses for a space of 40 cubic metres, 1,500 grammes of nitric acid, 2,000 of water, and 300 of copper turnings tied up in a thick paper bag to moderate the action. Even thus it is liable to become too violent, and much of the nitric acid is wasted as nitrous oxide or even nitrogen. Three-fourths of the nitric acid remain behind as cupric nitrate, and this, of course, would act slowly as a liquid absorbent. Payen's process was carried out in sealed rooms during the siege of Paris. He allowed forty-eight hours for complete disinfection. The cost is obviously very high.

* *Désinf. des Latrines*, 1881.
† Patent No. 18,486, 1881.
‡ Patent No. 4,714, 1885.
§ *Comptes Rendus*, March 6, 1871.

Notter * says that an atmosphere containing 0·35 per cent. of nitrogen peroxide killed all bacteria in putrid beef tea in forty-eight hours.

Sternberg † states that 1 per cent. of nitrogen peroxide in air will sterilise vaccine in six hours, while $\frac{1}{4}$ per cent. was not disinfectant. He makes this power to be identical with those of sulphurous acid and chlorine. There is, therefore, no apparent benefit resulting from its use. Severe bronchitis and several deaths from poisoning have been recorded as resulting from breathing this gas (*Angus Smith*).

Nitrous Ether (ethyl nitrite), $C_2H_5NO_2$, was tried both as an antiseptic and disinfectant by Peyrusson and by Guillaumet in 1881. The former considered that it disengaged ozone.‡ Vallin's experiments prove it useless. § Miquel states that in fifteen to twenty days at 20° C. it was absolutely incapable of destroying the vitality of bacteria.‖

Nitrobenzene will be alluded to among organic compounds.

In conclusion, the opinion is irresistible that nitric disinfection is the worst of all methods, and under no circumstances should be allowed. Fortunately the patents are few.

SULPHUR AND ITS COMPOUNDS.

The abundance of this element in volcanic districts, and the characteristic odour of its compounds, sulphurous acid and sulphuretted hydrogen, seem to account for the fact that sulphur and its compounds have had the earliest reputation as antiseptics and disinfectants.

In Fawkes' translation of Theocritus we read—

"Next with pure sulphur purge the house and bring
The purest water from the freshest spring,
This mixed with salt and with green olive crown'd
Will cleanse the late contaminated ground."

Sulphurous acid is still the *official* disinfectant; its ease of application and cheapness being its principal merits. The element itself, in the form of "flowers," is dusted on plants to kill aphides, and is extensively used for vines against *Oidium*, as well as for hops and seeds. Here it, undoubtedly, by slow oxidation, gives off sulphurous acid. Mixed with soap it generates an alkaline sulphide, and this in turn, by the action of the carbonic acid of the atmosphere, liberates sulphuretted hydrogen. Given internally, as "flowers" or "milk" of sulphur, it also creates sulphuretted hydrogen in the body, evolved subsequently by the skin, and killing or enfeebling such parasites and micro-organisms as cause many of the skin diseases. So "brimstone and treacle," and the modern "sulphur lozenges," reach their reputa-

* *Journ. Med. Science*, Dublin, 1881, p. 508.

† *Nat. Board of H.*, Washington, 1881.

‡ *Comptes Rendus*, 1881, p. 492.

§ *Désinfectants*, p. 214.

‖ *Org. de l'Atmosph.*, p. 291.

tion. In ointments also it is absorbed. The utility is undoubted, though the action is slow. To quicken it, it must be combined with oxygen or hydrogen, so as to be soluble in water, and diffusible in air.

Sulphuretted Hydrogen, H_2S.—This gas is slightly heavier than air, soluble in water (3 volumes dissolve in 1 of water at 15·5° C.), slightly acid, and blackens silver and some other metals. Its odour is well known, and it acts as a depressant poison, reducing the blood colouring matter of animals to methæmoglobin, which is incapable of carrying out respiration. It is, therefore, not suitable for an aërial disinfectant. Since it destroys most bacteria, especially that of tubercle, Dr. Bergeon * has employed it with marked success, by anal injections of the saturated aqueous solution, for pulmonary phthisis, &c. Niepce inhales the gas, but the former plan seems better, as not so toxic, since Claude Bernard has established the fact that some gases, which are poisonous when passed into the arterial system, become innocuous in the venous-per-intestinal absorption. Breathing continually small quantities of sulphuretted hydrogen is without doubt injurious to health, producing anæmia and low vitality.

The soluble sulphides of the alkalies and alkaline earths have similar properties, giving off the gas on exposure to air. Hence probably the use of sulphur springs for cutaneous affections.

Dr. Percy F. Frankland found that sulphuretted hydrogen was detrimental to the vitality of *Bacillus pyocyaneus*, Koch's bacillus, and *Spirillum Finkleri*, the ones specially selected as typical; also to the majority of microbes, a few, however, thriving on it.† It must be remembered that sulphuretted hydrogen is itself one of the products of putrefaction, one class of organisms, represented by *Beggiatoa* (the "sewage fungus"), not only reducing the sulphates to sulphides, but also converting the latter into solid, and often crystalline, sulphur within their protoplasm. To such, which are not the more dangerous ones, sulphuretted hydrogen would do no harm.

This gas is a reducing agent by means of its hydrogen, sulphur being liberated. It is destroyed by all oxidising agents, eventually producing sulphuric acid. The action of chlorine, bromine, and iodine upon it has already been mentioned (p. 58). Lime and alkalies, and salts of the heavy metals, except those of aluminium, absorb it, forming sulphides. Ordinary acids do not remove it beyond the extent of its solubility in water. Sulphurous acid decomposes it.

$$2H_2S + SO_2 = 2H_2O + 3S.$$

In sewer gas ammonium sulphide, as fetid and poisonous as sulphuretted hydrogen itself, always exists, and seems to be one of the

* *Brit. Med. Journ.*, Dec. 18, 1886. † *Proc. Roy. Soc.*, vol. xlv., p. 292.

chief narcotic agents in causing suffocation in sewers. If paper moistened with lead acetate be discoloured by any emanations, sewer gas is indicated, unless it be derived from a chemical or gas works. The absence of sulphuretted hydrogen or of smell is, however, no proof of efficient disinfection. Many so-called disinfectants, moreover, merely mask one smell by creating another. Even the presence of excess, as shown by the odour of the disinfectant, does not prove efficiency; there must beyond this be a sufficient percentage present, ascertainable only by experiment and calculation.

Sulphur Dioxide or sulphurous anhydride, SO_2, is a colourless gas of specific gravity 32 (air = 14·45), with the well-known odour of burning sulphur. One litre weighs nearly 3 grammes. It is obtained by burning sulphur or a sulphide in air—

$$S + O_2 = SO_2.$$

One kilogramme of sulphur gives 700 litres of the gas.

It is irrespirable, producing violent coughing and suffocation. About 5 per cent. in air has produced fatal results, causing acute catarrh, acid eructations, anorexia, irregularity of the bowels, and permanently impaired digestion (*Hirt*, *Eulenberg*, &c.), but ½ per cent. can be endured for a length of time. A wet towel moistened with washing soda enables a larger amount to be faced.

One litre of water at ordinary temperatures dissolves 50 litres, or 145 grammes, producing an acid liquid containing the unstable H_2SO_3—

$$SO_2 + H_2O = H_2SO_3.$$

This liquid smells strongly of the gas, as, gradually at ordinary temperatures and rapidly on heating, it decomposes again into sulphur dioxide and water. Hence it rapidly loses its strength unless well stoppered. (It only slowly attacks corks, so that it can be kept in a corked bottle.) In the anhydrous state it is not disinfectant; on adding water it becomes active; hence the term "sulphurous acid" will be used throughout for this agent, as more familiar and accurate. It acts in four ways:—

1. As an acid it absorbs ammonia, compound ammonias, and organic bases like "ptomaines" and the products of growth of pathogenic organisms. The salts so formed (sulphites) are much less injurious. It has this property in common with other acids.

2. It decomposes sulphides and sulphuretted hydrogen, as above shown.

3. It reduces organic matters, or combines with them, to form compounds which are in most cases inert. This explains its bleaching action on vegetable colours, as the compounds formed are nearly

colourless. But the action is evanescent, as on exposure to air it is oxidised to sulphuric acid, and the colour often reappears.

4. As a poison it kills living organisms.

The gas can be easily condensed to a colourless liquid by pressure, and preserved in strong metal vessels. About 3 atmospheres (45 lbs. on the square inch) is sufficient. Messrs. Boake & Co.* have introduced commercially this liquefied gas, and as it is attainable in any quantity at a cheap rate, it is much more convenient to employ than sulphur. The vessels are opened by a lever attached to a screw. The gas will flow steadily for forty hours, a single syphon evolving 500 litres of gas, equal to the amount obtained from about 1½ lbs. of sulphur. They also make hermetically sealed tins which are sufficient for the disinfection of a small room. The gas is obtained by cutting with a knife the soft metal pipe attached to the tin.

Whenever the anhydrous gas is used, the rooms must be sprayed or steamed to provide the necessary moisture to form the acid H_2SO_3.

Sponges are frequently disinfected and bleached by first immersing them in a bath of hyposulphite of soda (½ lb. to 1 gallon water), and then adding ½ lb. of oxalic acid in crystals; sulphurous acid is liberated and sulphur deposited in the pores of the sponges. After washing with boiled water, they can be kept in a weak carbolic acid solution.

The Governments of England, United States, Belgium, France, Austria, Sweden, and some others prescribe fumigation by burning sulphur for infected rooms. Hence, as Arnould says, it is the "official disinfectant *par excellence*." Germany, amongst European nations, however, does not recommend it officially. It is difficult to keep it alight, and various devices have been introduced to remedy this defect. When sulphur is used, instead of the compressed oxide, Corfield and Louis Parkes burn it in an iron vessel with a little spirit. Nicholls and Billyen, and also Vallin use 8 parts of flowers of sulphur, 2 or 3 of nitre, and 2 or 3 of bran or liquorice powder. This would give a deflagration, would retain much of the sulphur in the residue as sulphate, and would result in rather too rapid an evolution, so that the inevitable leakage would be greater. Another plan is to place it on an iron tray and throw a shovelful of red-hot coals on it. When this plan is adopted, there is usually a residue of unburnt sulphur left. A chafing-dish of coals, *properly protected*, with an iron tray over it, and lumps of sulphur distributed gives better results. Even with these devices, it is almost impossible to keep up a combustion sufficiently long, hence the liquefied gas, excluding, as it does, the risk of fire, is much to be preferred.

J. Robertson† has devised a portable iron stove provided with an

* Patent No. 12,238, 1885. † Patent No. 10,129, 1891.

evaporating or burning pan in which is placed the chemical to be evaporated or burnt, and connected with a fan, by means of which air is drawn through a hose or flue to the place where they are to be utilised.

J. H. Johnson * has a chamber for sulphuring clothes, rags, &c.

Kingzett's sulphur candles are made in the form of a night-light, and are placed in a water-jacket as a precaution against fire. They are made of sulphur with a "powerful oxidising agent," and a wick. These are arranged to burn two hours. They are very convenient if they yield sufficient of the gas. The cost is moderate.

Seabury's sulphur candles † also burn two hours, and differ from the above in having a large compound wick. Morse and Bourne's patent ‡ principally affects the shape of these candles. §

Neutral sulphites, such as sodium sulphite, Na_2SO_3, are not decomposed like hypochlorites by the carbonic acid of the air, hence they neither smell of nor give off sulphur dioxide. Both the acid and its salts absorb oxygen from the air, changing to sulphates, and therefore they act as reducing agents. The acid or bisulphites of sodium, calcium, and magnesium are much used for preserving provisions; they slowly evolve sulphurous acid gas. The sulphites, as distinguished from the free acid, are poor disinfectants, but a large number of patents have been taken out for their use either alone or in mixtures. Most of these patents are of doubtful utility.

A bisulphate mixed with a bisulphite would be a convenient form, which would evolve sulphurous acid on being moistened, thus—

$$NaHSO_4 + NaHSO_3 = Na_2SO_4 + H_2O + SO_2.$$

R. V. Tuson‖ suggested the use of various metallic sulphites, and ¶ proposed to employ a saturated solution of sulphurous acid in liquid phenol. G. Purvis ** charges sewage with sulphurous acid, then neutralises with lime and adds other substances in the proportion per gallon of 7·5 grains sulphurous acid, 7·5 grains lime, 4 grains aluminium sulphate, and 1 to 5 grains charcoal. ††

M'Dougal and Meldrum ‡‡ state that "the prejudicial and offensive products of the decomposition of sewage matter are mainly compounds of sulphur and phosphorus with hydrogen or alkalies. Sulphurous acid decomposes these, forming thiosulphates, hypophosphites, &c. This is the base of the process. The gas is generated by burning sulphur, pyrites or the spent oxide of gas works, and passed in until the liquid is acid."

* Patent No. 2,567, 1883. † Patent No. 6,407, 1893. ‡ No. 18,434, 1891.
§ *Journ. Soc. Chem. Industry*, Feb. 29, 1892. ‖ Patent No. 8,645, 1879.
¶ Patent No. 1,081, 1879. ** Patent No. 18,286, 1891.
†† See also Van Alsing, Patent No. 2,644, 1878. ‡‡ Patent No. 2,846, 1891.

Fryer and Alliott* place sewage pails in an air-tight vessel, exhaust the air, then let in steam, hot air, sulphurous acid, chlorine, phenol vapour, or other volatile disinfectant. The action is thus more concentrated. The process is also stated to be suitable for the disinfection of wearing apparel, bedding, &c. There are a number of other patents of less importance.

Thiocamf (Prof. E. Reynolds) is a liquid formed by leading sulphurous acid into a bottle containing camphor. The resulting product contains 30 to 35 per cent. of sulphur dioxide. Various other disinfectants (not oxidisers) can be mixed with it. On exposure to air it gives off its sulphurous acid and leaves a white antiseptic residue of, presumably, camphor. A 6-ounce bottle evolves about 20 litres of gas. It was recommended by the Disinfecting Committee of the House of Commons.

The official directions for sulphur fumigation are as follow:—British Local Government Board: 1½ lbs. of sulphur burnt over a small fire, in a carefully sealed room, for six hours or more. (This would give 1·76 per cent. of sulphurous acid in the air.) The wall paper is then to be stripped off and burnt, and the ceiling and floors thoroughly washed, &c. Recent suggestions of the Society of Medical Officers of Health add that bedding and clothes should be spread out on lines, that the sulphur should be burnt over a pail of water to supply moisture, and that the time should be twenty-four hours. In Belgium the disinfection is purely domestic, except in the case of persons. The quantity is 20 to 30 grammes of sulphur per cubic metre, or 2 to 3 per cent. In Paris 20 grammes is used per cubic metre for forty-eight hours. In Berlin sulphur disinfection is not much employed. In Austria and Sweden the official regulations advise the use of sulphurous acid. The American Committee on Disinfection enjoin "exposure for twelve hours to an atmosphere containing at least 4 per cent. of sulphurous acid in presence of moisture = 1½ to 2 kilos. of sulphur for every 28 cubic metres"—an ordinarily sized room.

For ships arriving in the Mississippi from infected ports, the cargo is sprayed with corrosive sublimate solution, but sulphur fumigation is used for the hold. A battery of eighteen furnaces contained in a specially constructed tug is used for heating the sulphur, and the gas mixed with air is forced into the hold at the rate of 180,000 cubic feet per hour by means of a fan. 100 lbs. to 1,700 lbs. sulphur is used for each vessel.

There has been a great conflict of opinion on the value of sulphurous acid disinfection. Vallin † pronounced it perfect, Arnould ‡ says that "sulphuric acid, even in the almost inapplicable dose of

* Patent No. 1,565, 1877. † *Traité des Désinfectants.* ‡ *Hygiene*, 1889, p. 501.

10 per cent., is an uncertain means of destroying spores; even moisture does not ensure success." Dr. Cassedebat, after a research at the Marseilles School of Medicine,* remarks "even in the highest doses it is too inconstant to be recognised in the disinfection of virus." Savarelli † condemns it. Miquel could not kill germs in twenty days.‡ Sternberg's experiments § were unfavourable—"it requires special conditions rather than abundance." Dr. A. J. Martin ‖ says "its efficacy is contestible, without counting its public nuisance."

Dujardin-Beaumetz,¶ who studied the behaviour of this gas with Pasteur and Roux, found that 20 grammes of sulphur, as used in the official French fumigation, did not kill *Bacillus anthracis*, though it sterilised tubes of vaccine.** Since Wolffhügel's experiments†† in 1881, sulphurous acid has quite lost its reputation in Germany. Koch ‡‡ obtained similar results; he spread the spores about in a room where sulphur was burnt, or laid them on boards which were then washed or sprayed with a solution of sulphurous acid and tested by transference to culture solutions or by inoculation.§§

Dubief and Bruhl ‖‖ state that "sulphurous acid has the most destructive effect on aërial microbes, especially moist, acting mainly on the spores of bacteria, and when pure and acting for a long period, it may prove fatal to dry germs."

M. d'Abaddee states that of the Sicilian labourers engaged in sulphur works only 8 or 9 per cent. suffer from intermittent fever as against 90 per cent. of those not so occupied. The sulphur works in the marshy plain of Catania protect the people in the vicinity from an evil that causes other villages to be deserted.¶¶ This tends to prove that sulphurous acid is strongly antagonistic to malaria.

Dr. P. Frankland *** found that it killed several pathogenic organisms. Baumann destroyed *B. tuberculosis* with it, and has cured several cases of early phthisis by burniug sulphur.

Klein has furnished the key to these discrepancies by showing that although "most pathogenic microbes do not thrive in an acid medium, some putrefactive and zymogenic organisms can thrive well in acid—*e.g.*, *Bacillus subtilis*, *Micrococcus ureæ* in acid urine, &c." †††

* *Revue de Hygiene*, 1891. † *Giorn. Soc. Ital. d'Hyg.*, 1890.

‡ *Les Org. vivants de l'Atmosph.*, 1883, p. 289, *et seq.*

§ *Med. News of Philadelphia*, March 28, 1885.

‖ *Soc. de Med. Publique*, 1892. ¶ *Bull. de l'Acad. de Med.*, Sept. 9, 1884.

** See Rochard's *Encyclopædie d'Hygiene*, vol. v., 1893.

†† *Mittheil. a. d. Kais. Gesundh.*, vol. i., p. 188. ‡‡ *Ibid.*, p. 234.

§§ Wolffhügel and Proskauer, *Chem. Centralblatt*, vol. xiii., p. 334.

‖‖ *Comptes Rendus*, 1889. ¶¶ *Journ. Soc. Chem. Ind.*, vol. i., p. 515.

*** *Proc. Roy. Soc.*, vol. xlv., p. 292.

††† *Micro-organisms and Diseases*, 1886, p. 258.

Therefore, sulphur disinfection, though generally successful, may sometimes fail. Wynter Blyth is also of the same opinion.

M. Thoinot sums up thus in his *Report to the Committee of Public Hygiene of the Seine*, 1891—"The disinfection by sulphurous acid is only a practice of waiting, but it is a good practice, and ought not to be despised." *

It was objected to the halogens that they were apt to corrode the fabrics submitted to them. The same thing is liable to happen with sulphurous acid, as its oxidation in air leaves behind sulphuric acid, which is not volatile.

Sulphurous acid and the bisulphites are widely used for preserving food. They act (1) by absorbing oxygen, (2) by suspending the growth of moulds and ferments, like those of the vinous, acetous, lactic, and butyric fermentations. In canned goods they are objectionable, as they dissolve tin and lead from the metallic envelope. Dr. Pfeiffer, of Munich, asserts that large quantities of sulphurous acid and bisulphites in beer, &c., are undoubtedly injurious to health. The maximum allowed for wine and beer in Austria is 8 milligrammes per litre, on the basis of the opinion of the Medical Faculty, March 19, 1887. But at least 40 milligrammes per litre might be allowed without injury.† Nessler says that 2·7 to 5·4 milligrammes per litre is sufficient to prevent secondary changes in wine, whilst 22 milligrammes suppresses fermentation for fully twenty-eight days.

Calcium bisulphite and sulphurous acid in more than a minute trace spoil the flavour of most foods, giving a flatness and metallic taste which is distinctly perceptible. These salts are extensively used in beer (in finings), in wines and fruit syrups to absorb oxygen, and to hinder secondary fermentations. They are the least noxious of preparations of this kind. L. Pfeiffer, in a paper on the poisonous action of sulphurous acid and its salts,‡ states that sulphites are sometimes added to wine in such quantities as to produce injurious results. Out of eighty specimens of wines examined by Kammerer, sixteen contained sulphites in quantities ranging from ·017 to ·093 gramme per litre. List detected sulphites in a large number of French wines, the amount varying from ·009 to ·135 gramme per litre. Their presence in wines is likely to cause irritation, if the quantity of acid exceeds 0·08 gramme per litre.

Johnson and Saladin § propose an apparatus for cleansing grain,

* See also Klein, Lawes and Lingard in *Report of M. Off. of Local Gov. Board*, 1884, on "Chlorine and sulphurous acid on Swine fever virus; and Crookshank's *Bacteriology*, 1887, p. 150.

† Lehmann's *Hygiene*, tr. by Crookes, 1893.

‡ *Med. Chronicle*, Oct., 1890.

§ Patent No. 689, 1893.

freeing it from dust, germs, &c., by blowing and washing, or sterilising with sulphurous acid, vapour of bisulphide of carbon, or other gas or vapour, by a tower arrangement down which the grain falls and is distributed and mixed in its course by baffling or deflecting pins. Thiosulphates (the "hyposulphites" of commerce) are antiseptic, but not strongly.

Sulphuric Acid, H_2SO_4, stands next to hydrochloric as an antiseptic; it is only partially a disinfectant. Koch first announced that the cholera bacillus was affected by acids. Kitasato subsequently showed that this acid and hydrochloric destroyed cholera germs in a few hours.

A. Stutzer* states that a solution of 0·05 per cent. of sulphuric acid is fatal to cholera bacilli in fifteen minutes (see Klein's remark, *ante*, p. 95). He tried 0·02 per cent., which took twenty-four hours; 0·03 per cent. even for five hours did not kill all. He also examined whether iron pipes could be disinfected by sulphuric acid without the metal being corroded, with the result that it cleaned out rust and sediment without sensibly attacking the metal. He estimates that 100 kilos. of 60° B. sulphuric acid (1 lb. of acid to 40 gallons of water) would disinfect 40,000 litres of water at an expense for acid of about 0·9d. per 100 gallons of water treated. Dr. Ivanoff † has also demonstrated that 0·04 per cent. of this acid destroys cholera bacilli in Berlin sewage, and 0·08 per cent. in that from Potsdam.

According to Miquel, 2 or 3 grammes of sulphuric acid produces an equal effect to 7 milligrammes of mercuric chloride. Endemann ‡ found it very difficult to develop bacteria in fluids containing acid phosphates. Whitthread's patent, 1872, for precipitating sewage by acid phosphate of lime and then milk of lime, was tried at Luton in 1874, and very favourably reported on by Corfield. He used a solution of 1 in 1000. The use of acid phosphates was proposed previously by David Forbes, and several patents claim them as disinfectants. § Endemann has also shown that many acids are powerfully disinfectant, destroying the life of bacteria completely, even if present in small quantities (but not of spores?). One part of hydrochloric acid in 64 parts of Cohn's fluid well stocked with bacteria, destroyed these completely.

The toxine *Cadaverine*, $C_5H_{14}N_2$ (*Brieger*), occurs in the products of cultivation of the cholera bacillus. Kobert ‖ says that it is less dangerous when converted into a neutral salt. To this he attributes partly the benefit derived in cholera from acid drinks (see p. 261,

* *Zeitsch. für Hyg.*, 1893, p. 116. † *Ibid.*, 1893, p. 86.

‡ *Chem. News*, vol. xli., p. 152.

§ Corfield and Parkes, on *Treatment and Utilisation of Sewage*, 1887, p. 306.

‖ *Pharm. Centralhalle*, 1891, p. 162.

Chap. xiii.), and from washing the intestines with acid liquids, of which weak sulphuric is the best, especially as it has been shown that the cholera bacillus itself is affected by traces of acid.

Rohe * is of the opinion that whilst sulphuric acid, 1 in 800, is antiseptic in some cases, it cannot be depended on as a general antiseptic.

The **Sulphates** are not perceptibly antiseptic. Miquel concludes that sodium and potassium sulphates, even dissolved to saturation in beef tea, are incapable of preventing the germination of bacteria. Sulphates of lime and magnesia actually encourage the growth of many organisms, being reduced to sulphides. Those of iron, mercury, and some other metals depend for their power on the base present, and not on the acid.

Bisulphide of Carbon, CS_2, is a colourless liquid, very volatile (boiling point 48° C.), and exceedingly inflammable; the vapour has caused dangerous explosions. It is heavier than water (sp. gr. 1·272), and insoluble in it. It has ordinarily a most offensive odour and is extremely poisonous, its vapour forming in the blood methæmoglobin, with destruction of the corpuscles.† In Patent No. 3,208, 1878, M. Simon exposes meat to the vapour of this compound for preservation.

Dujardin-Beaumitz used carbon bisulphide internally for typhus and diarrhœa, and found that "all offensive odours were removed from the breath and the stools were disinfected."‡

By burning it generates large quantities of sulphurous acid mixed with carbon dioxide. The yield cannot well be increased by dissolving sulphur in it, as the latter mostly remains unburnt in the dish.

Messrs. Price & Co. have devised a lamp for burning this liquid, so as to generate these gases,§ but it must be used with caution on account of its volatility and inflammability.

Carbon bisulphide is decidedly antiseptic, but its characteristics prevent its use. In combination with sulphides of alkalies it yields the sulphocarbonates, such as the potassium salt K_2CS_3, which crystallises in yellow needles, soluble in water and unstable. With an alcoholic solution of potash it forms an ethyl-sulphocarbonate or xanthate, $CS(OC_2H_5)SH$.

According to P. Zoller,|| small quantities of xanthates mixed with the soil prevent the formation of fungi. Zoller and Grete¶ recommend potassium xanthate as a remedy against *Phylloxera*.

* *Hygiene*, 1890, p. 357.

† See Westberg, *Zeitsch. für Anal. Chem.*, vol. xxxi. [4], p. 484.

‡ *Comptes Rendus*, vol. xcix., p. 509.

§ Parkes, *Hygiene*, p. 517.

|| *Dingl. pol. J.*, vol. ccxxi., p. 191; vol. ccxxii., p. 190.

¶ *Ber.*, vol. viii., pp. 802, 955.

Dr. Ross considers that the poisonous action of carbon bisulphide practically excludes it from use as a disinfectant.

Aqueous solutions containing 1 or 2 grammes of carbon bisulphide per litre have also been found very satisfactory against *Phylloxera.**

BORIC ACID AND BORATES.

Boric or Boracic Acid, H_3BO_3 (or $HBO_2 . H_2O$) occurs in inodorous, pearly crystalline scales, sparingly soluble in water (about 4 per cent.), and more soluble in alcohol. The crude Tuscan volcanic borax has to be refined for preservative uses. It has been proposed, in an Italian patent, to import it in the native solution, but the cost of transport would thereby be increased.

It is a weak acid, almost tasteless in dilute solution, and has no corrosive action either on tissues or metals; this and its absence of odour, with a certain amount of preservative power, and little effect on animals, have led to a large number of patents for the use of boric acid and borates for preventing the putrefaction of animal and vegetable substances. It is in no sense a disinfectant, and its antiseptic powers are low, although for many years it has held a place as a preservative for meat and vegetables. The original discoverer, Gahn, sold in Europe two mixtures—(1) boric acid with 1 part alum, called "aseptine;" and (2) boric acid with 2 parts alum, called "double aseptine." It seems probable that he recognised in the alum a greater activity than in the boric acid. Provisions in part preserved by boric acid are generally within one or two months covered with a black crust, but the presence of alum prevents this action taking place. Lehmann found that fresh beef with 1 per cent. of boric acid and 50 per cent. salt pickle kept for several months at 80°F. Endemann proved † that boric acid acted as a preservative to fresh meat only, and that previously salted meat could not be preserved by it. Lehmann infers in these cases it is not the boric acid that acts as a preservative but the substances produced by it, *i.e.*, the acid phosphates (see under sulphuric acid, p. 97). He states that "other mineral acids give exactly the same results without boric, especially phosphoric and hydrochloric." ‡

Miquel classes it as "moderately antiseptic." It required 7·5 grammes to "neutralise" a litre of beef tea.

According to Lazarus § milk can only be preserved by boric acid if the quantity added exceeds that which can be used without altering

* *Comptes Rendus*, 1891, pp. 1113, 1283, and 1330.

† *Chem. News*, April 2, 1880.

‡ Lehmann, *Practical Hygiene*, 1893, vol. ii., p. 247.

§ *Zeits. f. Hygiene*, vol. viii.

the taste. The microbicidal action of boric acid is very feeble. He is of the opinion that from 1 to 2 grammes per litre is without action (compare Miquel); yet Stokes* states that 1 in 1000, or roughly 7 grains per pint, of boric acid will keep milk "sweet" for forty hours. The difference is a question of time.

Mattern finds 1 per 1000 retards the coagulation of milk from twenty-four to thirty-six hours.

This acid has no action on vinous fermentation; it retards the formation of acetic acid from alcohol by *mycoderma aceti* only when acetic acid is not already present.† Lehmann sums up thus—"preservation by boric acid cannot be considered as involving a new principle; it is merely a variation of, but by no means an improvement on, vinegar pickling. The insipidity prevents its easy detection, and brings customers to the belief that the meat is fresh. This peculiarity is the only one recommending the use of boric acid." Dr. C. T. Williams, of Brompton Hospital, proved that the acid excercised no destructive influence on the bacilli of phthisis. In fact they increased abundantly in boric solutions and develop spores. A warm saturated solution of boric acid was recommended by Pasteur as an antiseptic in cases of puerperal fever, but has been superseded by mercuric chloride in the lying-in hospitals of Paris. The application of it to wounds and ulcers has decreased,‡ and in the French Army Medical Service four times as much sublimate wool is used as that impregnated with carbolic or boric acids. The latter wool contains from 14 to 36 per cent. of boric acid, which is in great part crystallised, and therefore irritating to the skin. This crystallisation may be prevented by keeping the wool moist by glycerine.§ There is no doubt that boric acid does preserve food when used in sufficient quantity. The earlier investigators employed such strengths as 1 in 12 (*Jalan de la Croix*); $\frac{1}{2}$ to 4 per cent. (*Neumann*); whilst Vallin, who used 2 to 4 per cent. of the acid, states that this strength kills germs when borax only stupefies them.‖

Borates.—Those occurring naturally are Tincal or native Borax, Boracite or Magnesium borate, and Borocalcite or Calcium borate, and others of less importance. Those which are soluble are somewhat antiseptic; they are decomposed by strong acids. The acid magnesium biborate is one of the most soluble, and may therefore be a useful salt for preservative purposes.¶

Borax, or Sodium diborate, $Na_2B_4O_7$, occurs in large transparent crystals, inodorous, having an alkaline taste and reaction, and soluble

* *Analyst*, 1891, p. 123.

† Herzen, *Biedermann's Centralblatt*, 1880, p. 487.

‡ *Lancet*, vol. i, 1890, p. 1266.

§ *Chemist and Druggist*, Feb. 18th, 1893.

‖ *Vallin*, p. 149.

¶ *Brit. Med. Journ.*, 1888, p. 1184.

in 12 parts of water. M. Dumas, in Aug., 1872, introduced boric acid and borax to the French Institute as preservatives for food. Borax may be used to neutralise the acid developed in milk by keeping. E. le Cyon * thinks that meat preserved by borax is not diminished in nourishment, and is more readily assimilated. Subsequent investigators have, however, arrived at an opposite conclusion.

Ammonium Borate is more soluble; a strong solution has been injected into bodies for dissection.

Among the numerous patents are—No. 2,375, 1877, Taylor, calcium borate; No. 3,001, 1880, Artimini, "boric tartrate" as an antiseptic; No. 4,910, ditto, ditto, boric acid and borax; No. 1,127, 1882, J. Imray, preserving meat with boric and malic acids; provisional protection; 1882, Haddan, borax, glucose, and boric acid evaporated till solid, for provisions; No. 5,153, 1882, Pielsticker, boric acid melted with sodium phosphate and formate, "very soluble and almost tasteless, for provisions;" No. 6,134, 1882, J. Townsend, boric acid, &c.; No. 274, 1883, Wilkins, ditto (these two are mainly mechanical); No. 1,429, 1883, Conron, boric acid, borax and potassium nitrate, "half a pint of concentrated solution to a barrel of 36 gallons," for various infusions; No. 5,326, 1883, Lake, glycerine and boric acid (not heated, compare Barff's patent).

"**Boroglyceride,**" No. 1,332, 1881, F. S. Barff, deserves further mention. "Heat glycerine to near its boiling point, and add boric acid as long as dissolved. Keep at 200° C. as long as water comes off. Animal or vegetable matter is preserved by immersion in a solution of the compound in water, alcohol, or other solvent." Boroglyceride claims to be *glyceryl triborate*—

$$C_3H_5(OH)_3 + 3HBO_2 = C_3H_5(BO_2)_3 + 3H_2O.$$

How far, like other esters, dilution breaks it up again into glycerine and the acid, is not apparent. The solution has a different taste from the materials, but the general properties are intermediate in their character. It has hardly answered expectation. See under *Glycerine* (p. 226) for the therapeutic effect of that body. Calcium and sodium boro-glycerates, obtained by heating calcium borate or borax with glycerine till the whole forms an oily liquid which solidifies on cooling, are recommended by Le Bon † for preserving food and for surgery.

It will be noticed that most of the above devices are intended to increase the sparing solubility of boric acid. It is one of its characteristics that, though having so feeble an affinity for bases, it seems always ready to form more or less stable combinations with other acids and with neutral bodies.

* *Bied. Centr. Agr. Chem.*, 1879, p. 869. † *Comptes Rendus*, vol. xcv., p. 145.

Potassic Borotartrate or "Soluble Tartar," $K(BO)C_4H_4O_6$, obtained by heating together 1 part of boric acid, 2 of cream of tartar, $KHC_4H_4O_6$, and 24 of water, evaporating to dryness, and treating with alcohol to remove excess of acid, is a white non-crystalline powder, insoluble in alcohol but very soluble in water. It has been employed as a purgative, and also as an antiseptic, and is the "boric tartrate" of Artimini's patent mentioned above.

Benzoboracic acid, with oils of thyme, *Eucalyptus*, *Baptisia*, *Gaultheria*, and *Mentha arvensis*, containing 1 part of the acid in 30 of the oils, is called "Listerine," and is used in surgery. There is also a benzo-boric mouth-wash. *Salicylic acid* is soluble in less than 600 parts of water; stronger solutions may be made by using boric acid in the proportion of 12 parts boric acid to 1,000 of water, when a 0·2 per cent. solution of salicylic acid can be obtained.* Strock's "Antiseptic paper" is made with two solutions—A, alcohol 500, boric acid 5, salicylic 7; B, water 1,588, sodium thiosulphate 60.† Radlauer's "Antisepsin" is a mixture of zinc sulphate 85, zinc iodide 25, thymol 2·5, with 10 parts of boric acid.

L. Hausler ‡ has recently made boroglyceride into a jelly by dissolving it in hot water with half or an equal weight of gelatine; he dips the provisions while the jelly is still liquid, and so gives them a protective coating. Before use the articles are washed in luke-warm water.

Boric acid is also used for preserving butter and cream, for curing hams, sprinkling over fish, &c. "Sodium chloro-borosum" is borax and common salt. "Barmenite," according to C. Schwartz, contains 80 per cent. borax, 15 boric acid, 3 salt, and 2 sodium chlorate, with traces of alumina. "Glacialin" is a fused mixture of borax and boric acid.§ These preparations are extensively used on the Continent for preserving meat, and the latter in this country for milk. How much boric acid enters into meat which is sprinkled with or soaked in it is not accurately known, but according to Roosen, who has patented the use of boric solution under pressure, 500 grammes of meat take up only $\frac{1}{4}$ gramme of the acid. Covering meat with 1 per cent. boric solution keeps it from putrefaction from four to seven days.

Hehner states,‖ on the authority of Polenski, that in Germany boric acid preservatives have been advertised under the following names:—Berlinite, Chinese preservative powder, Brockman's salt, Australian salt, Magdeburg preservative salt, and Heydrich's salt.

The physiological effects of borates in food seem to be more pro-

* *Revue de Chimie Industrielle*, April 15, 1893. † *Ibid.*, Feb. 15, 1893.
‡ Patent No. 9,145, 1893. § *Journ. Soc. Chem. Ind.*, 1890, p. 993.
‖ *Analyst*, 1890, p. 295.

nounced than was formerly supposed. Artimini and Polli asserted that doses of 3 or 4 grammes continued for months were well tolerated by men.* Large doses produce vomiting and diarrhœa, &c.,† but dilute solutions seem to have no visible effect. Forster and Schlenker have shown, in very careful and repeated experiments, that daily doses of ½ to 3 grammes of boric acid added to human diet affect the absorption of nutritious substances ingested, irritate the intestines and cause them to cast more mucus and epithelium. Borax probably acts like boric acid.‡ Forster concludes that the use of boric acid in preserved food is of questionable value, as it increases the secretion of bile and the excretion of albuminous matters. Gruber likewise states that the decomposition of albumen in animals is increased by borax. The use is said to be greatly extending, but preparations of borax for preserving meat are forbidden in the German navy.

A French commission appointed to investigate the influence of boric acid on the human system reported that it could be taken for a considerable time without injurious effect. "Yet it is certainly neither a regular constituent of the body nor naturally contained in food (beyond exceedingly minute traces), and it is therefore probable that in time constitutional difficulties would supervene."§ Leffman and Beam ‖ and H. A. Weber ¶ have shown that food preservatives interfere with pancreatic and salivary digestion, borax even keeping its retarding effect up to a dilution of 1 in 2,000. Both boric acid and borax delay, or even prevent, germination of seeds.**

If, as stated by Stokes, it requires 1 in 1,000 of boric acid to keep milk sweet for forty hours, 2 grains per diem are consumed per adult, and 15 to 30 grains daily by a bottle-fed baby. This amount may fairly be regarded as a medicinal quantity, and it is to be hoped that legislation will prevent its use in the future.

Tests for Borates.—To a large quantity of the milk, or of the aqueous extract of the food, add milk of lime in excess. Evaporate to dryness, burn to ash, and dissolve in a little strong hydrochloric acid. Filter, nearly neutralise the acid with lime, dip into it a piece of freshly made turmeric paper. Dry this on a water bath; if boric acid be present, the portion which has been dipped will show a rose colour, turned dull blue by dilute soda. If there be much boric acid, the

* *Annali di Chem. Med.*, 1877.

† Neumann, *Archiv. f. exp. Physiol.*, 1881, p. 148.

‡ *Ber. deutsch. Chem. Ges.*, vol. xvi., p. 1754.

§ *Acad. des Sciences*, Jan. 6, 1879. ‖ *Journ. Soc. Chem. Ind.*, 1888, p. 582.

¶ *Journ. Amer. Chem. Soc.*, 1892, p. 4.

** *Comptes Rendus*, 1892, vol. cxiv., p. 131.

remainder of the ash solution, if moistened with spirit, ignited, and stirred, will show a green mantle to the flame against the red of the calcium chloride and yellow of the soda. The green lines of boric acid should be looked for in the spectroscope.* The quantity may be determined by repeated distillation with methyl alcohol into a crucible containing a known weight of ignited lime. †

Kayser ‡ says that traces of boric acid are very widely distributed in nature. Carrots, beet sugar, Californian wines, &c., contain it, and it is often introduced into the glaze of enamelled vessels. But these would only be minute traces, whereas as a preservative it would be present in comparatively large quantities.

INFLUENCE OF GASES ON PUTREFACTION.

Bacteria have been divided into two classes—I., the *aerobic*, which live and work in presence of oxygen, and die when it is exhausted; their gaseous products are chiefly carbonic acid and ammonia: their type is *Bacterium termo*, the principal agent of putrefaction; they can be dealt with by exclusion of air, as in preserving in tins, especially if sterilised first, or by reducing agents such as sulphites;—II. the *anaerobic*, which exist in absence of oxygen, and are killed by its presence. Many of the pathogenic organisms belong to this latter class. Among the products are marsh gas, sulphuretted hydrogen, phosphoretted hydrogen, carbon monoxide, nitrogen and ptomaines. Oxidising agents like chlorine, hydrogen peroxide, and permanganate, are their most effective destroyers. These bacteria take up the process where the aerobic have ceased, hence the necessity of sterilising before excluding the air.

On the principle that all living beings are first restrained, and finally killed by their own excreta, any of the above gases should be to a certain extent poisonous to the micro-organisms which produce them. But they will be far more fatal to higher animals, the effects being not only on the blood and the lungs, but also on the central nervous system; the more highly developed the organism, the greater is the sensibility.§

Carbon dioxide, or "carbonic acid" CO_2, seems to have a special antiseptic and even disinfectant action, inasmuch as ærated waters and beverages have been found to be in many cases sterilised. Slater‖ has found that this gas in mineral waters has a remarkable effect in killing pathogenic bacteria (typhoid, cholera, *Staphylococcus*

* Kretzchmar, *Chem. Zeit.*, vol. xi., p. 476.

† Cassal, *Analyst*, 1890, p. 230.

‡ *Chem. Zeitung*, 1890.

§ Pettenkofer and Lehmann, *München Acad. d. Wissensch.*, 1887, p. 179.

‖ *Journ. of Pathol. and Bacteriology*, 1893, vol. i., p. 468.

pyogenes aureus, Finkler-Prior bacillus). Hochstetter * found the same in the case of typhoid, cholera, rabbit septicæmia, *Micrococcus tetragenus*, Finkler-Prior bacillus, *Aspergillus flavescens*, and anthrax bacilli but not anthrax spores.

It is well known that fermented liquors preserved in bottles remain stable for long periods, and this stability seems difficult to explain by the self-exhaustion or deposition of any bacteria present. Bethell in 1848 patented a process for preserving milk, which consisted in first boiling the milk to expel all the air contained in it, and then saturating the liquid with carbon dioxide. The milk when so treated remains fresh for a long time after being opened. Liquefied carbonic acid has also been used for preserving food. Thus, butter when placed in an iron vessel provided with a tap, and subjected to carbonic acid under a pressure of 6 atmospheres until all the air has been driven out, remains fresh for four or five weeks, and is not spoiled in flavour or consistency. Carbonic acid may also be injected into whey, giving "a refreshing drink like champagne. The carbonated whey can be enclosed in syphons and will keep for 6 weeks." † This method is quite innocuous, and should be substituted for the use of salicylic or boric acid or glycerine.

Cyanogen and *hydrocyanic acid* vapour do not seem to be so poisonous to lower organisms as they are to the higher animals.

Miquel gives 0·4 of hydrocyanic acid per 1000 as sterilising beef-tea.

Ammonia, *sulphuretted hydrogen*, *sulphurous acid*, *chlorine*, *oxygen*, *ozone*, and *oxides of nitrogen* are described under their respective headings.

* *Arbeiten a. d. kais. Gesundheitsamte*, 1887, vol. ii, p. 1.

† *Chem. Trade Journ.*, July 15, 1893.

CHAPTER VI.

METALLIC SALTS.

Salts of the alkalies and alkaline earths: Caustic alkalies—Quicklime—Sulphate of lime (Gypsum)—Slaked lime; its use as a precipitant—Sodium carbonate—Acid salts—Ammonia and ammonium carbonate. **Zinc**: Oxide—Chloride of Zinc—Burnett's fluid—Zinc sulphate, sulphite, and other salts—Various patents. **Copper**: Poisonous action—Cuprous chloride—Cupric chloride, nitrate, sulphate, and acetate. **Iron**: The use of metallic iron for purifying waters—Ferrous sulphate of copperas; the objections to it—Patents and processes—Ferric sulphate and its applications—Ferric chloride—The value of iron salts as disinfectants. **Manganese**: The metal—Manganese peroxide—Manganous salts—Manganates—Condy's fluids—Potassium permanganate—Other permanganates—Mechanical devices—Cost.

SALTS OF THE ALKALIES AND ALKALINE EARTHS.

THE hydroxides of potassium and sodium exercise an inhibitory influence on bacterial growth if they are present in quantities of not less than 2 to 5 per cent.; so do the carbonates in the proportion of 5 to 10 per cent.; the bicarbonates have hardly any action. Miquel classes caustic soda as "moderately antiseptic," stating that it requires 18 grammes per litre to preserve beef tea. He asserts, also, that many other potassium and sodium salts, and especially the sulphates and nitrates when dissolved to saturation in beef tea, are incapable, even in the proportion of 500 per mille, of preventing the germination of bacteria.

In laboratories it is noticed that the development of green *Protococcus* occurs most rapidly in solutions of potassium, calcium, and magnesium sulphates, and sodium phosphate. Calcium chloride solutions also rapidly show growths if exposed to air. Strontium salts do not seem to display any difference. The alkaline acetates, and tartrates quickly become mouldy, even in very strong solutions. It will be remembered that all varieties of protoplasm contain salts of the alkalies and alkaline earths; these, therefore, are actually favourable to the life of organisms, and thus are always added to Pasteur's and other artificial culture solutions.

Sodium chloride and the alkaline sulphates have already been discussed (pp. 70, 98). Forster * states that salt (NaCl) destroys the cholera bacillus, but not others. In curing hams the saltpetre is

* *R. Acad. of Science*, Amsterdam, April, 1890.

added to affect the colour and taste; it has no proved antiseptic action. Since nitrates are produced by the nitrifying organisms by a process of oxidation, and reduced to ammonia by the growth of other bacteria, and as these latter are very numerous the nitrates may properly be regarded as salts favourable to the development of many organisms.

The weak antiseptic action of potash and soda may account for the similar slight activity of soap, as the fatty acids do not seem to have any very pronounced antiseptic action.

Sulphate of Lime, on account of its power of absorbing ammonia, is a deodorant, but cannot be regarded as an antiseptic. When used in agriculture it prevents the ammonia from escaping, but does not hinder the decay. It has been a frequent ingredient in mixtures for precipitating sewage; it only acts mechanically, and has the great disadvantage that it adds to the permanent hardness of the effluent water (*Corfield and Parkes*).

Carbonate of Lime, and in fact all other insoluble metallic salts, are inert.

Quicklime, CaO, acts only as an absorbent; it destroys organic matter by its dehydrating action, and to this cause may be attributed its use for accelerating the decomposition of corpses dead of infectious diseases. There are very few microbes that can remain active any length of time in a dry state, but the bacilli of tubercle have been known to exist in dry dust for more than a year.* The spores of all known species resist drying for indefinite periods.† It is not safe, therefore, to trust entirely to the old method of burying in lime, as, on disinterring, the live spores may again be diffused, unless a very long period has elapsed.

Slaked Lime or calcium hydrate, $Ca(OH)_2$, absorbs acid vapours and sulphuretted hydrogen, and therefore acts to a certain extent as a deodorant. Vallin says ‡ that limewash applied to walls is in a certain degree antiseptic, as it forms insoluble compounds with the organic matter present in condensed pulmonary exhalations. For instance, it coagulates albumen and casein. This would deprive bacteria of food, as shown by the experiments of Pettenkofer, made for the German Cholera Commission of 1879. He concludes that "slaked lime destroys rapidly and completely the organisms of putrefaction; the proportion of $\frac{1}{2}$ per cent. is sufficient for slightly altered bilge-water, but when the putrefaction is strong, 1 per cent. is required. The action on wood and metal is very slight,

* See on the Vitality of Bacilli: Dr. Buchner, *Ohio Sanitary Record*, April, 1894.

† Klein, in Stevenson's *Hygiene*, 1893, p. 61.

‡ *Traité des Désinfectants*, 1882, p. 70.

but the lime removes the odour of the fatty acids of putrefaction, which is often more offensive than that of sulphuretted hydrogen." He mentions as a difficulty the blocking up of pipes and pumps when it is used. The precipitation of sewage by milk of lime was the first process tried by the Rivers Pollution Commission of 1868, and was pronounced to be a failure.* In the act of settling, the suspended lime carries down the greater portion of the organisms with other impurities, and renders the water clear. It has been stated also that the lime coats the bacteria and their spores with an insoluble envelope of carbonate of lime. This is the fundamental idea of the use, general in Leipzic, of the "Suvern mixture" for sewage (see chapter on "Regulations," p. 292). This theory does not seem to have been verified by microscopic examination. But many investigators have proved that, although the changes are much delayed, the water is not sterilised. The liquid is rendered alkaline, ammonia is developed, and, in the case of sewage, the effluent soon again becomes foul.

The State Board of Health of Massachusetts † found that it required about 2,000 lbs. of lime to 1,000,000 gallons of sewage to reduce the bacteria to an average of $\frac{1}{400}$ of what they were before. In the same experiments it was found necessary to add alum or aluminium sulphate in addition, to prevent the subsequent distribution of the precipitated microbes in the upper layers.

Numberless experiments on sewage have proved that, although a partial deodorant and a clarifier, lime alone is not an antiseptic, and still less a disinfectant.

The use of lime water for preserving eggs depends on the deposition of carbonate of lime in the pores of the shell, rendering it impervious, and also to the lime coagulating the albuminous envelope of the egg.

Sodium Carbonate, "Washing soda."—A strong solution is antagonistic to bacteria, but, as used for clothes, &c., is not effectual without boiling. Reinsch ‡ says that 0·1 per cent. of sodium carbonate (Na_2CO_3) caused the multiplication of bacteria, whereas 1 per cent. diminished the number, and 3 per cent. killed them in a sample of the Elbe water from between Hamburg and Altona.

Surgical instruments, after being well washed with soap and water, are frequently sterilised by boiling in a solution of bicarbonate of soda, $\frac{1}{8}$ oz. to the pint.

The acid salts of alkalies act by virtue of their acidity, as mentioned under *Sulphuric Acid* (p. 97). Acid phosphates probably have the most power in this way, but none of them have much value.

* *First Report R. P. Comm.*, p. 52. † *Reports*, 1888-90, vol. xi., p. 737.
‡ *Centr. f. Bakt.*, 1891, vol. x., p. 415.

Kingzett has made some experiments on the effects of chlorides, nitrates, and sulphates on the growth of mould on flour-paste, and on the putrefaction of extract of beef. His results generally corroborate the statements made above.*

Ammonia is a product of the growth of many bacteria, and can therefore only be a restraint on them when it is present in sufficient quantity to kill them by re-imbibition. Miquel classes it as "strongly antiseptic," saying that it requires 1·4 grammes per litre to preserve beef tea.

Ammonium Carbonate, or smelling salts, has a similar action. The same authority mentions ammonium chloride and sulphate as "very feebly antiseptic," the former requiring 115 grammes per litre, and the latter 250 grammes (or a quarter of the weight) to keep beef tea from putrefying.†

ZINC.

Oxide of Zinc, ZnO, is a white basic powder, and, being slightly antiseptic and emollient, has found favour in ointments.

Chloride of Zinc, $ZnCl_2$, is an exceedingly deliquescent and caustic salt; 10 parts dissolve in 4 of water, 1 in 1 of rectified spirit, 1 in 4 (nearly) of glycerine. Its solution is acid, tastes strongly metallic and astringent, and is very poisonous. Miquel placed it in his class 3 as "strongly disinfectant," stating that 1·9 parts in 1,000, sterilised beef tea. It is one of the most powerful of antiseptics, ranking next to copper sulphate and mercuric chloride. Crace Calvert found that a solution of albumen, to which 1 per mille of zinc chloride was added, required over forty days before germs developed. Koch says ‡ that zinc chloride does not act as a germicide, and that even a 5 per cent. solution was utterly useless. This was based on anthrax spores, which are apparently the most difficult of all to kill. Dr. Hamilton believes that although it may not kill the germs it may make the surface a barren spot as far as germs are concerned—*i.e.*, act as an antiseptic. Dr. Richardson made experiments with regard to this salt, confirming, on the whole, the views of Dr. Hamilton. In 1875 and 1876 Pettenkofer and Mehlhausen directed a number of trials in the German Fleet on the disinfectant value of zinc chloride. Bilge-water of a specific gravity of 1017 to 1035, with a slightly alkaline reaction, at a temperature of 20° to 30° C., was treated with a solution of 50 to 60 per cent. strength in the proportion of 1 part to 100 of bilge. A greyish flocculent precipitate rapidly settled, leaving a nearly clear

* *Brit. Med. Journ.*, vol. i., 1888, p. 150.
† Miquel, *Les Org. de l'Atmosphère*, 1883, p. 289.
‡ *Mittheil. a. d. k. Gesund.*, 1881, p. 234.

yellowish liquid. All odour ceased, the organisms seemed to be killed, and the reaction became remarkably acid. At the end of four weeks the mixture showed no signs of change. One part of the solution to 1,000 of bilge caused a decrease of the odour; 2 in 1,000 completely removed sulphuretted hydrogen, much reduced the rancid smell, and preserved the liquid for fourteen days.

A 5 per cent. solution was found to possess no corrosive action on iron, brass, wood, or caoutchouc. It neither bleaches nor rots ordinary fabrics, but causes a reddening and slight smarting sensation on the skin. The deposit does not clog the pipes or valves of the pumps as that formed when lime is used. The German Cholera Commission of 1879 prescribed zinc chloride for the disinfection of bilge-water.

In surgery an 8 per cent. solution of zinc chloride has been employed by Sir J. Lister for antiseptic dressings. A solution of 1 to 5 per cent. is sufficiently strong for most purposes.*

Sternberg † finds that a 2½ per cent. solution destroys bacteria, but a 1 per cent. solution does not prevent inoculation being followed by death. F. Boillat ‡ points out that although a 5 per cent. solution does not kill the spores of splenic fever, it is nevertheless a good antiseptic. He has also shown that it and zinc sulphate both combine with albumen to form albuminates, and that, provided sufficient of the salt be added to unite with the whole of the albumen, no growth can take place. In Koch's experiments he believes that the quantity of zinc salt added only precipitated part of the albumen, leaving therefore sufficient pabulum for the spores on the threads to develop.

Under the name of *Burnett's Disinfecting Fluid* this salt has had an extensive use in this country. This fluid is made by allowing the solid salt to deliquesce to a syrup, then adding water, if necessary, till the strength is 46 to 50 per cent. of zinc chloride.

Parkes § strongly recommends it for excreta, especially for military use. The French Pharmacopœia prescribes a solution of 1 in 6 with 1 per cent. of hydrochloric acid to dissolve the basic chloride which, if present, would render the solution not only turbid but somewhat weaker.

Burnett's fluid and the Dublin Pharmacopœia solution have a specific gravity of 2·00, but commercially, as being formed by mere deliquescence, are of varying strength, generally about 82 per cent. The "Liquor Zinc Chloride" has a specific gravity of 1·46 (1·53, Squire's *Companion*, 1890), contains 25 per cent. of zinc, or about 52 per cent. of the chloride. De Chaumont found in a sample of Burnett's fluid

* Vallin, *Désinfectants*, p. 128.

† *Bull. N. Board of Health, U.S.A.*, 1881, vol. iii., p. 21.

‡ *Journ. f. praktisch Chem.*, vol. xxv., p. 300. § *Hygiene*, 1878, p. 400.

69 per cent. Woodman and Tidy * give 47 to 53 per cent. as the strength. This variability is a great fault of the solution; it would be better to state the percentage of zinc, as in the British Pharmacopœia (25 per cent. Zn). Burnett's original formula is unknown (*de Chaumont*).

The medicinal preparations are:—*Lotion*, 1 grain of the liquor in 1 oz. of water, or about 1 in 1,000 of zinc chloride (London Ophthalmic Hospital); *paste*, liq. zinc chlor. and flour, equal parts; glycerine, enough to make a thick paste; an excellent antiseptic for wounds (London Hospital); opium is often added. *Compound powder*, zinc oxide mixed with an equal weight of zinc chloride keeps the latter dry enough to blow into cavities. *Points* or *darts* of zinc chloride fused in moulds and kept in glass tubes have been used in the treatment of anthrax.† *Compound ditto*, equal weights of the oxide and chloride mixed with 2 parts of flour and water to make a stiff paste, are milder and less irritating.

The official strength for rooms is 1 of the fluid to 100 of water (about 1 of zinc chloride in 200); for sewers and closets half this strength may be used.‡ For excreta a 10 per cent. solution should be stirred in, using 1 part to about 9 of the excreta, making about 1 per cent. of zinc chloride present.

"Eau de Saint-Luc," which is much sold in France, is a concentrated impure solution of chloride and sulphate of zinc, with occasionally some acetic acid. Specific gravity, 1·613; strength, 77 per cent. of zinc chloride. It must not be used without dilution.§

Prof. Lamelongue || injects small quantities of zinc chloride in tuberculosis to promote induration of the tissue, so as to "encapsule" the bacteria.

Dr. Vidal, as an injection for fetid discharges, employed a solution containing 15 grammes zinc chloride, 1 gramme boric acid, ammonia to just neutralise, and 1 litre of water.¶

Daudenant patented a process for sewage,** using lime, then salts of aluminium and zinc chloride.

This salt is also used for injecting corpses, using 8 litres of a solution of 40° Baume.

Zinc Nitrate, $Zn(NO_3)_2$, as a caustic eats deeper with less pain. As a disinfectant it is inferior to the chloride, and more expensive.

Zinc Sulphate, $ZnSO_4$, $7H_2O$, occurs in transparent crystals, of acid reaction and styptic taste; it is emetic and less antiseptic than the chloride.

* *Forensic Medicine.*
† *B. M. J.*, 1887, vol. ii. p. 644.
‡ *B. Med. B. of Health.*
§ *Vallin*, p. 126.
|| *Lancet*, July 11, 1891.
¶ *Ibid.*, p. 346.
** Patent No. 4203, 1886.

Calvert states that 1 in 200 will keep beef juice for 30 days "free from animalcules and fungi." Recent investigations by Koch, Klein, and others prove that it is of no value as a germicide. Still it has been a favourite substance to mix with sulphates of copper and mercury, probably from an idea of cheapness, although it is likely that it may add to their action. Patent No. 19,766, 1881, treats sewage with zinc sulphate.

Bierbach states that an article sold as "urinal cakes" consisted of a mixture of the sulphates of zinc, copper, iron, and soda, also some alum with resin, the salts probably being fused with the resin so as to make them dissolve more slowly. Holmes and Emmens* propose to utilise the spent liquor of batteries, containing zinc sulphate and sulphuric acid, as a disinfectant.

An acid solution of sulphate of zinc coloured with indigo has recently been used in Paris by M. Meillère for deodorising typhoid stools in the sick room.

The disinfectant employed on the Pennsylvania Railway consists of a solution of the chlorides of zinc, mercury, and copper, with a little turpentine to act as a tell-tale. W. T. Sedgwick has tested this mixture upon various typical bacteria, and concludes that its efficiency is due to the mercuric chloride.†

"Tuson's Disinfectant" is sulphite of lime with sulphates of aluminium and zinc. Every pound of this mixture is said to give off 7 gallons of sulphurous acid gas.‡ In his patent R. V. Tuson saturates a solution of zinc chloride (3 lbs. to the gallon) with sulphurous acid gas. Mercuric chloride may also be added.§

"Radlauer's Antisepsin" contains 85 parts of zinc sulphate, 25 of zinc iodide (a good but caustic antiseptic), 2·5 of thymol, and 10 of boric acid. It is said to be very successful for wounds and ulcers.

"Eau Larnaudes" is composed of ordinary water containing 23 per cent. zinc sulphate and 20 per cent. copper sulphate.||

Raymond of Paris has patented "an improved antiseptic, disinfecting, and deodorising fluid" of the following complicated composition:—Parts by weight: water, 1000; zinc sulphate, 300–500 (*i.e.*, a saturated solution); zinc acetate, 10–3; sodium hyposulphite, 30–5; aluminium sulphate, 30–45; boric acid, 4–7; mercuric iodide, 0·10 to 0·25 (only when required very powerful).¶ The hyposulphite would be decomposed by the acid, and in its turn would precipitate the mercury as sulphide.

* Patent No. 4,061, 1883.

† *Tech. Quart.*, 1893-6, vol. ii., p. 43.

‡ *Lancet*, 1891, vol. ii., p. 19.

§ Patent No. 12,222, 1887.

|| *Notice sur le nettoiement de la voie publique, Ville de Paris*, 1876.

¶ Patent No. 11,275, 1892.

Zinc Acetate is used as an antiseptic in ophthalmia and gonorrhœa.

Zinc Sulphite is insoluble. Tichborne and Henston* make an antiseptic gauze by boiling the latter with zinc sulphate, then dipping in hot sodium sulphite solution, and washing. Zinc sulphite, $ZnSO_3$, is precipitated in the tissue.

Acid Sulphite of Zinc is a soluble salt, and its use as an antiseptic has been patented by Boake and Roberts.†

Zinc Sulphocarbolate is strongly antiseptic, has no odour, and does not cause irritation. To spray the throat in diphtheria, &c., 5 grammes per ounce is used; for the eyes, 4 grammes per ounce; and for injections, 60 grammes to the pint. These strengths seem very insufficient, but perhaps there is some danger of poisoning.

Rotterine ‡ contains 45 grains each of zinc chloride and sulphocarbolate, 27 of boric acid, 2½ of sodium chloride, 6 of salicylic acid, and 1 grain each of citric acid and thymol, all dissolved in a pint of water. It is said to be more effective than 1 per mille of mercuric chloride.

Zinc Salicylate is antiseptic and sparingly soluble. Bovet § proposes to antisepticise all houses in the course of building, by incorporating 5 per cent. of zinc salicylate in the plaster, soaking the woodwork with 4 per cent., and the papers and hangings with 1 per cent. He says that the additional expense does not amount to more than 2 per cent. of the total cost of construction.

All soluble zinc salts absorb ammonia and sulphuretted hydrogen.

COPPER.

The soluble salts of copper have a distinctly poisonous action on bacteria. They coagulate albumen, and combine with most of the organic acids present, to form non-putrescible salts. They absorb sulphuretted hydrogen, ammonia, and compound ammonias, and therefore combine with "ptomaines." In fact, copper salts rank next to mercury in power as antiseptics. They are used (Kyan's method) for injecting timber to kill the spores of the fungi (mainly *Merutius lachrymans*) causing dry rot. It is difficult by law to keep them out of pickles and preserved vegetables, as they improve the colour and add to the keeping qualities. In several cases of prosecution under the Food and Drugs Act, for copper in food, it has been adduced by authorities that a small quantity of copper is not injurious.‖ Copper salts are not volatile, their action is, therefore, strictly local. As antiseptics they give way to zinc salts, since any surface washed with

* Patent No. 11,985, 1890. † Patent No. 8,509, 1886.

‡ Dr. Rotter, *Chem. and Drug.*, 1889, p. 35.

§ *Bull. Soc. Ind. Mulhouse*, 1890, p. 546.

‖ *Soc. Chem. Ind.*, 1895, pp. 539 and 705.

copper salts (or mercury) is blackened by sulphuretted hydrogen, whereas zinc sulphide is white. Nevertheless, M. Bureg recommended that curtains, clothing, wood, &c., should be impregnated with copper salts.

Cuprous Chloride, Cu_2Cl_2, is white, almost insoluble in water, but somewhat soluble in dilute hydrochloric acid. On exposure to air it becomes oxidised to cupric chloride, and therefore acts as a reducing agent.

Kroncke * points out that for sewage treatment, compounds having a great affinity for sulphur should yield the best results. He has experimented with cuprous chloride as being a salt which fulfils this condition. It is readily prepared, very easily removed from solutions, and becomes much less poisonous when oxidised. It has the further advantage of not being acted on by carbonate of lime. (2) The following method was found suitable for the purification of water :—Cuprous chloride amounting to $\frac{1}{20000}$ of the water to be treated, and ferrous sulphate (as far as possible free from ferric), to the extent of $\frac{1}{50000}$, are added to the water. After six hours, $\frac{1}{100000}$ part of lime is added, and agitated for one hour. After settling for one and a-half hours, the water is filtered through sand. The water, which originally contained 40,000 to 50,000 germs per cubic centimetre, was then found to be completely sterilised, clear, almost colourless, and free from iron and copper. The sand filter can be used a long time without cleansing. The cost of purifying is estimated at 1s. per 1,000 cubic metres. The sediment may be burnt and the copper recovered.

Cupric Chloride, $CuCl_2$, occurs as green very soluble crystals. Dr. Green † has examined various copper salts as to their relative value as disinfectants. He tried 1, 2½, 5, and 10 per cent. solutions. The test objects were—twenty-four hour old bouillon cultures of cholera, enteric fever, *Staphylococcus pyogenes aureus*, anthrax free from spores, and spores of same dried on silk threads, besides several mixtures of excreta and urine infected with cholera, &c. The 5 per cent. solutions were in most cases fatal after two hours, but with anthrax only the specimens on the threads were killed, and then only when in contact with a 5 per cent. solution of copper chloride for twenty-seven days, and with the 10 per cent. solution for eighteen days. The other solutions only retarded the growth. The general result is that cupric chloride is the most active, and that their relative activity is in accordance with the proportion of copper in the compounds—viz., chloride 1 in 2·7, acetate 1 in 3·1, nitrate 1 in 3·8, sulphate 1 in 3·9. He

* *Journ. für Gasbeleucht*, vol. xxxvi., p. 513.

† *Proc. Inst. Civil Eng.*, vol. cxiii., p. 42. *Zeit. für Hyg.*, 1893, p. 495.

states that 5 per cent. solutions of copper salts cost approximately the same as 5 per cent. carbolic acid. It is also pointed out that although cupric sulphate is somewhat extensively used as a disinfectant, the chloride should take its place as being the better salt to use.

If the above results with anthrax be confirmed, there seems to be considerable risk attending the use of copper salts altogether, as it is impossible to be certain that anthrax or other spores are absent in general disinfection.

Leveson and Slater* proposed for purifying sewage the addition of crude aluminium chloride (made by treating shale with hydrochloric acid), then chloride of copper, carbon, clay, and, finally, lime to neutralise the acid and precipitate the metals. This patent is typical of a large number of complicated processes that have been introduced for the utilisation of this salt for sewage treatment.

Cupric Sulphate, $CuSO_4$, $5H_2O$, the cheapest copper salt, is soluble in 4 parts of water. To kill bacteria of putrefaction, according to Miquel,† a solution of 1 in 111 is required; according to Bucholtz‡ 1 in 133. Calvert and M'Dougall found that a strength of 1 in 900 prevented the growth of organisms in beef tea for eighty-six days. It may be taken, then, that 1 per cent. is disinfectant, while 1 in 1,000 is antiseptic for most bacteria. Kingzett also noticed that a solution of 0·25 per cent. of cupric or mercuric sulphate prevented putrefaction in broth for sixteen days; the observation did not last longer.§

The French authorities (1892) decided to adopt as their official disinfectant, in combating the cholera, sulphate of copper in a 5 per cent. solution, and, specially for the disinfection of rooms, a solution of corrosive sublimate and tartaric acid in the proportion of 1 of the former to 3 of the latter.

Eau Désinfectante Larnaudes, sold in France, is a mixture of the sulphates of copper and zinc. Vallin states‖ that this solution usually contains only a little copper, and that when used as spray on walls and floors persons entering the room just after the operation notice a marked cupreous taste and the styptic flavour of the zinc salt. Vincent disinfects fæces and the contents of cesspools with acid copper sulphate, using 6 kilos. per cubic metre per twenty-four hours.¶

Cohn, in experiments on chicken cholera, considered sulphate of copper and chloride of zinc superior to borax and chloride of lime. But the German government have adopted neither of the former.

Verdigris (cupric acetate) is used as a wash for destroying the parasites of plants, especially *Peronospora infestans*, the potato blight.

* Patent No. 11,641, 1884.

† *Les Organismes*, p. 289.

‡ *Arch. exp. Pathol.*, vol. iv., p. 1.

§ *Lancet*, 1889, vol. i., p. 144.

‖ *Désinfectants*, p. 62.

¶ *Compt. Rend.*, vol. cxix., p. 965.

Still better is the copper-lime-sugar wash of Michel Perret.* These and the sulphate are also used for soaking seed, corn, &c.

Fumigation with copper salts does not seem possible, but Clemens † proposed a lamp filled with a solution of cupric chloride in alcohol and chloroform, which when lighted is meant to give off vapours of copper chloride. Reichardt ‡ pronounced its use to be offensive, poisonous, and variable. Clemens also sprinkled the straw, &c., in stables infected with rinderpest with the same solution. For this it would doubtless be efficient, but the expense would be very great, and the animals must be removed.

Bona § proposed a mixture of cupric sulphate and alum under the name of "Cupralum."

IRON.

Metallic Iron has long been used as a purifying agent for waters exposed to air. In water free from oxygen, carbonic acid, and chlorides, pure iron can only rust by decomposing the water itself, forming a crust of ferrous oxide which protects the surface, and liberating hydrogen. If oxygen be present, the ferrous oxide rapidly turns to red ferric hydrate, still giving a protective coating. But if carbonic acid be also present in excess, it dissolves the ferrous hydrate as ferrous bicarbonate, which in turn is oxidised to ferric hydrate, and the carbonic acid is again free to act on the iron, until the whole of the iron is corroded and the ferric hydrate has deposited as an ochreous sediment, leaving the water almost free from iron. The action is hastened if the iron contains other metals, through electrolytic action. Chlorides of sodium, calcium, and magnesium are also partially decomposed, nitrates reduced to ammonia, and sulphates changed to sulphides, which are finally precipitated by the iron. The water thus becomes alkaline, and if it contain organic matter, much of the iron remains in solution. Water is thus liable to acquire a peculiar unpleasant odour, due probably to hydrocarbons, and a styptic ferruginous taste. The iron salts not only exert an antiseptic action of moderate strength, but the ferric hydrate, like alumina, effects the removal of bacteria, and also in the same way "mordants" and precipitates the colouring and other organic matters present. If lime be subsequently added, or it be filtered through carbonate of lime and then aerated, it becomes colourless and very nearly pure. The treatment increases the amount of ammonia present, if nitrates are present in the original water. The hardness is not much affected. It is

* A. Girard, *Comptes Rendus*, 1892, vol. cxiv., p. 234.

† *Deutsche Industriezeitung*, 1866, p. 268.

‡ *Disinfectionsmittel*, 1881, p. 65. § *Brit. Med. Journ.*, 1875, p. 239.

advantageous to filter also through peroxide of manganese to complete the oxidation.

Bischof's Spongy Iron Filter and "Carferal"* are applications of this principle. Frankland proved that metallic iron exerts a special destructive action on bacteria, and pointed out that though bacteria prosper and multiply in sulphurous acid, cyanides, and other poisons, they are, on the contrary, rapidly destroyed by metallic iron.†

Irving‡ causes the water to flow over metallic iron cascades, so as to be at once exposed to the action of the metal and of air; he then filters.

Anderson has several patents for the agitation of water with scrap iron or filings, or with spongy iron reduced from native oxides by heating with carbon. In Patent No. 5,496, 1884, he suggests the use of revolving cylinders, so that the iron continually falls through the water, which passes in a slow current.§ Nunn forces in air by perforated pipes under pressure.‖ An elaborate apparatus, with grids and special means for cleaning the metallic surface, has also been proposed.¶

Bischof** agitates sewage with spongy iron, allows it to subside, and then assists the separation of the iron by aeration.

The water of the River Severn at Worcester has been purified in this way by agitation with metallic iron.††

Several patents do not reduce the oxide to the metallic state, but to the lower oxide, Fe_3O_4. It must be remembered in the use of iron that the metal itself cannot be in contact with the water, or there would be the inevitable unpleasant taste and odour mentioned above. The purification is due to the oxides, which act as carriers of oxygen from the air to the organic matter present, and the core of metal is intended to act as a reservoir of fresh oxides.

Magnetic Carbide‡‡ consists of iron ore, coke, and sawdust heated together at a red heat in a gas muffle so as to form the oxide Fe_3O_4. The product is then extracted with dilute hydrochloric acid to remove lime, &c.

Magnetic Spongy Iron as used for filters is made from carbonaceous iron-stone (black band) by heating it in closed vessels until all vapour ceases to be evolved.§§ It is also used for sterilising air‖‖ and for

* Patent No. 12,392, 1892. *Journ. Soc. Chem. Ind.*, 1893, p. 539.

† Letter to the Engineers of the Municipal Council, Paris, 1881, p. 67 of their *Observations*.

‡ Patent No. 8,056, 1884.

§ See also Patent No. 10,706, 1889.

‖ Patent No. 4,619, 1891.

¶ Patent No. 14,735, 1891.

** Patent No. 3,461, 1887.

†† *Trans. San. Institute*, 1892, p. 309.

‡‡ Rimmer, Patent No. 8,357, 1887.

§§ Candy, Patent No. 1,793, 1886.

‖‖ Angell and Candy, Patent No. 14,999, 1887.

precipitating sewage. In a later patent iron pyrites are roasted in air and steam, the evolved gases (containing sulphurous acid) passed over ferric hydrate, mixed with bauxite (native alumina) and the residue lixiviated with water. The insoluble portion is then roasted with coal tar, &c., short of the metallic state, crushed, and used with the solution for sewage precipitation.*

Carferal (an abbreviation of carbon-ferrum-alumina), already mentioned, is similar.

Rusty scrap iron mixed with peat or wood-charcoal has been protected by Cox and Cox † for the treatment of sewage.

Ferrous Sulphate, $FeSO_4$, $7H_2O$, occurs in green crystals, soluble in 1·6 parts of water.

All ferrous salts absorb oxygen from the air, becoming converted into basic ferric salts which deposit as a rusty precipitate, and acid ferric salts which remain in solution. Hence they act as reducing agents. Owing to the formation of iron moulds, the iron salts are inapplicable for the disinfection of clothing, &c. They deodorise fetid liquids by absorption of ammonia and sulphuretted hydrogen, but at the same time form a black coating of ferrous sulphide, which slowly passes to brown basic ferric sulphate by absorption of oxygen. This ferric coating can again absorb sulphuretted hydrogen, and again be oxidised, and thus acts as a kind of perpetual deodorant.‡

Virchow has pointed out one of the inconveniences of iron salts. The volatile fatty acids, butyric, valeric, &c, which cause a part of the offensive odour of putrefaction, are commonly combined with ammonia. When iron salts are added the fatty acids are set free or turned into unstable iron compounds, so that the immediate effect of the projection of sulphate of iron into latrines is often an augmentation of the fetor; this soon decreases, but usually reappears after a time.§ The same result would accrue on adding almost any acid or acid salt, and thus, as well as for other reasons, it is necessary to supplement the use of an acid or treatment with an iron salt by lime. Lake,‖ proposes "iron salt, then lime, then filter;" Lockwood,¶ "iron salt, then hot milk of lime;" and Conder ** uses ferrous sulphate both for the treatment of water or sewage and for the preservation of meat.

Deposits of sulphide of iron in sewers may be a source of danger, since they are liable to produce sulphuretted hydrogen on the influx of any acid liquid. An oxidising disinfectant like chlorine would,

* Candy, Patent No. 18,598, 1892. † Patent No. 1,259, 1886.
‡ *Kuhlmann*, quoted by Vallin, p. 62. § *Ibid.*, p. 63.
‖ Patent No. 3,953, 1884. ¶ Patent No. 2,560, 1892.
** Patent No. 6,459, 1885.

however, convert it into a sulphate and allow of its removal. All reducing disinfectants are open to the following objections; (1) they permit the reduced organic matters to be oxidised again by the air; (2) they are themselves in great part at first wasted by the free oxygen of the air and the water; (3) unless kept out of contact with air they lose strength more or less rapidly by absorbing oxygen; (4) the anærobic bacteria are mostly reducing in their action and flourish readily in surroundings deprived of oxygen, whereas free oxygen is capable itself of killing them and destroying their food. With many organic substances, *e.g.*, tannin, iron salts produce a black colouration and hence the French administration have prohibited the use of iron salts where pavements or gullies can be discoloured. In December, 1879, a Paris manufacturer recovered heavy damages from a Disinfecting Company for stains on his materials caused by careless disinfection by ferrous sulphate. Vallin significantly adds (p. 755), "It seems that the disinfection was proved by the evidence to have been quite insufficient whatever may have been the quantity of sulphate of iron employed." Pettenkofer states that for the disinfection of discharges it requires 25 grammes of ferrous sulphate per head per day, or about 1 in 400 on the quantity of excreta. The strength of solution recommended is 28° Baume or about 37 per cent. of crystallised ferrous sulphate.

Miquel classed ferrous sulphate as "moderately antiseptic," 11 grammes per litre being required to prevent putrefaction of beef juice. This amount agrees closely with that proposed by Crace Calvert, who advocated the use of a 1 per cent. solution.

The memorandum of the British Local Government Board, 1892, says—"A substance generally available in the removal of filth from privies and ashpits, and for application to foul earth and the like, is sulphate of iron (green copperas), either in a strong solution made by stirring the crystals with 5 or 10 times their bulk of hot water, or in the form of powder, to which form the crystals may be readily brought after desiccation.* This agent should be used in quantity sufficient to destroy all odour† and in the removal of filth accumulations it should be well mixed with successive layers of the matter to be removed. It cannot confidently be stated that either the iron salt or any available substance will effect a true disinfection of such masses of filth as are here in question."

* By this they lose water of crystallisation, which is nearly half (44 per cent.) their weight, and become rather less easily soluble. If overheated a great loss would occur from oxidation and production of a basic salt. So that desiccation is of very doubtful expediency.

† See Virchow's remark, *ante*, p. 118.

The Society of Medical Officers of Health have also recently approved of ferrous sulphate for excreta.

The Belgian Government disinfect dejecta with ferrous sulphate (or 2 or 3 per cent. carbolic), obtaining a supply by suspending a bucket containing 50 kilogrammes in a cask full of water.

Germany, Austria, Sweden, and the United States do not officially use it. In Jena a mixture of 1 part of the salt to 2 or 3 of ground gypsum (which absorbs ammonia) is sprinkled on the drains,* and is called "Lüder and Seidloff's Disinfecting powder." Candy † uses for sewage the waste iron filings from aniline works dissolved in hot sulphuric acid. This would give an acid mixture of ferrous and ferric sulphate. Kidd ‡ mixes ferrous sulphate 20 parts, with lime 4 parts, and uses the wet precipitate with 1 pint of refuse soap for sewage treatment. Bog iron ore without lime has also been suggested as a mechanical precipitant, possibly acting as a feeble carrier of oxygen, and a partial deodorant.

Harvey § proposes soda waste 1,000 lbs. to 1 million gallons of sewage, then adding 62·5 gallons of burnt pyrites dissolved in hydrochloric acid, or practically a mixture of ferrous sulphate with some ferric chloride. He states that the specific gravity of the solution is 1·275, and that the sewage is rapidly and effectively clarified. But the effluent would be acid. Roth and Lex || show that a mass of fæces treated with a very strong solution of ferrous sulphate developed fungi in abundance.

Ferric Sulphate, $Fe_2(SO_4)_3$, in solution is brown and strongly acid. It is moderately antiseptic, an imperfect deodoriser, and is open to the same objections as ferrous sulphate, except that it is not a reducing agent. It has recently been proposed as a cheap non-poisonous disinfectant. It gives precipitates with nitrogenous organic matters, and coagulates albumen. Fresh urine treated with ferric sulphate yields a precipitate containing 5·34 per cent. of nitrogen and 12·42 per cent. of phosphoric acid. It may be conveniently obtained by the action of sulphuric acid on burnt pyrites, but the solution would contain also some ferrous sulphate in most cases. It has been manufactured into briquettes, $Fe_2(SO_4)_3$, $9H_2O$, of a greyish pink colour, which are very dense, and as compact as cement if mixed with plaster of Paris. Phenolic briquettes are also made from 100 parts of ferric sulphate, 60 per cent., 5 parts phenol, and 16 of water.

Sacre and Grimshaw ¶ use the ferric hydrate obtained as a waste product in the purification of zinc chloride as a cheap source for the

* Reichardt's *Désinfection*, 1881, p. 100.
† Patent No. 19,587, 1892.
‡ Patent No. 16,060, 1885.
§ Patent No. 6,994, 1889.
|| *Handb. d. Militar.*, vol. i, p. 524.
¶ Patent No. 17,911, 1891.

production of ferric chloride or sulphate, to be used to purify sewage.

Wohanka and Kociau, of Prague, propose adding to ferric sulphate (brown iron ore and sulphuric acid) lime, and afterwards water-glass (silicate of soda). The patentees claim that such treatment destroys the organisms in sewage. A clear effluent is obtained after filtration.*

Wolff grinds puddle slag containing 54 per cent. of iron with acids, then adds chalk, and mixes with sewage. The sludge gives a manure, and the effluent is stated to be clear and not to putrefy for months. One cubic metre of waste water (*e.g.*, from paper works) requires only a few grammes.†

It is to be regretted that ferric sulphate, which could be so cheaply made, is not of the value that the above statement would imply. It does not kill bacteria unless it be of impractical strength.

Ferric Chloride, Fe_2Cl_6, is very soluble in water, giving a yellow or brown strongly acid solution. In properties it resembles ferric sulphate, but is said to be slightly more powerful. It is a feeble oxidising agent, absorbing ammonias and sulphuretted hydrogen. It checks fermentation and the growth of bacteria without killing them, unless it is concentrated.‡ With excreta it is apt to cause a very nauseous odour. Wernich gives a favourable account of its action as a precipitant:—"Putrid and offensive material containing ammonium carbonate cause a precipitate of iron oxide which carries down the suspended matters; the supernatant liquid is clear, and both it and the precipitate are inodorous, the sulphuretted hydrogen being removed as ferrous sulphide and free sulphur, and the ammonia turned into ammonium chloride."§

Sternberg says that it quickly paralyses the power of infection, which, however, after a time revives.||

Drs. Hofmann and E. Frankland, in a report to the Metropolitan Board of Works in 1859, recommended chloride of iron for the deodorisation of sewage, and found that to deodorise 7,500 gallons, $\frac{1}{3}$ gallon of perchloride of iron was equivalent to 3 lbs. of chloride of lime or 1 bushel of lime. The first of these kept the tank free from odour for upwards of nine days, whilst the lime treatment broke down on the third day, and that with bleaching powder after five days.

Vallin condemns it as a disinfectant.¶ It has no official recognition. Nevertheless two English patents were taken out for its use in 1892, Nos. 13,316 and 15,235.

* Patent No. 278, 1887. † Wolff, *Dingl. Pol. Journ.*, vol. cclxiii., p. 484.

‡ Frankland and Ward's Second Report, *Journ. Soc. Chem. Ind.*, 1893, p. 1,052.

§ *Désinfection's Lehre*, 1882, p. 180.

|| *Nat. B. of Health, U.S.A.*, 1881, vol. cxi., p. 4. ¶ *Loc. cit.*, p. 65.

MANGANESE.

The metal is at present commercially unavailable for water purification; it would act like metallic iron, but with greater energy. "Ferro-manganese," an alloy containing up to 80 per cent. manganese, and "Spiegeleisen" might be useful substitutes for iron in water purification.

Peroxide or Dioxide of Manganese, MnO_2, found native as Pyrolusite, does not yield its oxygen to organic matters at the ordinary temperature. The precipitated peroxide (hydrated) is also sluggish. Candy asserts* that "sewage may be purified by agitation in a suitable vessel with granular manganese dioxide, the average time of contact being about five minutes." This statement seems to require confirmation, as it is difficult to understand how any purification other than mechanical can take place under these conditions. If it be heated strongly in closed vessels with carbon, a mixture of the excess of carbon with lower oxides of manganese or perhaps the metal itself is obtained. By this treatment the carbon is at the same time purified and deprived of its hydrogen and any tarry products which may be present. Such a preparation is much more active as a carrier of oxygen than the similar one made with oxides of iron (see *ante*, p. 117). Moreover it does not yield metal to the water, as iron does. "Manganous carbon" was introduced by Bernays.

This oxide when heated with hydrochloric acid is the ordinary source of chlorine—

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

As mentioned under the halogens, if it be heated with a chloride, bromide, or iodide and sulphuric acid, it gives off the whole of the chlorine, bromine or iodine. Such mixtures have been much used for disinfecting rooms (*ante*, p. 57).

Manganous Salts.—Both the manganous chloride, $MnCl_2$, and the sulphate, $MnSO_4$ are slightly antiseptic. Miquel calls the former a weak antiseptic since he required 25 grammes of it to prevent growths in a litre of beef tea. Page considers that these salts are good disinfectants, but adduces no experiments in support of his conclusion.

Slater, Page, and others† proposed manganese chloride, and sulphate for sewage treatment, either alone or mixed with salts of aluminium.

Chloride or sulphate of iron mixed with vitriol or hydrochloric acid, manganese dioxide, or hydrated ferric oxide, and ground bauxite has

* Patent No. 15,391, 1891. † Patent No. 3,973, 1886.

been recently advocated for sewage treatment.* It is a mixture of iron, manganese, and aluminium salts, possessing no apparent advantages.

Manganous salts as such may be excluded from the list of useful disinfectants, antiseptics, or even deodorants. They do not oxidise on exposure to air, and, therefore, do not act as carriers of oxygen. Even if lime be added, so as to precipitate manganous hydrate which is re-oxidised by air, the action in presence of much water and organic matter is unsatisfactory, and the expense would be great.

Manganates and Permanganates.—The manganates of the alkalies are dark-green, unstable salts; they are produced by fusing potash or soda or their carbonates with manganese dioxide in the presence of air, or with an oxidising agent, such as potassium or sodium chlorate or nitrate. Impure sodium manganate, Na_2MnO_4, with much sodium chloride, is known as "Condy's Green Fluid;" it also contains some permanganate (if barium chloride be added, the manganate is precipitated, and the crimson permanganate is left in solution), and is strongly alkaline from excess of the base. It is a cheap oxidiser, but as being impure and of varying strength, is much less used than the permanganate. It spontaneously gives up 1 atom of oxygen with great readiness, turning brown and turbid from the precipitation of the hydrated peroxide thus—

$$2Na_2MnO_4 + 6H_2O = 4NaOH + 2Mn(OH)_4 + O_2.$$

If a dilute acid be added, even carbonic, it changes its colour to crimson, forming the permanganate, while hydrated peroxide is again precipitated thus—

$$3K_2MnO_4 + 2H_2SO_4 = K_2Mn_2O_8 + Mn(OH)_4 + 2K_2SO_4.$$

The decanted solution is nearly neutral, consists of permanganate and sulphate, and is known as "Condy's Red Fluid." If evaporated it yields crystals of permanganate, which are purified by recrystallisation. An application of this reaction is made in J. C. Stevenson's patent † "acid sodium sulphate, ground with crude sodium manganese, gives permanganate when dissolved."

Stevenson and Tatters ‡ use dry sodium manganate 6 parts, bleaching powder 3 parts; this yields a mixture of manganate, hypochlorite, and chloride. Duprè and Hake § propose "a manganate with magnesium sulphate or kieserite, calcium sulphate, zinc sulphate, or boric acid. The manganate and one of these reagents are mixed in a dry fine state of division."

Manganate of soda introduced into sewers in sufficient quantities

* *Chem. Trades Journ.*, Feb. 25, 1893.

† Patent No. 2,739, Feb., 1885.

‡ Patent No. 381, Jan., 1887.

§ Patent No. 4,283, 1887.

at different points, not only destroys organic impurity, but prevents any noxious smells, and by further treatment at the outfall, the effluent matter may be rendered perfectly odourless, so as to be discharged into streams with safety. Being strongly alkaline, it disengages ammonia, which should be removed at the outfall by acid treatment. Manganates have been employed by the Metropolitan Board of Works, and by the London County Council, with fair results. Vallin, on the contrary, asserts that sodium manganate is almost inert. The amounts of available oxygen in two commercial fluids acidified by sulphuric acid, as determined by Allen in 1872, were—

	Green.	Crimson.
Available oxygen in grammes per litre,	3·883	3·921

Potassium Permanganate, $K_2Mn_2O_8$, occurs in dark-red needles, which are permanent in the air, and easily soluble in 15 or 16 parts of cold water, giving an intensely crimson solution. In contact with organic matter, when acidified with sulphuric acid, it can furnish 5 atoms of oxygen—

$$K_2Mn_2O_8 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 3H_2O + 5O.$$

The solution should remain clear. If the acid be insufficient, a brown precipitate of hydrated peroxide falls, and then only 3 atoms of oxygen are liberated—

$$K_2Mn_2O_8 + H_2SO_4 + 3H_2O = K_2SO_4 + 2Mn(OH)_4 + 3O.$$

The progress of the reaction can thus be watched by the loss of colour of the permanganate, the final point, when excess is reached, being sharply indicated by the persistence of the pink colour of the permanganate. Its disadvantages are :—

1. It leaves a brown stain on fabrics, and if concentrated it corrodes them.

2. Like chromic acid, it must first expend itself in oxidising sulphuretted hydrogen, nitrites, ferrous salts, and most organic matters, before attacking organisms, which are so resistant to it that Koch states * that it is applicable only in concentrated solutions (5 per cent.) Miquel puts it in the third class of disinfectants, requiring 3·5 grammes to sterilise 1 litre of beef tea. Calvert, on the other hand, found that 1 in 125 "prevented animalcules in beef juice and albumen for six days." Hankin considers it a specific for cholera bacilli.†

3. Not being volatile, it can only act locally. Condy in 1859 proposed its employment for air-disinfection by hanging up sheets saturated with the solution, by sprinkling walls, and by exposing layers of it in dishes in infected rooms. By such procedure a large quantity of air must escape contact with the liquid.

* *Mitth. a. d. kais. Ges.*, Dec. 3, 1881. † *Brit. Med. Journ.*, Mar. 16, 1895.

The solid when treated with strong sulphuric acid gives off ozone, but the reaction is a violent one, and is dangerous in inexperienced hands.

Demarquay spoke favourably of it for surgical use in a solution containing 1 in 1,000, as disinfecting very well, and as hardly irritant. But its action is rapidly exhausted, and it does not prevent the secretions from retaining their virulence, and Vallin is of the opinion that it is of more value as an immediate deodorant than as a destroyer of virus.* This statement has since been corroborated by Blyth,† and by Klein.‡

4. Permanganates do not absorb ammonia, and do not attack urea nor fatty acids.

Condy and Mitchell's original patent has long expired. In 1877 the former invented a very ingenious contrivance with vertical threads hanging close together in a ring, down which a solution of permanganate trickled from a circular basin above to a similar one below. This, of course, could be applied to other disinfectants; with volatile ones it would be more effective.

Among the numerous patents covering the application of permanganates for disinfecting purposes are:—Reidemeister of Magdeburg,§ "Small quantities of potassium permanganate and peroxide of hydrogen are added to water when a bulky precipitate forms, carrying down all suspended matter and the smallest organisms, while oxygen is evolved."

Tweedie and Hartin's "Crimson Salt"‖ is 1 part of potassium permanganate, 8 of potash alum, 1 of borax, 6 of sodium chloride. H. B. Condy¶ proposes the use of the aluminium salt "In 1,000 parts by weight of a 33 per cent. solution of aluminium sulphate, dissolve 53 of potassium permanganate by heat. On cooling, potash sulphate alone crystallises out, leaving permanganate of alumina and excess of aluminium sulphate in solution."

Lumps for closets containing the following mixture have been proposed:—Boric acid 10, salicylic acid 10, potassium permanganate 40, potassium or sodium silicate 40, made into a hard mass.** Meyer uses "Dry powdered barium permanganate 25 parts, to sodium bisulphate 16 parts, mixed in the dry state; an inert body like barium sulphate may be added to give bulk. If sufficient water be added to form a thick syrup, ozonised oxygen will be evolved." ††

* Vallin, *Traité*, pp. 325-328.

† "Studies of Disinfectants by New Methods," *Proc. R. Soc.*, 1886.

‡ Stevenson and Murphy's *Hygiene*, 1893, p. 61.

§ D. Patent, July, 1882.

‖ Patent No. 9,538, June, 1884.

¶ Patent No. 10,015, 1884.

** *J. Soc. Chem. Ind.*, 1890, p. 98.

†† Patent No. 16,463, 1888.

Hamilton* fuses potassium chlorate, manganese dioxide, and potash, saturates the solution with carbonic acid, and crystallises. This is simply an old method of making permanganate. He then mixes it with borax.

"Taylor's Roylat Disinfector" is an ingenious contrivance for liberating the liquid in cisterns automatically. Stoneware bottles are filled with permanganate and hermetically closed, with the exception of a small glass tube which reaches to the bottom. The bottle is inverted and placed at the bottom of the cistern. When the latter empties some strong solution flows out.†

"Condy's powder" contains a small proportion of alkaline permanganate and has no smell.‡

Disinfecting tablets or blocks have been proposed by Thornton.§ They are "prepared by mixing potassium permanganate or other disinfectant, paraffin wax, sulphate of calcium, or any other suitable cement, with some absorbent material, such as asbestos, cotton yarn, pumicestone, cinders, &c.

"Permanganate of potash is mixed with plaster of Paris or other cement or plaster, and cast into bricks or balls or into perforated tin cases, the object being to economise the permanganate."‖

One or two patents propose to recover the manganese or iron oxides precipitated in the sludge in sewage treatment, by pressing the latter, adding more ferric or manganese oxide, if necessary, heating in a closed retort, utilising the ammonia and evolved gases, cooling out of contact with air, and using the mixture of carbon with metallic oxides as a filtering medium.¶ The process, however, is not economical, as there is so much water to remove, and the product is of very inferior value.

M'Dougall calculated that "at the commercial price of Condy's fluid in his time, it would cost £10,400 per annum to disinfect with permanganate the typhoid stools of a hospital having an average of 30 cases." Crystallised permanganate has since been much cheapened, but the cost yet remains sufficiently formidable to prevent its extended use, and, as already pointed out, its applications are somewhat restricted.

* Patent No. 6,571, 1887.

† *Cf.*, "A similar Method for Cisterns," by B. S. Proctor, *Chemist and Druggist*, April 28, 1894.

‡ *Lancet*, 1887, p. 683.

§ Patent No. 17,421, 1891.

‖ M. Syer, Patent No. 11,049, 1892.

¶ Wilson, Patent No. 17,275, 1891, and others.

CHAPTER VII.

METALLIC SALTS (*continued*).

Aluminium Salts: Use in Sewage Precipitation—Alums—Aluminium Chloride—"Chloralum"—Acetate—Sulphites—General Character of the Salts. **Chromium**: Chromic Acid—Potassium Bichromate. **Arsenic**: Arsenious Acid—Arsenites—"Paris Green"—Arsenic Acid—Prohibition in France. **Lead and its Salts**: Nitrate and Acetate. **Mercury**: Oxide and Nitrate—Corrosive Sublimate; its power as a Disinfectant—Applications—Iodide—Mercuric Iodide Soaps—Cyanide—"Zinc Mercuric Cyanide"—Objections to Mercury Compounds—Organic Mercurials. **Tin**: Stannous Chloride. **Bismuth**: Subnitrate—"Dermatol." **Silver**: Nitrate of Silver—Osmic Acid. **General Remarks on Disinfectants.**

ALUMINIUM.

THE soluble salts of aluminium generally are powerfully astringent, acid, styptic to taste, and in solutions of moderate strength are not poisonous. They also produce no stain on fabrics, do not act upon metals, and are inexpensive. On addition of lime or ammonia they give a bulky flocculent precipitate of hydrated alumina, carrying down mechanically with it not only the solid matter in suspension and any germs that may be present, but also much of the dissolved organic matter, forming more or less definite combinations analogous to the "lakes." They have therefore been most extensively tried for sewage, both alone and with iron salts, lime in most cases being added. The effluent by this treatment is in most cases found to be clear, nearly colourless, apparently sterile, and deprived of most of its odour. Unless an equivalent of lime or ammonia is present, the effluent is acid and has an injurious influence on fish. The precipitate or "sludge" should include all the phosphates, most of the nitrogenous matter, and, since it contains no poisonous disinfectant, be available commercially as manure.

The antiseptic power of the alums and of aluminium sulphate, the forms most commonly used, is only slightly greater than that of the sulphuric acid they contain, and most authorities are of the opinion that when these salts are used in sewage treatment the germs are not entirely removed; a few escape precipitation and soon commence to multiply afresh; consequently the effluent again becomes foul, and on being diluted by passing into rivers, is capable of contaminating immense volumes of water. That the whole of the river is not polluted is due to the fact that "purified" sewage does not readily mix with ordinary water, but flows on for long distances in a separate stream.

The "sludge" also becomes quickly offensive in warm weather. Repeated attempts to utilise it as manure, by straining, pressing, drying, and even fortifying with phosphates, &c., have hitherto met with only partial success.

Attempts to burn it for cement, utilising the ammonia and other gases evolved, have also been made. The great difficulty is the removal of the water, which gives in drying, and still more in burning, offensive vapours.

The following is a brief summary of the processes that have been tried for sewage precipitation, of which many involve the use of aluminium salts :—

1. *Lime Process.*—The *First Report of the Rivers Pollution Commission*, vol. i., p. 52, pronounced it a failure.

2. *Lime and afterwards Ferric Chloride.*

3. *Ferric Chloride alone.*—Too expensive.*

4. *Zinc and Manganese Salts.*—Unsatisfactory.

5. *M. and C. Process*, 1875.

6. General Scott's Sewage Cement process, 1872. *Lime and Clay.*—Abandoned.

7. *Hille's Method.*—100 lime, 6 tar, 12 calcined magnesium chloride (mother liquor of sea water). Expensive. Sludge useless. Water deodorised, but bad.

8. *Black Ash Waste.*†—This material must be free from calcium sulphide—*i.e.*, must be old and oxidised to thiosulphate. Its use has not met with any degree of success.

9. *Blyth's.*—Superphosphate of magnesium, to add to the value of the sludge as manure.

10. *Holden's.*—Ferrous sulphate, lime, and coal-dust or clay. 1868.

11. *David Forbes' Phosphate Method.*—Described under "Acids" (p. 97).

12. *Whitthread's Patent*, 1872.

13. *Bird's Process.*—Crude aluminium sulphate, obtained from pulverised clay and strong sulphuric acid, which are heated together, and the mass allowed to settle, and then filter through coke. The effluent is acid.

14. *Stothert's.*—Aluminium and zinc sulphates and charcoal, then lime.

15. The well-known *A.B.C. Process.*—" Alum, blood (freshly drawn), clay, charcoal, some compound of manganese, and various other ingredients in smaller proportions." Tried on the large scale at Leamington in 1867. Unfavourably criticised by the Royal Commission of 1870.

* *Second Report of Sewage of Towns Commission*, pp. 17 and 72.

† Hanson, *Roy. Comm. of Metr. Sew. Discharge*, vol. xi., p. 97.

16. *Anderson's.*—"The sewage, after subsidence, is agitated with a saturated boiling solution of crude aluminium sulphate, then milk of lime, then filtered through soil into the river." The effluent is not pure, the cost is great, and the manure of little value (*Corfield*).

17. Lower Thames Valley, 1884. *Aluminium and Ferrous Sulphates, and Lime.*—Rejected by a Committee of the House of Commons.*

18. *Wimbledon Process.*—Spence's "alumino-ferric" (composition, Al_2O_3, *soluble* 14 per cent.; Fe_2O_3, 0·75; SO_3, 33·81; free acid, none; water, 51·44) is used with lime. In very hot weather, sodium manganate is used in addition, to prevent the setting up of secondary fermentations, and the production of offensive odours when the sewage is applied to the land. The manganate is dissolved in warm water, and is added to the clarified sewage in the settling tanks in the proportion of about 2 grains per gallon. Nearly every known reagent has been tried at Wimbledon, but up to the present the above has been found the best.

During the Royal Commission to investigate the conditions of the Metropolitan Discharge,† Mr. Dibdin pointed out that it is possible to thoroughly deodorise the sewage by means of potassium permanganate and sulphuric acid (giving ozonised oxygen) either before or after the removal of the suspended matters by precipitation. Large quantities of sodium manganate are now used for this purpose, which salt seems at present to be the only one of value, but the cost is considerable. Ferrous sulphate also remains in favour. Obviously the two cannot be used together, as one being an oxidising and the other a reducing agent, they would destroy one another.

Parkes and Corfield summarise as follows:—"All to a certain extent purify the sewage and prevent the pollution of rivers, chiefly by removing the suspended matter, but they all leave a large amount of putrescible matter in the effluent, and at least all the ammonia." Most of the phosphoric acid is also precipitated, and in many of the processes the hardness of the water is increased.

A multitude of patents exist which have been taken out for slight variations in the use of blast-furnace slag, clay, or shale alone, either raw or burnt, or the products of their treatment with acids, yielding crude salts of aluminium and iron, with lime, peat, charcoal, coke, &c. One or two examples may be noticed:—In Patent No. 2,068, 1882: "Cannel coal broken small with 10 per cent. of alumina, preferably as aluminous clay or brick earth, coked in a kiln," is used as a deodorant. In Patent No. 13,761, 1885: "Native aluminium phosphate dissolved

* See a paper on Sewage disposal, *Soc. Med. Off. of Health*, 1884-5, by Dr. Stevenson.

† Vol. xi., p. 142.

in acid, and the same substance dissolved in soda are added successively to the sewage. The acid and alkali neutralise one another, and the whole of the phosphate is precipitated." Unfortunately, phosphate of alumina is so soluble that it is the least useful phosphoric salt for manure. Similarly it is proposed to add sodium aluminate to acid aluminium sulphate.*

Kruger,† after stating that Bolton, Hueppe, and Frankland's experiments are not entirely exclusive, details his examination of the action of clay, carbonate of lime, kieselguhr, alumina, brick-dust, charcoal, coke, and sand, on sewage. He points out that finely-divided, chemically inert substances, when introduced into water, take down with them the greater part of the bacteria present. The action is more intense the slower, within certain limits, that the deposition takes place, and the greater the quantity of precipitant supplied.

He gives another series of experiments with chemical agents, including aluminium sulphate. The sterilisation is far greater when, in addition to the merely physical deposition, a chemical precipitation supervenes. In the purification of sewage water, therefore, preference should be given to chemical treatment, and inert substances should merely be regarded as mechanical aids.

Leeds‡ states that half a grain of alum per gallon reduced the micro-organisms from 8,100 in 1 c.c. to 80.

V. and A. Babes found that 0·2 gramme per litre after twelve hours carried down all the microbes from a water containing 1,200 per c.c., and the supernatant liquid was sterile. The sediment also contained from 20 to 100 living bacteria, whereas the untreated water had 1,500 to 6,000.§

A report by Lepoins, published by the Frankfort Commission on Sewage, 1891, states as follows:—"The effect of chemical precipitation is not so greatly superior to the purification obtained by simple deposition in tanks, as to warrant the adoption of any of the above processes in preference to simple mechanical treatment."

The result of trials at the St. Lawrence Experimental Station in Massachusetts has shown that "a mixture of lime and aluminium sulphate has little to recommend it."

Sir R. Rawlinson‖ remarks, "To disinfect the sewage of the Metropolis would cost millions per annum, and, according to Dr. Parkes, the most powerful disinfectants would not give safe results. 'Clarification' may be accomplished temporarily by chemicals, but

* Maxwell Lyte, Patent Nos. 900 and 6,054, 1885.

† *Zeit. f. Hyg.*, 1889, p. 86.

‡ *Potable Water*, Boston, 1891, p. 86.

§ *Centr. f. Bakteriol.*, 1892, vol. xii., p. 132.

‖ *Journ. Soc. Arts*, vol. xxxviii., p. 65.

will not then produce permanent purity. It will cost £1,500 to £3,000 for each million gallons per diem, and even the less amount will reach £225,000 per annum for the Metropolis, while expenses will raise this half a million." Notwithstanding, patent 24,080, 1892, proposes "to sterilise water without filtration by adding alum, 1 to 2 per 1,000, and leaving to settle for twelve hours."

At Glasgow aluminium sulphate and lime, with filtration through coke, gravel, and sand, and subsequent aëration is employed before the water effluent passes into the Clyde.

Aluminium Chloride, Al_2Cl_6, occurs in white crystals, very soluble in water, strongly acid, non-poisonous, but powerfully astringent when diluted; it absorbs ammonia and compound ammonias, but not sulphuretted hydrogen, therefore it is only a partial deodorant. It is more antiseptic than the sulphate, and still more than alum. Miquel gives the minimum for sterilising a litre of beef tea as Al_2Cl_6 1·4, potash alum, 4·5 grammes, as compared with mercuric chloride 0·07, copper sulphate 0·9, and zinc chloride 1·9, so that its behaviour is intermediate between copper sulphate and zinc chloride. It is a good local disinfectant when strong.

Slater and Stevens* dissolve "Gibbsite" or any aluminium compound containing a considerable proportion of hydrate of alumina in hydrochloric acid. The acid solution is used for sewage, preceded by lime, with the addition of clay and charcoal ground up together.† Again,‡ Slater and the "Native Guano Company" add "clay, crude aluminium chloride, and other substances to sewage." The use of slag and hydrochloric acid have also been patented by Slater.§ In another patent crude aluminium and iron sulphates from shale are mixed with calcium chloride, yielding aluminium chloride and calcium sulphate, the latter being used for manure.

Chloralum was the title given to a disinfectant much advertised in England for some years, but now almost disused. Fleek, of Dresden, states that it contains chlorides of aluminium, lead, copper, iron, and calcium of various amounts.

Wanklyn || pronounced it to be a deodorant superior to chloride of lime. M'Dougall by experiments maintained that it arrested putrefaction and prevented the growth of organisms more than other antiseptics. He recommended it for washing infected matters, for disinfecting sewers and the soiled linen of hospitals. But O'Neill's experiments¶ tended to show that neither chloralum nor chloride of

* Patent No. 15,810, 1884.

† See also Patent No. 16,592, 1894.

‡ Patent No. 17,453, Oct., 1890.

§ Patent No. 12,830, 1884.

|| *Brit. Med. Journ.*, "Action and Relative Value of Disinfectants," 1873, p. 275.

¶ *Army Med. Report*, 1871.

aluminium itself arrested putrefaction. "Even on adding 1 part of chloralum to 2 parts of organic matter, animalcules were abundant on the fifth day, and a putrid odour was distinct on the seventh day. Aluminium chloride was slightly better, as the odour was delayed to the tenth day, with 1 part in 6 or 8. Vallin states that "Cupralum," a mixture of alum with copper salts, has aimed at replacing "chloralum," but with no greater success.

Aluminium Acetate has been much praised by Barow, Kuhn, Wernitz, and Jalan de la Croix. It would doubtless be useful for surgical dressings, but is unnecessary and unsafe as a disinfectant. Maas recommends a 2·5 per cent. solution for surgical work.

Aluminium Sulphites have been recommended by Wade as non-poisonous and non-irritating antiseptics.*

CHROMIUM.

Chromic Acid, CrO_3, is a powerful oxidiser, and instantly coagulates albumen. It combines with a great many organic compounds, producing brown or yellow substances. This staining or mordanting action causes it to kill bacteria by an action on their envelopes. It ranks with the halogens, nitrate of silver, and permanganate, in its special action both as an antiseptic and disinfectant. Its cost and poisonous and corrosive nature have excluded it from the list of useful disinfectants.

Potassium Bichromate, $K_2Cr_2O_7$, is similar, but less vigorous, in its properties.

The earlier investigators made many experiments with these two agents. M'Dougall † in experiments on vaccine and other virus, found that 1 in 2,200 of chromic acid "prevented animalcules" in infusions for six days, 1 in 500 for seventy-eight days. O'Neil ‡ using beef juice, states that with 1 in 120 of bichromate of potash "there were no signs of decomposition in twenty-four days, with 1 in 150 a great number of animalcules appeared on the eleventh day; on the twenty-fourth day there was still no really disagrecable odour." Davaine § found that the virus of anthrax and septicæmia was definitely destroyed by 1 in 6,000 (anthrax) or 1 in 3,000 (septicæmia) of chromic acid. These experiments are of no real value (*Klein*), since the conditions are inexact and are not those of actual practice.

Lanjorrois ‖ to 500 cubic centimetres of urine and blood added 5 grammes of bichromate, and found that in eight months there was

* *Pharm. Record*, Nov. 1, 1888. † *Med. Times and Gaz.*, 1872, p. 485.
‡ *Army Med. Report*, 1872, p. 202. § *Gaz. Med.*, 1874, p. 44.
‖ *Chem. Centr.*, Cl., 1884, p. 676.

no putrescence. He does not say whether any coagulation of the latter occurred. Milk with 1 per cent. of bichromate remained unaltered for three months. But owing to its poisonous action a bichromate cannot be used as a preservative.

Kidd has patented a mixture of potassium or sodium bichromate, or chromic acid, with a little sulphuric acid, for disinfecting sewage. Even if efficient, the expense would be prohibitive.

ARSENIC.

Arsenious Acid, As_2O_3, is a white powder, slightly soluble in water (about 1 in 1,000), giving a feebly acid and almost tasteless solution which is yet strongly poisonous. It dissolves, however, very easily in alkalies forming arsenites. It is also soluble in hydrochloric acid as arsenious chloride, or "liquor arsenici hydrochloricus." The latter is to be preferred as it has the additional antiseptic properties of a solution of hydrochloric acid.

These compounds are deodorants, as they absorb sulphuretted hydrogen and compound ammonias.

Although arsenic is so powerful a poison to higher animals and insects, it has little effect on lower forms of life.* Miquel ranks As_2O_3 as "moderately antiseptic," requiring 6 grammes per litre to prevent growth in beef tea.

"Gannal's solution," formerly used in France for injecting corpses, contained 21 grammes of As_2O_3 and 1,000 grammes of aluminium sulphate per litre. Seed-corn was often sprinkled with As_2O_3 before sowing, to kill fungi and insects. Copper sulphate is much better and safer for this purpose.

Potassium Arsenite, "Fowler's solution," and **Sodium Arsenite**, have long been employed as "Sheep-dips," for killing insect parasites. Robertson patents the following preparation † :—"3 of rosin, 1 of grease melted with 6½ tar oil (containing 25 per cent. tar acids), and 2 of 95 per cent. phenol. Add 2 of arsenious acid dissolved in 1½ per cent. soda-lye, or an equivalent quantity of arsenic sulphide may be used. The product is soluble in cold water, and has the properties of a simple carbolic dip and an arsenic dip, the tar acids coagulating the parasites, and the arsenic having a continuous poisonous effect on their progeny."

Acetoarsenite of Copper, "Paris Green," contains 28·5 per cent. of arsenic and 32 per cent. of copper. It is insoluble, but is one of the best agents for killing insects on trees, sprayed over them in the proportion of 1 ounce to 10 gallons of water.

* Frankland and Ward, *Journ. Soc. Chem. Ind.*, 1893, p. 1,053.

† Patent No. 2,990, 1893.

Arsenious Sulphide, As_2S_3, dissolved in alkaline sulphides, is used in tanning to prevent fermentation and putrefaction. But S. Sadlon says * that common salt, together with an alkaline sulphide, will produce the same result.

Arsenic Acid, H_3AsO_4, is much more soluble, and reputed to be more poisonous, than arsenious acid. But neither it nor the arsenates are of any value as germicides. Miquel states that the potassium salt is "very feebly antiseptic," requiring 125 grammes per litre to prevent growth in beef tea, while sodium arsenate is "moderately antiseptic," requiring 9 grammes per litre.† Loew ‡ remarks that "the acids of arsenic are poisonous towards algæ only in the same degree and for the same reason as are acetic and citric. Larvæ and infusoria live in a 1 per mille solution of potassium arsenate, though higher animals die."

In France the use of arsenical compounds as antiseptics has been totally prohibited since 1876.

Considering the ease and rapidity with which arsenic is diffused, and the insidious action, even of traces, in water, food, or air, even if it were a good antiseptic, its use should be penal in all countries.

LEAD.

Lead salts absorb sulphuretted hydrogen, ammonia, and their derivatives, and are therefore deodorant. Measured by the amount required to sterilise a litre of broth, Miquel classes them as "strongly antiseptic," only slightly below zinc chloride, where 1·9 grammes of the latter is used, 2 grammes of lead chloride, or 3·6 grammes of lead nitrate, are required.

Nitrate of Lead, $Pb(NO_3)_2$, is the basis of a "disinfectant" long known under the name of "Ledoyen's liquid," composed of 1 part of the salt in 10 of water. M. Fermond in 1858 used it in the closets of the Saltpetrière, and found it was effective in removing the odour, as other metallic salts would be, but it had the disadvantage of being easily precipitated as lead sulphate, and of covering the basins with a black coating of lead sulphide. It is expensive, and does not absorb ammonia readily. It is inapplicable for wounds, on account of its ready absorption and poisonous effect on the system.§

Basic Acetate of Lead, or "Goulards' Extract," is used for burns and bruises, but only for its cooling qualities.

In conclusion, lead compounds are of no value as disinfectants.

* *Der Gerber*, 1891, vol. xvii., p. 284.

† *Les Organismes*, p. 289.

‡ *Centr. f. Agric. Chem.*, vol. xiii., p. 68.

§ Vallin, *Désinfectants*, 1882, p. 66.

COMPOUNDS OF MERCURY.

Mercuric Oxide, HgO, like insoluble substances generally, has no action by itself on organisms, but it easily dissolves in even vegetable acids to form many soluble, and therefore active, salts. Admixed or combined with phenol it has been used for a "carbolate of mercury" soap, which, according to Dr. Woodhead,* is not a valuable preparation. Combined with oleic acid it forms a strongly anti-parasitic basis for ointment. Oleate of mercury is in the British and most other pharmacopœias.

Mercuric and Mercurous Nitrates are strongly antiseptic soluble salts, but are not used because they are caustic and are easily decomposed by a large quantity of water. "Unguentum Hyd. Nitratis" is a parasiticide.

Mercuric Chloride, $HgCl_2$, perchloride of mercury, or "corrosive sublimate," is probably the most powerful disinfectant we possess. It will be seen that the poisonous action of a great number of antiseptics depends on their property of precipitating albumen and other allied ingredients of protoplasm. For example, phenol, mineral acids, copper and iron salts, alum, tannin, chromic acid, all form insoluble compounds with albumen. Mercuric chloride possesses this property in a very marked degree, but the compound produced re-dissolves in excess of albumen. It is, therefore, necessary to have mercuric chloride present in excess. Mercuric chloride is soluble in 15 parts of water, and still more in alcohol, ammonium chloride, sodium chloride, and dilute acids. It is exceedingly poisonous, a dose of 2 centigrammes daily soon producing poisonous effects. This almost prevents its use internally, and even makes its external employment dangerous. Hence solutions of it used for disinfection should be coloured, preferably blue. In the United States it is recommended to add an equal quantity of potassium permanganate to distinguish the solution. As to the efficiency of mercuric chloride, the earlier investigators gave varying but very high results. Bucholtz, in a comparative list of the amounts of different disinfectants required to suppress the growth of bacteria in culture solutions, places mercuric chloride in the foremost place, and recommends a solution of 1 in 20,000.† Miquel says that a solution of 1 in 14,000 is disinfectant, and Sternberg 1 in 30,000. Koch asserts that "a single application of a solution 1 in 1,000 or even 1 in 5,000 is sufficient to destroy the most resistant organism in a few minutes; with a longer exposure it only begins to be unreliable at 1 in 20,000."‡ Davaine§ stated that 1 in 15,000 killed anthrax.

* *B. M. A. Reports*, 1888. † *Archiv. f. exp. Pathol.*, vol. iv., p. 80.

‡ *Mittheil. a. d. k. Gesund.*, 1881, p. 234.

§ *Bull. de l'Acad. de Med.*, July, 1880.

Vallin says that 1 in 2,500 is effective under most unfavourable circumstances.* Billroth, Haberkorn, and Kuhn likewise recommend it. Therefore, though it cannot be employed for preserving food on account of its poisonous nature, it has been used for injecting corpses and by most governments for local disinfection. Dr. Collingridge, in a private communication informs me that for ships' crew's spaces, rooms, &c., after fumigation by sulphur either by the ordinary process of combustion or by the liquid sulphurous acid, he washes with a solution of mercuric chloride of 1 in 2,000. Vessels entering the Mississippi suspected of contamination are sprayed over all surfaces excepting the cargo with a solution of 1 in 1,000.† The hold is then disinfected with sulphur. Since mercuric chloride is non-volatile at ordinary temperatures, it cannot affect the air throughout the spaces, hence it only acts as a strictly local disinfectant.

But Klein has very much reduced the above too favourable estimates of the power of this salt. He considers it an efficient germicide, but maintains that Koch and others have overrated it. In 1885 Blyth conducted a series of experiments in which he treated anthrax spores with 1 in 1,000 solution of mercuric chloride, as others had done, when he noticed that the bacteria were apparently killed and the spores ceased to develop; but on then inoculating guinea-pigs with the apparently sterilised infusion, anthrax rapidly appeared, the animals died, and the blood was swarming with *Bacillus anthracis*. He concludes that a solution of 1 in 1,000, although it kills the non-spore-bearing organisms, only stupefies and does not destroy the spores of *Bacillus anthracis*.‡ Dr. Woodhead§ explains Klein's result as due to the precipitation of the mercuric chloride by the albumen present, "which gave a coating or pellicle of albuminate of mercury round the spores, protecting them from further action until they were introduced into the blood of the animals, when the excess of albumen re-dissolved the pellicle and set the organism free to flourish in its new surroundings."

Crace Calvert also pointed out, many years ago, that mercuric chloride "destroys vibrios but not fungi;" and H. Schulz || has shown that a solution of 1 in 500,000 increases the activity of *Saccharomyces cerevisiæ*.

Koch has repeated his experiments and somewhat modified his earlier conclusions. He still affirms that mercuric salts, especially the chloride, are most valuable. "For a ship's bilge, where a 5 per cent.

* *Traité*, p. 117. † *Pharm. Journ.*, 1887, p. 144.
‡ *Micro-organisms of Disease*, 1886, p. 261.
§ *Proc. Roy. Soc. of Edinburgh*, vol. xv., p. 246.
|| *Pfluger's Archiv.*, vol. xlii., p. 517.

solution of carbolic acid must be left for forty-eight hours, a 1 in 1,000 mercuric chloride solution only required a few minutes." He admits that "there is on the other hand reason for doubting the efficacy of this salt, for though anthrax spores subjected to a 1 in 20,000 solution for ten minutes and then washed in alcohol gave no growth in nutrient gelatin, silk threads infected with the spores and then exposed for ten minutes to a 1 in 20,000 or even 1 in 10,000 solution proved fatal to mice." *

Herroun considers that the value of this substance as an antiseptic has been very much overrated, as he has cultivated ordinary septic bacteria in albuminous filtrates containing 1 in 20,000 of mercuric chloride. "It is precipitated by albumens if used in greater strength, and is readily converted by the sulphur of all bodies into insoluble mercuric sulphide which is practically inert." It may be remarked also that mercuric chloride is precipitated by any alkaline solution such as ammonia, &c. Laplace in a series of experiments found that 5 c.c. of blood serum was sufficient to precipitate the mercury from 5 c.c. of a solution of the strength of 1 in 1,000, but that by adding hydrochloric acid in the proportion of 5 in 1,000 the formation of the precipitate is prevented. Similar results are obtained when tartaric is substituted for hydrochloric acid.† When about 10 parts of sodium chloride are added to 1 of mercuric chloride, the coagulation of the albumen is also prevented.

It may be concluded that Klein's results are confirmed, and that Woodhead's explanation is at any rate part of the truth. It follows that the minimum must be raised to 1 in 500, and that the solution should be acidified, preferably with about ½ per cent. of hydrochloric acid, which adds much to the antiseptic power. If, as already mentioned, permanganate is used with it, or some colouring matter like indigo or aniline blue be added, the advantage of the warning colour is obtained. In the United States mercuric chloride is held in great esteem. Dr. Mead Bolton ‡ gives the following table of the minimum strength required of various disinfectants :—

Organism.	Chloride of Lime.	Mercuric Chloride.	Carbolic Acid.
Typhoid bacillus, . .	1 in 2,000	1 in 10,000	1 in 100
Cholera spirillum, . .	1 in 2,000	1 in 10,000	1 in 100
Anthrax spores, . .	1 in 100	1 in 1,000 (?)	1 in 50 (?) (Uncertain.)
Staphylococcus aureus, .	1 in 200	...	1 in 100
,, *citreus*, .	1 in 50	...	1 in 100
,, *albus*, .	1 in 200	...	1 in 100

* Crookshank's *Bacteriology*, 1887, p. 150. † *Brit. Med. Journ.*, 1888, p. 148.
‡ *Report of Comm. on Disinfectants of Amer. P. H. Assoc.*, 1889, p. 236.

The American Public Health Association recommend a solution of 1 in 500 of mercuric chloride to be used for spore-containing infected material, and 1 in 2,000 for that which does not contain spores, as compared with 5 per cent. carbolic or 10 per cent. zinc chloride. Hands are washed in a 1 in 1,000 solution. The dead are wrapped in sheets saturated with 1 in 500; walls are washed with 1 in 1,000, and ships sprayed liberally with the same strength.

The French authorities adopt a solution containing 1 gramme of mercuric chloride and 3 of tartaric acid in 500 of distilled water for disinfecting rooms (Laplace's formula).

In Paris, spraying rooms after infectious disease with a 1 in 1,000 solution of mercuric chloride by means of a "pulverisateur" has found much favour during the last few years, and the results obtained are said to be highly satisfactory. No bad effects have followed this practice in Paris, although 35,000 houses were disinfected in this way in 1893, and considerably more in 1894. In Berlin this practice is not recommended, and in India cases of salivation have been attributed to the use of a mercuric chloride solution as a disinfectant wash for floor boards.

The Italian Minister of the Interior has recently called the attention of the railway companies to a clause of the sanitary laws which is as follows:—"The whole inside of the carriage is to be repeatedly brushed over with a 2 per mille solution of sublimate. Cattle trucks are to be thoroughly washed with a solution of carbolic acid, or an equivalent disinfectant, and with corrosive sublimate when animals suffering from a contagious disease have been in the trucks." It is to be noted that mercuric chloride solution, especially if acidified, would rapidly injure the cushions or hangings. Dr. Thorne, the Medical Officer of the British Local Government Board, believes corrosive sublimate, so far as cholera is concerned, to be its most potent germicide. The official circular issued by Sir G. Buchanan in April, 1888, was confirmed by the Board in 1892. The following method is recommended:—"For the purposes of the sick room, such as reception of soiled handkerchiefs, sheets, and the like, as well as for the swabbing of floors, a valuable disinfectant solution may be made with perchloride of mercury. It is well to have this solution slightly acid, coloured also in such a way that it shall not readily be confused with drinks or medicines; and proper caution should be given to avoid accidents in its use. Sanitary authorities will find it advantageous to have such a solution prepared under the direct instructions of the medical officer of health, and supplied at a uniform strength at the infected house by the order of that officer. A solution fitted for the desired purposes may be made with half an ounce of corrosive sublimate, 1 fluid ounce hydrochloric acid, and 5 grains of commercial aniline blue, in 3 gallons (a bucketful) of common water. It ought not to cost more than threepence the bucketful, and should be further diluted. The use of non-metallic vessels (wooden or earthenware) should be enjoined, and articles that have been soaked in it should be set to soak in common water for some hours before they go to the wash." The strength of the above solution is 1 in 960; it should be 1 ounce of mercuric chloride, or about 1 in 500.

Dr. C. T. Williams, of Brompton Hospital, states that mercuric chloride (as well as arsenic, boric, and strong acids) do not interfere with the tubercle bacillus, but rather promote its growth. Dr. Whitelegge, on the other hand,* asserts that sulphate of iron and chloride of zinc are useless, and that the best known disinfectant is mercuric chloride. Ratimoff † gives a table of comparative values of disinfectants, and cites experiments showing that amounts of mercuric chloride from 1 in 13,300 to 1 in 800,000 killed, in his experiments, various infective organisms, which results are at variance with those of other observers. Dr. A. Ivert in 1889 treated forty-five cases of Asiatic cholera in Tonquin with mercuric chloride internally, in doses of ·02 to ·04 gramme per twenty-four hours. The death-rate among these was 20 per cent., whereas the general death-rate was not less than 66 per cent. He also tried it as a prophylactic agent, and in no case did any signs of cholera develop.‡ F. A. Coward § gave mercuric chloride (and tinct. ferr. perchlor.) internally in sixty cases of diphtheria. In some cases he also sprayed the throat with a solution of mercuric chloride, glycerine, and potassic chlorate. All were successful, even without the spray.

Solutions of the strength of 1 in 1,000 to 1 in 10,000 have been for many years used as antiseptic dressings by surgeons and by dentists. If strong, the mercury will be absorbed, causing salivation, and local irritation may also be produced. The formation of an insoluble mercuric "albuminate" with the serum exuding from a wound is apt to throw the mercury out of action. In Laplace's solution this is prevented by adding tartaric acid to the liquid (see p. 138); but Drs. Lubbert and Schneider found that the acid caused irritation to wounds, therefore they use a solution containing mercuric chloride 2 parts, sodium chloride 100, distilled water 600, glycerine 100, rectified spirits 200, to prevent the albuminate precipitating.‖ Dr. Wilson's solution is 1 of mercuric chloride, 1 of ammonium chloride, and 1,000 of water.¶ The "St. Bede Disinfectant," made at New-

* *Lancet*, 1887, p. 76.
† *Bied. Centralblatt*, vol. xiv., p. 360.
‡ *Comptes Rendus*, vol. cvii., p. 695.
§ *Brit. Med. Journ.*, 1891.
‖ *Chem. and Drug.*, 1893.
¶ *Pharm. Journ.*, 1891, p. 960.

castle-on-Tyne, consists chiefly of sodium sulphate, mercuric chloride, and a little sulphuric acid, formed into blocks with indigo, eucalyptus, and thymol.*

M. Balme has invented an antiseptic paper in the shape of perforated sheets like postage stamps, made into a book. A white unsized paper is employed, as it is found not to reduce the mercury and lose strength as gauze does. In the manufacture, on to each sheet is dropped from a pipette a known quantity of a standard sublimate solution. When dry they each contain an exactly known amount of the agent, and only require to be moistened and applied to the wound.†

"Sublimate gauze," as used in the German Army, contains about 1 in 200 or 300 of $HgCl_2$, and is coloured pink by magenta to distinguish it. "Sal alembroth" (ammonio-mercuric chloride) gauze is also made coloured with aniline blue.

It has been mentioned that it is better to employ distilled water for making up sublimate solutions, as the carbonate of lime in ordinary water causes a precipitate. As distilled water may sometimes, as in war, be unattainable, the difficulty can be avoided by adding an acid, as in the English and French prescriptions. As an alternative an alkaline chloride may be added; ordinary salt is generally chosen for this purpose. Victor Meyer considers the addition of salt and the use of distilled water to be unnecessary, since he found that a 1 per 1,000 solution of mercuric chloride made even with a bad pond water kept well in the dark for two months.‡

C. J. Bond§ recommends a pellet containing 4½ grains of mercuric chloride and 4½ of sodium chloride which can be dissolved in a pint of water in about three minutes, forming a solution of 1 in 2,000. Solutions made with salt do not turn milky with hard water like those with ammonium chloride.

Vignon‖ points out that as a definite strength is of the utmost importance, the permanence of the liquids must be secured. He noticed that a 1 per mille solution of mercuric chloride in pure distilled water becomes slightly turbid in from twenty-four hours to two or three days, and gradually gives a white precipitate. He obtained the following results:—

	Mercuric chloride per litre (in solution).
Original solution, ...	1·00 gramme.
Open to air for 7 days (volume reduced by evaporation from 500 to 385 c.c., and, therefore, solutions became stronger), .	0·57 ,,
In a closed flask for 7 days, ...	0·97 ,,
In a closed flask for 220 days, ...	0·67 ,,

* *Lancet*, vol. ii., 1889, p. 701.
† *Chem. and Drug.*, 1889, p. 119.
‡ *Ber.*, vol. xx., p. 2,970 (1888).
§ *Chem. and Drug.*, Aug. 9, 1890.
‖ *C. R.*, 1893, Dec. 4.

Colouring matters diminish the loss, indigo being better than fuchsine (because the former is acid), but still there is a loss under the best circumstances from 1·00 to 0·98 in 7, and to 0·80 in 220 days. The alkaline chlorides generally help the keeping power. Solutions with 10 grammes of sodium, ammonium, or potassium chloride to 1 gramme of mercuric chloride, keep practically unaltered for a very long time. 1 per 1,000 of hydrochloric acid acts in the same way, and would be as useful in those cases in which its irritant effect was not objectionable.

It is evident that the weakening is due to dissociation, a basic chloride precipitating and an acid remaining in solution. Exposure and heating cause the hydrochloric acid to be volatilised. The double salts are more stable, therefore 1 per cent. of salt, or 10 per cent. of hydrochloric acid, should be added in making up the solution. The sublimate dissolves more readily when it is finely powdered and well agitated with the liquid, as it is sparingly soluble and rapidly settles.

Mercury Albuminate, the white flocculent precipitate given on mixing mercuric chloride with dilute albumen, is non-putrescent, insoluble in water, but soluble (while moist) in sodium chloride, and in excess of albumen, therefore in blood, serum, &c. Gauze impregnated with it is a slow, but mild and effective mercurial antiseptic.*

Mercuric Iodide, HgI_2, made by precipitating a mercuric salt by potassium iodide, is scarlet, insoluble in water, but easily soluble in excess of potassium iodide, to form a double salt, potassio-mercuric iodide. This has lately come into use as a disinfectant, being said to have "double the bactericidal power of corrosive sublimate, while it is less poisonous." It was first suggested by Dr. Bernardy, of Philadelphia,† and has been patented in France and England by Collin and Benoist.‡ They use 1 part of mercuric iodide to 1 part of potassium iodide. "5 to 15·5 grains are added to a litre of the animal or vegetable liquid to be preserved. Solids are treated with a solution of 15·5 grains per litre (1 in 1,000) for twelve to twenty-four hours, when the germs are all destroyed." They also mention mixing it with eucalyptus and other substances. It is asserted that a solution of this compound of 1 in 4,000 is equivalent to 1 in 2,000 of mercuric chloride. "For washing floors a solution of 1 in 4,000 should be employed, for disinfecting the hands 1 in 2,000, and for instruments 1 in 2 to 3,000.§ Steel instruments would be attacked unless immediately rinsed.

The solid compound is manufactured under the name of "Iodic

* Schneider, *Pharm. Centralblatt*, 1888, p. 141.

† *Brit. Med. Journ.*, 1887, p. 789. ‡ Patents, Nos. 15,766 and 16.935, 1887.

§ *Brit. Med. Journ.*, 1887, p. 789.

Hydrarg.," and is stated to dissolve without decomposition in an equal weight of water. It is recommended by Waschejewsck for ophthalmia in a strength of 1 in 5,000. "It does not precipitate albumen nor cause irritation, and can even be given internally in doses of a quarter grain." It has also been compressed into tablets of definite weight. One soloid of "Hydrarg. Perchlor." in a pint of water gives a solution of 1 in 1,000. Two of "Iodic Hydrarg." in the same quantity gives a strength of 1 in 4,000.

P. K. Bolshesolsky * strongly recommends a 1 in 10,000 solution of this salt as an antiseptic in obstetrical and surgical practice.

Thomson proposes as an antiseptic, 1 to 3 of mercuric iodide and 1 to 3 of potassium iodide to 100 of soap. The solution for use contains 1 of mercuric iodide in 4,000 of water. Dr. Woodhead has experimented on it with favourable results.†

Mercuric Cyanide, $Hg(CN)_2$, is sparingly soluble in water, slightly acid, and inodorous. The basic or oxy-cyanide is similar, but slightly alkaline. Both are antiseptic and very poisonous. Solutions of the latter, 1 in 15,000 strength, do not seriously injure instruments, only slightly precipitate albumen, and are tolerated by wounds and by the mucous membrane. Chibret ‡ found when he added it to peptonised broth that it had six times the antiseptic power of the chloride, although it does not act so powerfully on *Micrococcus aureus*. It has also been found of service in cases of diphtheria.

Stellden § reports on 1,400 cases of diphtheria treated with this remedy, when only 5 per cent. of deaths occurred, as compared with the ordinary 92 per cent. in that district at the time. (Honey, 450; tinct. aconite, 30; $Hg(CN)_2$, 0·3 grain; also a gargle of 1 $Hg(CN)_2$ in 10,000 of Aq-menth. pip.). Frequent doses and applications were said to suppress the bacillus.

Zinc Mercuric Cyanide.—Sir Joseph Lister introduced this compound in 1889. To a solution of potassio-mercuric cyanide a zinc salt is added; the bulky white precipitate is washed with water till the washings are almost free from mercury, then drained, triturated with starch, ground with potassium sulphate to aid the pulverisation, and carefully dried. To fix it on gauze, 3 to 5 per cent. of it is suspended in a 1 in 4,000 solution of mercuric chloride, and the gauze dipped with agitation. The powder keeps when dry, but the gauze must be prepared when required, and used moist.

B. Dott ‖ cast some doubts on the definiteness of this compound,

* *Proc. Arkhangelsk Med. Soc.*, 1894, vol. ii., p. 191.

† *Brit. Medical Association*, Edinburgh Meeting, 1888.

‡ *Compt. Rend.*, vol. cvii., p. 119.

§ *Merck's Bull.*, vol. i., pp. 28-40.

‖ *Lancet*, vol. ii., 1889, p. 1133.

questioning the presence of mercury in any quantity. Dunstan * proved that the original precipitate, which he prepared by a variety of methods, was a true double salt of the formula $Zn_4Hg(CN)_{10}$ or $HgCN_2$, $4Zn(CN)_2$, but that it was decomposed in the washing, the soluble $Hg(CN)_2$ being removed, and the insoluble $Zn(CN)_2$ remaining, so that the result was a mixture of variable composition consisting mainly of zinc cyanide, with, in different samples, 6, 8·5, 10, and 18 per cent. of $Hg(CN)_2$—that is, about a $\frac{1}{4}$ to $\frac{1}{8}$ of what it should be. Long washing or hot washing removes all the mercury.

However useful in practice this preparation may prove to be, the variation in its composition militates against uniform results. Dunstan tried to prepare it in alcohol and other ways, but without success.

Mercuric Chloro-amide, $HgNH_2Cl$, is the soluble white powder well known as "white precipitate." It is much used for killing *Pediculi*, and is a mild intestinal antiseptic.

The following organic mercurial compounds are all antiseptic and have varying disinfectant powers. All are poisonous. They are occasionally used in emulsified lotions or injections, or in ointments and gauze, against syphilis :—

Carbolate, $(C_6H_5O)_2Hg$ (*Szadek*), **Sulphocarbolate**, and **Benzoate** (*Stukowenkow*) are white powders, almost insoluble in water.

Salicylate (*Silva-Araujo and Szadek*) in pills, $\frac{1}{60}$ to $\frac{1}{8}$ grain, and as an injection in 0·4 per thousand solution for gonorrhœa and syphilis, has perhaps been more widely used than any other of the newer compounds of mercury.

Thymolate $(C_{10}H_{13}O)Hg.HgNO_3$, **Thymolacetate**, and **Thymosulphate**, $\frac{1}{12}$ to $\frac{1}{6}$ grain in pills, were recommended by Kobert for syphilis.

Tannate, greenish-brown insoluble scales; 1 to 2 grains have been recommended as an antisyphilitic by Lustgarten.

Imidosuccinate, $(C_2H_4(CO_2)_2N)_2Hg$, is soluble in 25 parts of water. $\frac{1}{5}$ grain is used hypodermically in syphilis (*Von Mering and Vollert*, 1888).

Naptholate and **Naptholacetate** are condemned by Iaddosohn and Zeissing as producing pain.

Peptonate and "Glutino-peptone sublimate," made by acting on gelatine with hydrochloric acid and adding 25 per cent. of mercuric chloride, are met with in 1 per cent. solution for injections, and are said to be almost painless and to be rapid and efficient (*Dr. Hufer*). The doses are about equal to $\frac{1}{6}$ grain of mercuric chloride.

Any surfaces washed with a mercury salt will soon be blackened

* *Chem. Soc. Journ.*, 1892, p. 666.

with sulphuretted hydrogen. Organic matter is liable to reduce and throw the mercury out of action. The mercuric solutions are compatible with peroxide of hydrogen, acids, permanganate, zinc and copper salts, glycerine, phenol, and most aromatic compounds, but not with borates, sulphates, phosphates, carbonates, or alkalies, which precipitate them.

COMPOUNDS OF VARIOUS METALS.

Tin.—Stannous Chloride (protochloride of tin), $SnCl_2$, has been suggested as a disinfectant.* It is comparatively safe, and does not corrode lead pipes. A solution containing 1 per cent. kills spores after an exposure of two hours. When kept for use it should be mixed with an equal quantity of ammonium chloride, which prevents the formation of the insoluble oxychloride of tin.

It is difficult to see any advantage in its introduction, as its bactericidal powers are feeble, and chiefly due to its hydrochloric acid. It would absorb ammonia and sulphuretted hydrogen, like many other agents.

Bismuth.—Gayon and Dupetit † were the first to point out that salts of bismuth, even in small quantities, completely prevented the secondary fermentations which take place in worts, but they have not been used to any large extent.

Bismuth subgallate, $C_7H_7O_7Bi$, formed by the action of bismuth nitrate on gallic acid, is soluble in water, alcohol, and ether, has lately been introduced under the name of "Dermatol." F. Rohrer ‡ says of it, "This new disinfectant in the different forms of purulent inflammation of the outer and middle ear, also in affections of the nose, has lately claimed to be a great success. A bacteriological test, in which dermatol mixed with broth or gelatine was infected with anthrax, has revealed, however, that it is not a germicide, and does not even retard the growth. In fact, the bacillus actually changes the dermatol, which becomes yellow, and finally black. The same discoloration occurs in the ear." So that it simply acts as an astringent.

Colosanti and Dutto, on the other hand, report favourably on its use as an internal disinfectant.

The salts of other metals have not been used to any large extent.

Miquel classes **Silver Nitrate** as equal to mercuric chloride.

Osmic Acid is a very powerful bactericide, as mentioned by Klein and supported by Koch. Koch says that **Silver** and **Gold** compounds are all inhibitory on tubercle, especially **Gold Cyanide**, $Au(CN)_3$, dissolved in potassium cyanide; 1 part $Au(CN)_3$ in 2,000,000 parts of solvent checking the growth of tubercle bacillus.

* *Year-Book of Pharmacy*, 1887. † *Comp. Rend.*, vol. ciii., p. 883.
‡ *Centr. f. Bacteriol.*, 1892, vol. xii., p. 625.

With reference to compounds generally, in view of the search for new disinfectants, it may be mentioned that—

1. As free acids, even the weakest, such as acetic and carbonic, retard, as a rule, the growth of bacteria, which usually require a slightly alkaline medium, the acid salts and those of the metals which have an acid reaction retard putrefaction by virtue of their acid constituent, and independently of the nature of the metal.

2. Some metallic salts precipitate albumen—*e.g.*, those of mercury, copper, and most of the heavy metals. Such, by coagulating protoplasm, must kill the organisms, if they can penetrate deep enough. With these salts, disinfection is, therefore, a condition of quantity and time.

3. These metallic salts, and some other substances, such as lime, alumina, phosphates, and charcoal, may starve bacteria by withdrawing, or rendering insoluble, their food.

4. The borates, aromatic substances generally, and a few other compounds exert a direct toxic influence on organisms which, as far as known, is physiological and not chemical. Given sufficient quantity and time, they may actually kill the bacteria and so act as real disinfectants, but they usually only retard the growth, and therefore are chiefly used as antiseptics. It is possible that some of them may form loose compounds with protoplasm which interfere with its vital fuuctions.

5. Reducing agents, such as sulphites and ferrous salts, withdraw oxygen, which element is necessary for the growth of most organisms.

6. Oxidising agents, like ozone, peroxide of hydrogen, the halogens, and permanganate, act on bacteria by destroying their food, poisoning them, and finally completely destroying them. These are the only perfect disinfectants, yielding the ideal condition of sterility, nothing to grow, and nothing to feed on. It remains solely to find the minimum required, and then to use a little more for safety. All other disinfection must be unsatisfactory, and only means suspension for a time.

7. A few easily reducible metallic salts are fed on by the organisms, which assimilate one of the elements, to be deposited in their tissues as coloured granules distinctly visible under the microscope. Silver, gold, and some iodine compounds are examples. After a time this deposition chokes, and finally kills them. Probably this accounts for the fact so often observed, that very minute percentages of many poisons actually promote the growth of organisms, which larger amounts destroy. Ordinary therapeutics furnish many parallel instances.* Richet remarks † that, although very small quantities of

* Note Crace-Calvert's observation under *Mercury*, p. 136; Dr. Williams, *ibid.*, p. 139.

† *Comptes Rendus*, 1892, p. 1494.

certain metallic salts retard or wholly prevent the development of the lactic ferment in milk, still smaller quantities even act as accelerators of the fermentative action.

This explains the absolute necessity of working quantitatively in disinfection, and also many of the discrepancies and misstatements which exist in the literature of the subject.

Richet also observes * that the ferment appeared indifferent to salts of copper and mercury in quantities inferior to ·00025 gramme per litre; in doses of ·0005 gramme per litre these salts possessed an accelerative action, and in quantities of 0·001 per litre their antiseptic properties first became evident. The toxic action of the metallic poison does not appear to affect the chemical activity of the ferment, but rather its powers of multiplication. The biological relations as regards the toxicity of metals do not follow chemical laws, as certain metals which are chemically very similar have a very different toxicity, and it is especially noteworthy that the rarer metals, to which the ferment is probably not so well accustomed, appear more toxic than the common metals. The prohibitive dose of zinc is 1 gramme, whilst 0·15 gramme of cadmium sulphate completely prevents fermentation. Ferric and manganese salts are also less toxic than cobalt and nickel salts.

While calcium salts are constituents of food, barium, chemically the next metal, gives compounds that are poisonous. Among the rarer metals may still be found a stronger antiseptic than any yet examined. It would appear that in a series of similar metals the higher the atomic weight the more toxic the salts. In the case of the non-metals the reverse may be the case, but at present there is want of data for ascertaining how far the periodic law of the elements bears on their antiseptic and disinfectant action.

* *Loc. cit.*

CHAPTER VIII.

ORGANIC SUBSTANCES.

COAL TAR AND ITS PRODUCTS: General Account—Tar Water. **Hydrocarbons (Neutral Tar Oils)**: Benzene—Toluene—Naphthalene—Anthracene—Naphthalene Urinal Cakes—"Lauraline." **Petroleum. Phenols.** PHENOL OR CARBOLIC ACID: "Properties"—Variation in the Commercial Strength—The "Victoria Carbolic Acid Powder"—Carbolic Fumigation—Antiseptic Power of Phenol—Not a Disinfectant—Uses and Dangers—Objections to the employment of Phenol—Prescriptions in Different Countries. **Carbolic Powders**: M'Dougall's — Calvert's — Mayor's — Phenolith — Other Patents. **Surgical Preparations**: Carbolised Oil—Gauze—Carbolic Wool—Danger of Phenol in Surgery—Carbolic Soaps—Tooth Powders—Various Preparations—The cost of Phenol. **Halogen Compounds of Phenol**: Tribromophenol—Iodophenols. **Sulphonic Derivatives**: "Sulphocarbolates"—Sozo-iodol—Aseptol—Sozol—Benzene-sulphonic Acid—Phenyl substituted Fatty Acids. CRESOL AND ITS HIGHER HOMOLOGUES: Table of the Phenol Series—Sources—Creosote Oil—Uses of Creosote Antiseptic Powder—"Bacillite"—Lysol—Experiments on its Efficiency—Pixol—Pixene—Question of Solubility—Tricresol—Jeyes' Disinfectant and **Creolin**—Creolin Baths—Smith's Carbolated Fluid—Artmann's Creolin—Strathclyde Disinfectant—Essets' Fluid. **Saprol**: Its Peculiar Properties—Allen's Fluid—Production of Ozone. **Izal**: Europhene—Resorcinol—Pyrocatechol—Pyrogallol. WOOD-TAR DERIVATIVES: Products of Destructive Distillation of Wood—Stockholm Tar—Retinol—Resol—Fatal to Plants. **Wood Creosote**: Uses and Antiseptic Power. **Guaiacol**: Medicinal Uses—Guaiacol Carboxylate—Creosol—Kresyline—Little's Soluble Phenyle. NAPHTHALENE AND NAPHTHOL: Naphthalene—Naphthalene-Sulphonic Acids—Naphthols—Beta-naphthol—Its Value in Internal Antisepsis—Betol "Microcidine"—Alumnol—Hydronaphthol—Its Use in Gauze—Oxynaphthoic Acid.

TAR AND ITS PRODUCTS.

IT has long been known that the varieties of tar have antiseptic and preservative properties; hence the use of coal tar for coating wood, and of wood tar for ropes and sacking. Coal tar consists for the most part of a mixture of "aromatic" compounds derived from the hydrocarbon benzene, C_6H_6. They are more or less volatile; many have offensive odours, and act as narcotic poisons. This poisonous action may render them disinfectant when used in sufficiently large quantities. Some coagulate albumen, and are caustic, like phenol. A few are soluble in water, and these are the most powerful physiologically. As far back as 1753 Bishop Berkeley extolled the virtues of tar water for nearly every ailment; but its use is now replaced by more definite preparations.

By treatment with acid and alkaline solutions in succession, the tars are separated into three groups of bodies:—

I. **Hydrocarbons**, such as benzene, toluene, xylene, naphthalene, anthracene, &c. These are neutral bodies, insoluble in water, alkalies, and acids. Most of them, however, can be dissolved, or at least emulsified, by heating with a strong solution of ordinary or resin soap, with or without the addition of alcohol or wood spirit. The dark-brown clear syrup turns white and milky with water, the hydrocarbons being precipitated in minute oily globules, which slowly rise as a scum to the surface, leaving a strongly alkaline solution in the soaps. All these mixtures smell of tar, and are in different degrees antiseptic, but less so than the phenols. They are known in commerce as "neutral tar oils." Specifications for disinfecting powders generally demand their absence, and in fact they are looked upon usually as a detriment, or even as an adulteration, if present in any quantity in disinfectants. The hydrocarbon *benzene*, C_6H_6, and its higher homologues *toluene*, C_7H_8, &c., have no antiseptic value. The derivatives of thiophene (a compound usually present in crude benzene), C_4H_4S, have been used for skin diseases.*

Naphthalene, $C_{10}H_8$, and *anthracene*, $C_{14}H_{10}$, when pure are white crystalline solids of greasy feel and tarry odour, slowly volatile, insoluble in water, and feebly antiseptic. Naphthalene is used as an insecticide, and is sometimes employed locally in scabies as a 10 to 20 per cent. solution in oil. It is to be avoided in cases where large surfaces are exposed, but has been used internally† and as an antiseptic for wounds.‡ Its derivatives will be further considered (p. 177). Naphthalene is at present much used as the basis of cakes or blocks sold very cheaply as "disinfectants" to hang up over sinks and in closets, and to place in the basins of urinals. Some are said to contain "camphor and eucalyptus." The urinal blocks certainly prevent the urinous smell, partly by masking it and partly by retarding the ammoniacal fermentation, but they are of no use as disinfectants. There is a recent patent§ for naphthalene tablets.

"Lauraline" contains camphor and carbolic acid with much naphthalene.||

Petroleum may here be incidentally mentioned, although it consists mainly of the paraffin series of hydrocarbons, chiefly hexane, C_6H_{14}. It has long been used as an insecticide in horticulture.

* *Répertoire de Pharm.*, 1892, p. 157. † *Amer. Journ. of Pharm.*, 1834, p. 645.
‡ Squire's *Companion*, 1890, p. 289. § No. 5,036, 1892.
|| *Chem. and Drug.*, Sept. 3, 1892.

II. **Phenols** or so-called "tar acids," carbolic, cresylic, &c. They are hydroxy-derivatives of the aromatic hydrocarbons, and combine with caustic alkalies to form carbolates, &c., soluble in water, from which acids again liberate the phenol. The series include phenol, cresol, and higher homologues; the latter are present in the fractions of higher boiling point, and form unstable compounds with alkalies which are even decomposed by water; hence their solutions turn milky on dilution. They are the subject of a large number of proprietary preparations, and will be described further under phenol, cresol, &c.

III. **Basic substances** are extracted from coal tar by treatment with acids. They include aniline, pyridine, quinoline, &c. They are mostly soluble in water, and are discussed more fully in a later section (p. 184).

PHENOL OR CARBOLIC ACID.

Phenol, $C_6H_5(OH)$, is the simplest member of the group of phenols or hydroxy-benzene derivatives, and is commercially known as carbolic acid. The phenols all contain hydroxyl united to the "aromatic" nucleus or benzene ring of carbon atoms, and are more or less antiseptic. Most of them coagulate albumen, and are therefore styptic; they are poisonous in different degrees, and thus, if in sufficient quantity, may be true disinfectants. They are mostly of sparing solubility in water, which militates against their general use; they easily dissolve in alkalies and alkaline earths, forming substitution compounds usually called carbolates. These compounds are alkaline, odorous, and somewhat caustic; acids, even carbonic, render their solutions turbid, separating the phenols as an oily layer if the solution is moderately concentrated. Such substances, made with lime or magnesia, constitute a number of the "disinfecting powders," which slowly give off the phenols on exposure to air, leaving behind the inert carbonates of lime and magnesia. The earthy bases then only act as a vehicle, and any undue excess of them must be considered as an adulteration. The pure compounds are not used, as they are deliquescent, caustic, and too rapidly soluble. The powders are usually valued and sold as containing a stated percentage of the phenol, &c. Many so-called disinfecting powders now in the market are supposed to contain 15 per cent. of phenol, when in reality they possess only a trace. "A 15 per cent. carbolic acid disinfectant powder, free from tar oils and sulphuretted hydrogen" (*i.e.*, not made from gas-lime), is a common form of specification for this class of disinfectant.

A striking example of the absolute necessity for carefully examining all such powders before use is furnished by the recent exposure of the "Victoria Carbolic Disinfectant Powder." Dr. Barwise found in an epidemic of typhoid at South Wingfield in 1892 that "excreta well mixed with the powder and buried" polluted the drainage, so that the infection was carried to a large number of people lower down the hill. Although the powder was stated to contain 15 per cent. of carbolic acid, an analysis showed that it had barely any odour of carbolic acid and only the merest trace of tar oil, and there was no weighable quantity of carbolic acid. Moreover, even the best powders deteriorate on exposure to air, and may become inert. Phenol itself is prepared from tar distillates, and in the crude state is a dark oily liquid containing also the higher homologues, cresol, xylol, cumol, and cymol, besides neutral tar oils of less disinfecting power. "Synthetic" carbolic acid (made from benzene), and free from cresol, &c., has been sold, but its price is somewhat prohibitive. Pure phenol forms colourless crystals, turning red in the light. It melts at 41° C. and boils at 181·5° C., and therefore is not easily volatile. It can be volatilised more rapidly by melting and then dropping on to a heated shovel—not too hot, or it is liable to catch fire (*Calvert*). The vapour is apt to cause severe headache, giddiness, and nausea. A small quantity of water liquefies the crystals, forming a hydrate, which, however, when added to more water, only dissolves to the extent of 1 in 15, the rest generally at first floating as an oily layer, although it is slightly heavier than water (specific gravity, 1·065). Hence it must be made into a solution for use by mixing with excess of water and agitating until dissolved.

It is certainly antiseptic; but as to its disinfecting power, opinions are very diverse. M'Dougall and Calvert extolled it above other disinfectants; but the latter observer, though he states that 1 in 200 prevented the putrefaction of beef juice for six days, yet acknowledges that when added in that proportion to already putrid beef juice or egg albumen, it had no effect on the organisms present. The vapour also produced no effect during twenty-four hours on vaccine lymph.

Miquel asserts that the vapour of phenol "after fifteen or twenty days of action at 20° C. is absolutely incapable of destroying the vitality of bacteria," and that 3·2 grammes of phenol is required to prevent growth in a litre of beef tea.*

Pasteur and Lister have strongly advocated its use in surgery where antiseptic action is mainly aimed at. Phenol was extensively tried by Crookes under the sanction of the Cattle Plague Commission. His report estimated its value in destroying the infectious matter as very high (1867).

Koch remarks † that "carbolic acid also kills if of considerable strength and acting for a long period." He also observed that solu-

* *Les Organismes*, 1883, p. 290.

† *Mittheil. a. d. K. Gesund.*, 1881, vol. i., p. 234.

tions of carbolic acid in oil do not possess the same disinfecting power as those in water. This is important, in view of the frequent use of carbolised oil in surgery.

When disinfection is required to be completed in less than twenty-four hours, which is generally the case, Wolffhügel and Von Knorre find carbolic acid useless.*

In Koch's later experiments, silk threads with anthrax spores were placed in carbolic solution of various strengths. A 5 per cent. solution killed the spores in two days, whilst sporeless bacteria, as those from fresh blood, were killed by 1 per cent. solution, but not by ½ per cent. solution, as proved by inoculation. "For safety the strength should be 5 per cent. or even more to kill in twenty-four hours." "As an antiseptic, phenol solution 1 in 850 entirely prevented the development of anthrax spores, 1 in 1,250 caused marked hindrance. Other bacteria are less affected. The vapour at ordinary temperatures, even when allowed to act for six weeks, had not the slightest effect on spores, but at 55° C. many were destroyed in half an hour. After three hours there was very little germinating power, after five or six all were killed. Other disinfectants act similarly at high temperatures."† (See p. 139 for Ratinoff's comparison of phenol with mercuric chloride, &c. His effective strength is 1 in 400.)

Klein observes that phenol (1 in 400 or 500) in nutrient solutions has a decided restraining power, but he emphasises the fact that the spores are only "stunned," not killed; for, if removed and inoculated into an animal, they recover and rapidly cause death. He continues, "as is obvious, according to the nature of the bacillus, the strength of the solution, and the time of action, the result varies. For instance, mature *B. anthracis* is killed by 5 per cent. phenol in five minutes, but is not injured by 1 per cent. in five minutes."

Crookshank obtained favourable results on the tubercle bacillus. Patients whose lungs were tuberculous have been benefited by inhalations of carbolic vapour.‡

As to the typhoid bacillus, it is so resistant to phenol that the isolation of this organism is effected by growing in a carbolised culture which kills other germs, but has no action on it.§ It is grown in tubes of gelatine by adding to each 10 c.c. of the nutrient medium, 4 or 5 drops of 1 in 20 per cent. phenol. Cassedebat at Marseilles found that several other organisms offered quite as much resistance to phenol as the typhoid bacillus itself.‖ Yet Dr. Cameron recommends

* *Journ. Soc. Chem. Ind.*, June 29, 1882.

† *Mittheil. a. d. K. Gesund.*, Dec. 3, 1881. ‡ *Bacteriology*, 1887, p. 151.

§ Chantemesse and Widal, *Gaz. Hebdomadaire*, 1887, p. 146.

‖ *Ann. Inst. Pasteur*, Oct. 25, 1890.

a 5 per cent. solution of carbolic acid for the "decomposition" of typhoid stools;* and even more recently Dr. Gover, in his report to the Director-General of Prisons, asserts that "Carbolic acid is the most certain and powerful of the numerous substances used as antiseptics and disinfectants."

The value of phenol may be summed up as follows:—

1. In a strength of 1 in 400 it is a powerful antiseptic, restraining putrefaction when started, and preventing it for a long time when not commenced, but in this respect it is far inferior to mercuric chloride.

2. To actually kill bacteria it requires the high strength of 1 in 20, and even this has not a certain action with all organisms, nor does it kill the spores of such as anthrax. Therefore it is not a satisfactory disinfectant.

3. It does not absorb sulphuretted hydrogen nor ammonias, hence it is not a deodorant.

4. Its persistent odour is a decided disadvantage, as the smell remains even when the quantity is utterly insufficient.

5. For treatment of sewage it is a failure, even in proportions practically impossible. Moreover, it renders the material useless for manurial purposes. In Japan, after a cholera outbreak in 1882, the Government instituted some experiments to elucidate this point, and clearly showed that "a solution of 0·05 gramme of phenol in 100 c.c. of water weakened the germinating power of the seeds, and with a solution of 0·1 per cent. only one-third of the possible seeds germinated, and in all cases the acid delayed the process of germination."

6. In surgery it is of considerable value. Lister has recently pointed out that it has a powerful affinity for the epidermis, penetrating deeply into its substance, and mingling with fatty matter in any proportion, whereas mercuric chloride required a special cleaning of the skin, as it could not penetrate in the slightest degree into anything greasy. It is free from the danger of mercurial poisoning, but if used too strong it may itself be absorbed and cause dangerous symptoms. For aseptism (prevention) as against antiseptism (cure) in surgery it has, therefore, a distinct field of usefulness.

Carbolic acid is still in high favour with different Governments and medical associations. Thus the recent suggestions made by the Society of Medical Officers of Health are as follows:—

1. For the air of sick rooms: sheets are suspended and saturated with carbolic solution or chloride of lime.

2. For matters passed: ferrous sulphate is added.

* *Brit. Med. Journ.*, 1890, p. 376.

3. All utensils should be washed in carbolic solution.

4. Linen should be treated with the same.

5. Ambulances and steamers should be cleansed with carbolic solution.

The solution recommended is a $\frac{1}{4}$ pint of carbolic No. 4 (a pure liquefied acid containing about 90 per cent. phénol) to a gallon of water.

These recommendations are open to the criticism that :—

1. The prescribed solution which only contains about $2\frac{1}{2}$ per cent. to 3 per cent. of phenol is only half the strength specified by Koch and others as capable of killing mature germs, and far below that required to destroy spores.

2. The odour from a suspended sheet is liable, as before mentioned, to cause headache and nausea, and it is very improbable that such a method of application does more than partially disinfect the air, even if the carbolic solution is a saturated one.

The Commissioners of Inland Revenue in 1892, in an investigation for the Board of Trade, state in their report, "That nearly every liquid disinfectant on the list was found to be inferior to an equal weight of the carbolic acid powder." The Committee decided to adopt as standards a solution containing 80 per cent. of carbolic acid, and a powder containing 20 per cent. This is practically Messrs. Calvert's strength for their liquids No. 4 and 5. Their powder is guaranteed to contain 15 per cent. of carbolic and cresylic acids.

In the Clerkenwell Vestry district where carbolic acid is distributed free to ratepayers, it is bought on the following specification :—

"(1) 95 per cent. of clear carbolic acid fluid, free from tar oils and sulphuretted hydrogen; (2) 15 per cent. carbolic disinfecting powder, with same proviso; (3) 70 per cent. carbolic acid dissolved in caustic soda, also free from tar oils and sulphuretted hydrogen."

In Russia, carbolic acid seems to be the chief, if not the only, disinfectant employed by the officials. In that country the slightly active 50 per cent. to 60 per cent. crude acid has been officially prescribed, whereas the German law properly orders the use of crude 100 per cent. acid, which consists of the really active phenol unmixed with valueless tar oils.*

The Berlin administration order solutions of two strengths—"strong," consisting of 1 part pure phenol to 18 of water; and "weak," 1 to 45 parts.† The same regulation points out that fumigation by means of aromatic substances is of no value in disinfection.

* *Pharm. Zeitung.*, Aug., 1892. † *Polizei Verordnung*, Feb., 1887.

The Belgian Government order 2 or 3 per cent. to be mixed with excreta, under the same conditions as in this country.

Carbolic Powders.—In many cases the base of the powder consists of slaked lime, but the "carbolate" of lime, which is formed in this way, only slowly gives up its phenol. One of the oldest forms is "M'Dougall's Disinfecting Powder," prepared by adding crude carbolic acid to impure sulphite of lime obtained by passing sulphurous acid over ignited limestone. The sulphite of lime in this powder is added to absorb sulphuretted and phosphuretted hydrogen. It dissolves readily in water, so that there is no danger of choking drains or appreciably increasing the quantity of solids in the sewage. For fumigating purposes the powder is mixed with water in an ordinary zinc pail, preferably a wooden or earthenware receptacle, adding a little sulphuric acid. A "sewage carbolic acid" of 25 per cent. strength has been advocated for use in conjunction with the powder and with lime, in the proportion of 1 gallon of carbolic acid, 10 lbs. of disinfecting powder, 10 bushels of lime, and 100 gallons of water. This mixture is stated to be sufficient for 50,000 gallons of sewage, which is rendered imputrescible, and all smell is removed. If the powder contained 15 per cent. carbolic acid, the total amount present in the sewage would barely amount to 8 parts per million, and this quantity is totally inadequate for sterilisation.

Allen* gives the following as the composition of a sample of the base of M'Dougall's powder after extraction of the carbolic acid :—

Silica,	2·4
Alumina,	3·4
Ferric oxide,	Traces.
Lime,	46·5
Magnesia,	0·3
SO_2,	7·5
SO_3,	29·2
CO_2 (water and undetermined matter),	10·7
	100·0

Corfield remarks: "Carbolates of lime and magnesia and sulphites, such as M'Dougall's powders, merely assist in delaying decomposition, but do not prevent it ultimately."

"Calvert's Carbolic Powder" is guaranteed to contain 15 per cent. of carbolic and cresylic acids. It is prepared by adding crude carbolic acid to the residue left from the manufacture of aluminium sulphate from shale or kaolin. The following is an analysis of the base after extraction of the phenol :—†

* *Commercial Organic Analysis*, 1886, vol. xi.

† *Analyst*, 1878.

Silica,	67·4
Alumina,	28·0
Ferric oxide,	Trace.
Lime,	0·8
Undetermined,	3·8
	100·0

"Mayor's Disinfecting Powder" has also a silicate base and "contains 15 per cent. carbolic acid." The advantage claimed is that "the action of the acid is entirely free to perform its work of disinfection, none of it being absorbed and retained by the base."

"Phenolith" contains the phenols and cresols of tar with infusorial earth (siliceous), sawdust, &c.;* the patent also includes the use of mixtures of phenol and boric acid for preserving meats, hides, &c.

Tweedie † patented a mixture of phenol, turpentine, and camphor with "any dry vehicle."

The carbolic powders of commerce are generally coloured pink or brown by aurin or ochre.‡

It is now generally admitted that road disinfection by carbolised lime is of little value, since the volume of air and earth is too great for any real disinfection to be effected in this way. Local authorities, however, in many districts generally regard such treatment with favour.

In surgery the following preparations containing phenol are used:—

Carbolised Solution, 1 or 2 of phenol in 40 of water; **Carbolised Oil,** same strength used as a dressing (Koch states that it has much less power than the solution); 2 per cent. solution for hypodermic injections and as spray for erysipelas;§ 5 per cent. injection for anthrax.‖

Carbolised Gauze (Lister).—Phenol, 1; resin, 4; paraffin, 4; melted together and the gauze dipped in this mixture. Vaseline is sometimes added to give pliancy. Absorbent gauze is made with phenol, glycerine, and dilute alcohol, and is stated to be more powerful than the ordinary gauze. At the temperature of the body the phenol is slowly given off, causing an antiseptic vapour to envelop the wound.

Carbolic Wool should contain 5 per cent. phenol. Five commercial samples analysed were found to contain 1·06, 1·07, 0·69, 0·25, 5·08 per cent. respectively, showing that they were either badly prepared or had lost their strength by careless keeping. Carbolic wool, like all articles containing volatile medicaments, should be preserved in perfectly air-tight vessels.

* Holtz, Patent No. 5,193, 1878. † Patent No. 17,042, 1888.
‡ *Journ. Soc. Chem. Ind.*, 1889, p. 913.
§ *Brit. Med. Journ.*, 1886, vol. xi., p. 947. ‖ *Ibid.*, p. 601.

Danger of Phenol in Surgery.—According to Lowe, the effect of the contact of phenol with any large surface of the lower part of the body is apt to be fatal, but it has often been applied to the arms with impunity. Gosselin made a series of experiments bearing mostly on the action of phenol on the living body, as in surgical operations, using 1 to 5 per cent. solutions in dilute alcohol upon blood circulating through a membrane, and found that the circulation of the blood through the capillaries was arrested, in direct proportion to the strength of the solution. He supposes that the phenol coagulates the blood like a caustic, first (?) acting as a germicide, then "as a semi-caustic or astringent."

Carbolic Soaps are made in great variety. They should contain about 8 per cent. or more of phenol, but many contain not more than 1 per cent. Woodhead* and Cameron † have pronounced against their use. They are largely used in washing, and contain tar oils, naphthalene, &c., with varying amounts of phenol. Their value is more than doubtful as disinfectants, though they certainly are potent against insects.

Carbolic tooth powders are also made. They are antiseptic, but are not very pleasant.

A few other preparations remain to be mentioned. There are a large number of patents for mixing "phenoloids," containing more or less carbolic acid, with peat fibre, ground blast-furnace slag, cinders, sawdust, and other inert absorbents. They present no special advantage.

"Disinfectol" is an oily blackish liquid containing resinous soaps, soda, and compounds of phenol dissolved in hydrocarbons introduced into commerce by Loewenstein. It mixes readily with water, forming an emulsion. Several preparations of this type, tar products dissolved in alkalies, will be described under *Cresol.*

"Rademann's patent" is pure phenol melted on a water bath, cooled quickly and stirred. The small crystals that separate are mixed with 10 per cent. of pure boric acid and pressed into cakes. He claims that this form is not injurious to the skin. ‡

An "Aromatic Carbolic Liquid," much used in Russia, is a tincture of phosphorised phenol with musk, oil of wintergreen, &c.§

Phenol has been used internally in capsules and solutions to arrest fermentation, but opinions as to its value are conflicting. Betol has been found far preferable for this purpose (*q.v.*).

* *Brit. Medical Assoc.*, Edinburgh Meeting, 1888; see under HgI_2, p. 142.

† *Sanitary Record*, 1890.

‡ *Journ. Soc. Chem. Ind.*, 1889, p. 131.

§ See *Chemist and Druggist*, 1888, p. 32; A. H. Allen, in the *Brit. and Colonial Druggist*, 1887, p. 364; and *Journ. Soc. Chem. Ind.*, 1887, p. 761.

Vallin points out* that using 1 litre per day of a 5 per cent. solution of phenol for adding to excreta, &c., 50 grammes of phenol, or nearly 2 ounces, would be required daily for each patient. This would be a large item of expense in a hospital, and even in those devoted to infectious cases, the consumption of carbolic acid is seldom a fraction of this quantity.

HALOGEN DERIVATIVES OF PHENOLS.

The substitution in phenol of one or more of the hydrogen atoms by chlorine, bromine, or iodine can be easily effected by the action of these elements in the presence of water. Such substitution seems to increase the antiseptic power, but at the same time it causes the compounds to become much more unpleasant in odour, diminishes their solubility, and makes them more corrosive and very irritating to the eyes.

Parachlorophenol, C_6H_4OHCl, is a crystalline body, m.p. 33° C., soluble in spirit, ether, and fixed oils, and practically insoluble in water. It has been used as an ointment (2 to 3 per cent. with vaseline) in the treatment of erysipelas and lupus.

A. Spengler also uses a 2 per cent. solution as an effective disinfectant for the sputa of phthisical patients.†

Hargreaves ‡ manufactures "chlorophenols by the action of chlorine or hypochlorites on carbolic acid, tar, &c., mixed with absorbents to form a disinfectant."

Tribromophenol, $C_6H_2Br_3OH$, is a white or brownish crystalline volatile substance, very insoluble in water, obtained by adding bromine water to phenol solution, when it falls as a white precipitate. It is interesting as a delicate test for phenol, and as a way of separating it from cresol, since tribromocresol is liquid. Both compounds have disagreeable odours, and are antiseptic, but too insoluble to be of much use.

Iodophenols are similar, but very unstable, being easily decomposed by light. Experiments with these compounds generally have not been favourable.

SULPHONIC DERIVATIVES.

Concentrated sulphuric acid acts on almost all the phenols, forming compounds soluble in water, and yielding soluble and crystallisable salts which are usually inodorous. In most cases two or more isomeric acids are formed, differing in characters. When phenol is so heated, the ortho- and para-acids are formed. Their solubility, absence of

* *Désinfectants*, p. 385. † *Sem. Med.*, Oct. 31, 1894.
‡ Patent No. 18,460, 1889.

odour, and the comparative harmlessness of the salts, have directed much attention to them as antiseptics. Their formation may be typified by the following equation—

$$C_6H_5OH + SO_2\langle{}^{OH}_{OH} = H_2O + SO_2\langle{}^{C_6H_4OH}_{OH}$$

The salts in commerce were formerly called sulphocarbolates, or phenyl-sulphates. The sodium and zinc salts are in the British Pharmacopœia. They easily crystallise and are inodorous.

Sodium Paraphenol Sulphonate ("Sulphocarbolate") is a mild antiseptic, and is used in medicine for "disinfecting the intestinal tract." It is probably broken up in the body into phenol and acid sodium sulphate, each of which exerts an antiseptic action.

$$C_6H_5NaSO_4 + H_2O = C_6H_5.OH + NaHSO_4$$

The **Zinc Salt**, $Zn(C_6H_4O.HSO_3)_2$, has in addition the antiseptic and astringent properties of zinc.

Vigier * who has studied the relative antiseptic value of the three isomeric phenol sulphonic acids, asserts that the ortho-acid is the most energetic.

Sozo-iodol, a derivative of one of the di-iodophenols, obtained by combining sodium paraphenolsulphonate with iodine, is sparingly soluble in water, but easily soluble in alcohol or in glycerine. Its iodine is liberated by the action of light. It has been used locally in nasal and pharyngeal disorders, and in parasitic skin affections.†

Sozo-iodol-mercury contains 31·2 per cent. mercury and 38 per cent. iodine.‡ Draer has studied the action of both these compounds on the cholera bacillus.§

Aseptol is an ill-defined mixture of phenyl ethers and sulphonated phenols prepared by the action of sulphuric acid on phenol in the presence of alcohol.||

Sozal is described by Dr. Schaerges of Berne, as aluminium paraphenolsulphonate $(C_6H_4OHSO_3)_6Al_2$. "It is a bactericide having the advantages in surgery that corrosive sublimate possesses, without its toxicity. It occurs in small crystals which have a strong astringent taste and only a slight odour of phenol. The salt is readily soluble in water and glycerine, and also in spirit." If these high claims are justified it will be of great value in surgery.

* *Journ. Pharm.*, [5], vol. xi., pp. 145, 214.
† *Brit. Med. Journ.*, 1889, vol. xi., p. 42.
‡ *Pharm. Journ.*, 1889, p. 577.
§ *Am. Journ. Med. Sci.*, March, 1894.
|| Serrant, *Jahresbericht f. Thierchemie*, 1885, p. 499.

Hueppe describes a sulphonic derivative of phenol-orthophenyl sulphonic acid, which is less caustic and more antiseptic than the parent substance.* Kaemar † covers the use of certain sulphonates as disinfectants.

Benzene-Sulphonic Acid, $SO_2(OH)C_6H_5$, an acid liquid obtained by adding benzene cautiously to sulphuric acid with 30 per cent. of sulphuric anhydride, is patented by Giles and Shearer ‡ as an antiseptic, disinfectant, and deodoriser. They minutely describe its preparation and purification. It is a question whether it would be superior to sulphuric acid alone. It is the source of synthetical carbolic acid (p. 150).

There are numbers of other sulphonic acids, but at present they have no special interest as disinfectants, but it will be noted that sulphonating reduces the poisonous action of both the hydrocarbons and the phenols without destroying their disinfecting properties. Further comparative experiments with known organisms with the same weight of compound with and without a "sulphonic group" would be of value. The sulphonates of hydrocarbons containing more than one closed chain should be especially active.

Phenyl-substituted Fatty Acids.—Klein § showed that phenyl-propionic acid has a more powerful antiseptic action on anthrax bacilli than phenyl-acetic acid. J. Parry Laws ‖ has further shown that phenyl-butyric acid restrains the growth of anthrax bacilli when present in the proportion of 1 in 2500, and that it kills the sporeless bacilli when they are exposed for thirty minutes to a solution of 1 in 1000, or for ten minutes to a solution of 1 in 700.

The following table shows the relative value:—

	Phenol.	Phenyl-Acetic Acid.	Phenyl-Propionic Acid.	Phenyl-Butyric Acid.
Restraining Power, .	1 in 700	not determined	1 in 1900	1 in 2500
Killing Power, .	1 in 200	1 in 450	1 in 600	1 in 1000
Length of Exposure, .	45 mins.	30 mins.	30 mins.	30 mins.

Thus they increase in antiseptic power with increase of molecular weight. Duggan ¶ has shown that the converse is true in the case of the fatty acids when tested on *B. subtilis*. His results give—

Formic Acid.	Acetic Acid.	Propionic Acid.
7 per cent.	9 per cent.	12 per cent.

* *Brit. Med. Journ.*, 1891, p. 1107; also on the Sulphocarbolates see *Journ. Soc. Chem. Ind.*, 1889, p. 912.

† Patent No. 3933, 1892.

‡ Patent No. 14,864, 1887.

§ *Thirteenth Annual Report L. C. B.*

‖ *Chem. News*, 1895, p. 15.

¶ *Am. Chem. Journ.*, vol. vii., p. 62.

These percentages almost exactly correspond to their relative molecular weights, and consequently to their relative saturating power of bases.

CRESOL OR CRESYLIC ACID AND THE HIGHER PHENOLS.

The higher phenols may be regarded as derivatives of phenol in which one or more of the hydrogen atoms of the "benzene ring" have been replaced by methyl or other fatty radicles. These substitution products form a homologous series of progressively increasing density and boiling point, of which the following are known :—

TABLE OF THE PHENOL SERIES.

Systematic Name.	Commercial Name.	Empirical Formula.	Rational Formula.
Phenol, . .	Carbolic Acid.	C_6H_6O	$C_6H_5 . OH$
Methyl-Phenol, . .	Cresol or Cresylic Acid.	C_7H_8O	$C_6H_4(CH_3) . OH$
Dimethyl-Phenol, .	Xylenol.	$C_8H_{10}O$	$C_6H_3(CH_3)_2 . OH$
Trimethyl-Phenol, .	Cumenol.	$C_9H_{12}O$	$C_6H_2(CH_3)_3 . OH$
Tetramethyl-Phenol, .	Durenol.	$C_{10}H_{14}O$	$C_6H(CH_3)_4 . OH$

Of all, except the first, several isomerides are known. They are all antiseptic; as to their relative values the authorities differ, but all agree that there is not much difference in power between phenol and the cresols. All dissolve in strong alkalies, giving soapy antiseptic solutions, but the compounds of the higher members of the series are decomposed by water, yielding milky emulsions which slowly deposit the oil. They are less poisonous than phenol, and are classed together as phenoloids.

A mixture of these bodies from which phenol had been separated formerly constituted a waste product of the carbolic acid manufacture under the name of "creosote oils," and was used for preserving timber, &c. They are difficult to separate by fractional distillation, and now in various mixtures they are largely used for disinfectants under fancy names, such as Creolin, &c. Some of them contain also the hydrocarbons, or neutral tar oils.

The waste gases from blast furnaces, formed by the destructive distillation of the upper layers of coal and bituminous iron ore, when cooled deposit large quantities of empyreumatic products, from which is manufactured on a large scale in Scotland the mixture called "blast-furnace creosote oil" for creosoting timber. It contains 20 to 35 per cent. of phenoloid bodies soluble in caustic soda, the coal-tar creosote oil made in London only containing 5 to 10 per cent. Watson Smith found one sample of the phenoloids obtained from blast-furnace tar to contain only 1·33 per cent. of phenol, having a boiling point of 182° C., while those obtained from Lancashire tar contained 65 per cent. of crystalisable carbolic acid (the phenol may have been previously separated from the former). The fraction that would contain cresol had 4·5 per cent. of phenoloids, and the fraction boiling from 210° to 230° consisted of a mixture of the xylenols and cresols. The "creosote oil" is treated with caustic soda, the insoluble hydrocarbon oils separated, and the soda compound decomposed by the waste gases from the furnace. Sodium carbonate is formed, setting free the phenoloids. The carbonate of soda is treated with lime, giving fresh caustic soda for another quantity of oil. The crude phenoloids are distilled, yielding the "creosote" of commerce. It contains about 1 to 2 per cent. of phenol, a large quantity of cresols, and a smaller quantity of the higher homologues. The oxyphenols, similar to those found in wood creosote, are present only in very small quantities.

Schulze* has found in coal-tar cresols 40 per cent. meta-cresol, 35 per cent. ortho-cresol, and 25 per cent. para-cresol.

When fresh, creosote is almost as colourless as water, but it gradually darkens on keeping, slowly forming tarry products of less potency. It is quite as good an antiseptic as crude carbolic acid, and has not such a caustic action on the skin.

Buchholtz states that the least quantity of creosote that would prevent bacteria from developing in Pasteur's fluid† was 1 in 2,000.

Creosote has a strong power in checking fermentations, hence its name (κρεας, flesh ; σωξω, I keep). Although only slightly soluble in water, its solution has preservative powers. It has been used for preserving organic putrescible liquids, and for keeping meat, &c., but its taste and odour are more unpleasant than those of the "creosote" from wood tar. It is administered internally to check fermentation in the stomach, but is a dangerous and unpleasant remedy, as it suspends digestion. Inhalations of coal-tar creosote vapour have no effect on phthisis, but are useful for cases of fœtid expectorations arising from bronchiectasis (*Chaplin*).

With reference to the antiseptic power of these creosotes, it has been asserted with some show of probability that mixtures have often been found to have more energy than any of the ingredients used singly. This may be due to the fact that different species of organisms have quite distinct susceptibility to different agents. Lacroix Hunkiabeyendian states that a mixture of ortho-, meta-, and para-cresol exerts a stronger action upon microbes (*Staphylococcus*

* *Ber. d. Chem. Gesells.*, vol. xx., p. 410.

† 10 grms. sugar, 1 grm. ammonium tartrate, and ½ grm. potassium phosphate in 100 c.c. of distilled water.

pyogenes aureus, *Tetragonus prodigiosus*, and the bacilli of cholera and typhus) than any of the pure compounds used singly.* As the solubility of the cresols in water is increased by the presence of a small quantity of the sodium compound, there is therefore some excuse for the complicated nature of many of these patent specifications.

Bacillite.—Hope† treats the sewage, &c., in suitable tanks with a current of "antiseptic steam" till deodorised (?). The antiseptic steam is generated from a solution of 1 gallon of "bacillite" (composed of cresylic oil 8 parts, sulphur ½ part, sodium hydrate 2 parts, sodium carbonate 1 part, resin 2 parts, boiled for two hours) "or other suitable disinfectant," in 200 gallons of water. "This quantity is sufficient to disinfect 4,000 gallons of sewage." But it will be noticed that most of the ingredients are non-volatile, and would not pass over with the steam; in fact, the soda would hinder the cresol from volatilising. It would seem better to add the "bacillite" to the sewage and then pass in steam.

Lysol, prepared by Schulke and Mayr, of Hamburg, is a brown transparent syrupy fluid which turns litmus blue "but contains no free alkali." The ash is about 6 per cent. and is mainly carbonate of potash. Lysol contains about 51 per cent. of volatile oils, consisting of higher phenols, and no carbolic acid. It is miscible with water in all proportions, hence it can be used of any strength. Dr. Schottelius‡ gives the minimum effective strength of the following in per cents.:—

	Lysol.	Kreolin.	Phenol.
Staphylococcus pyogenes aureus, .	0·3	1·2	2·5
Typhus bacillus, ...	1·2	...	...

Pearson's kreolin (Jeyes) was used. Lysol of ·33 per cent. destroyed in twenty minutes cholera and typhus bacilli.§ The English patent for lysol|| describes it as "tar oil mixed with a fat or fatty oil, and saponified with alkali in presence of alcohol. Homogeneous and soluble."

Lysol is thus a mixed disinfectant produced by dissolving in fat, and subsequently saponifying, with the addition of alcohol, the fraction of tar oil which boils between 190° and 200° C. (practically the cresols, excluding almost all the less soluble xylenols, &c.). It is a brown, oily-looking, clear liquid, with a feebly aromatic creosote-like odour. It contains 50 per cent. of cresols and is miscible with

* *J. de Pharm. et de Chemie*, 1892.

† Patent No. 17,924, 1891.

‡ *Münchener Med. Wochenschr.*, 1890, No. 20.

§ Engler, *Dingl. pol. J.*, vol. cclxxviii., pp. 26 to 78; *Journ. Soc. Chem. Ind.*, 1890, p. 1,136.

|| Damman, Patent No. 1,017, 1890.

water to a clear saponaceous, frothing fluid. It shows turbidity when mixed with hard water from the formation of the well-known precipitate of lime and magnesia soaps, but its disinfectant quality is not impaired thereby. It acts to all intents and purposes as a soap; and seems well adapted for use in surgical operations. Lysol forms a clear solution with alcohol, glycerine, &c.

It removes all dirt, fatty and resinous spots from the skin, as well as from linen, instruments, and the like.* To remove the soapy feeling, the hands may be rinsed in sterilised water, and dried with a sterilised towel.

Gerlach and Simmonds tried it on infected fæces with success. Cramer and others recommend it for surgery. From these reports lysol appears to be an efficient preparation for surgical purposes, but its mode of preparation would seem to make it too expensive for use in large quantities for public disinfection.

Pixol (*Eberman and Raptschewski*) is made by slowly adding a mixture of 3 parts of tar and 1 part of "green soap," heating, if necessary, to 3 parts of a 10 per cent. solution of caustic soda. A clear brown liquid, miscible with water, results. "A 5 per cent. solution has the same power as lysol of the same strength, and is cheaper." The *Lancet*, Oct. 14, 1893, states that this disinfectant was found useless in the cholera wards of the Obrickooski hospital at St. Petersburg. The solution of tar does not kill cholera bacilli, and has only a slight inhibitory power on their growth.

"Pixene" is a preparation of the same class, made by Wheeler from light tar oils. It mixes readily with water.

The real question at issue is—Should a disinfectant be easily soluble in water or not? On the one hand, it is obvious that to penetrate through the envelopes of bacteria requires an agent which is in solution, and therefore diffusible. But Mr. Worrall, the inventor of the Thorncliffe disinfectant, now called "Izal," takes exception to such a conclusion, and claims that "insolubility in water is one of the most valuable properties of this preparation, since when once applied to a part requiring disinfection it is not easily washed away, and therefore fulfils its purpose more effectively."

There is no doubt that emulsions of tar oils have several sources of popularity with the public; they look strong, their odour enables their presence to be felt, and their appearance enables one to judge when they are properly mixed, instead of falling to the bottom of the liquid, like solid disinfectants, or floating on the top and being carried away, like phenol. Moreover, the minute oily globules in these emulsions do slowly dissolve, and exercise a strong inhibitory action

* Engler and Dieckhoff, *Arch. d. Pharm.*, vol. ccxxx., p. 562; vol. ccxxxii., p. 351.

on the germs for long periods of time, so that the sewage may be carried away before it has a chance of conveying infection.

The best of these preparations may be regarded as strongly antiseptic and useful against infection, though it must always be remembered that, as Klein has pointed out in anthrax, Karlinski in excreta of typhus, and Kitasato in cholera stools, the matter apparently disinfected, in which no growth may appear for days, if it be removed to fresh sterilised excreta (*Kitasato*), or inoculated into the blood of fresh subjects (*Koch*, *Klein*, *Blyth*, &c.), will often begin to grow and prove fatal, the spores having been stupefied and not killed.

Here the emulsified and slowly dissolving oil might have a distinct advantage, as, so long as sufficient of it remained, the spores would be prevented from growing.

Another soluble preparation closely resembling lysol is **Tricresol**, introduced by Scherings, of Berlin. It is a mixture of the three cresols found in coal tar—viz., the ortho-, meta-, and para-cresol—"has the advantage over carbolic acid of being non-toxic, and is superior to other cresol compounds in being soluble in cold water." Tricresol is synthetically prepared from toluene, $C_6H_5(CH_3)$. According to Professor Gruber, water dissolves from 2·2 to 2·5 per cent. of tricresol; but a 1 per cent. solution only is required in surgery, "that being equal in antiseptic power to a 3 per cent. carbolic acid solution." * Tricresol is at first perfectly colourless, has the odour of creosote, and boils from 183° to 205° C., the fractions being—

	Below	183°	=	...	per cent.
183°	,,	185°	=	4·3	,,
185°	,,	190°	=	5·3	,,
190°	,,	195°	=	56·0	,,
195°	,,	202°	=	34·4	,,
				100·0	

"As phenol boils at 183°, and the cresols between this temperature and 202°, it follows that phenol, xylenol, and the other members of this series are practically absent. The specific gravities of the fractions are 1·042 to 1·049 at 20° C. It is stated to contain 40 per cent. of meta-, 35 per cent. of ortho-, and 25 per cent. of para-cresol." The following table gives the physical properties of these three compounds :—

	Boiling Point.	Melting Point.	Spec. Gravity.	
Orthocresol, . .	191°	30°	1·0053	Crystalline.
Metacresol, . .	203°	4°	1·05	Liquid.
Paracresol, . .	202°	36°	·996	Prisms.

* *Pharm. Zeitung*, 1894, No. 4; 1895, No. 97; *Archiv. f. Hygiene*, vol. xvii., p. 618.

Von Heyden asserts that the higher phenols are rendered soluble by mixing with sodium salts of acids like benzoic, salicylic, &c.* The *British Medical Journal*, 1891, p. 414, states that a mixture of soluble tar products with sodium salicylate and water under the name of "resole" made a solution which was very effective. Engler and Dieckhoff have recently made an exhaustive examination of those cresol preparations which are soluble in water.†

Among the emulsions containing cresols the more important are Jeyes' disinfectant and creolin.

In the first patent ‡ " resin and creosote or naphthalene are heated with soda." Patent No. 5,249, 1877, proposes " coal-tar distillates above a 1,000 specific gravity" (this would include phenol and a large number of other bodies) "to be mixed with resin, soda, and vegetable oils" (giving a resin soap and a fat soap) "so as to make a milky emulsion with water." An anthracene salt (?) or naphthalene also may be added. This very complex mixture seems to have been the original form of "Jeyes' disinfectant," a dark brown, syrupy liquid which gave a brownish-white milk easily diffused through water, a large proportion of the oils, &c., remaining quite insoluble. In its original form it had an unpleasant smell and left dark tarry stains on the flooring, &c. It has since been considerably improved, containing more of the cresols, and not so much of the naphthalene and neutral tar oils.

Another application § melts together resin, naphthalene, and pitch, mixes with soda or potash, and makes into cakes, which are broken up and dissolved in water when wanted. Unless there were a great proportion of alkali, the "solution" in water would be very slow, and would require a great deal of stirring.

It may here be mentioned that potash, the basis of lysol, saponifies more rapidly than soda, and the product, being a soft soap, is more soluble than the hard soap made with soda. The mixture of the two alkalies is therefore advantageous.

For drains, &c., the fluid is directed to be mixed with 50 parts of water. It is also recommended for gargles (a teaspoonful to a pint), as spray, and for fumigation; here it would have the same limitations as other preparations of slight volatility.

That Jeyes' fluid and creolin are non-poisonous, or at least far less so than phenol, is proved by a recent case in London where a woman took 4 ozs. of Jeyes' fluid with the object of committing suicide, but was not injured. The *British Medical Journal*, Jan. 11, 1890, also cites a case in which a man took nearly 9 ozs. of creolin with the same object. "He soon became unconscious, but was

* Patent No. 9,103, 1890.

† *Archiv. der Pharm.*, No. 232, pp. 351-365.

‡ No. 4636, 1877.

§ Patent No. 2,669, 1882.

discharged, cured, in the third week after admission." Such a result would have been impossible with carbolic acid.*

Creolin is a more refined preparation by the same makers. It contains mainly the cresols as alkaline salts, without phenol or other tar products. It is a brownish-black alkaline syrupy liquid of empyreumatic odour, giving a soapy emulsion with water.†

The bacteriological reports on these two fluids are very favourable. Dr. von Esmarch in Koch's laboratory at Berlin found that "1 per mille killed the cholera bacillus in ten minutes, whereas carbolic acid took four days." Dr. Eisenberg, of Vienna, states that 6 per cent. of it killed even anthrax spores in twenty-four hours, while phenol did not destroy them in a week. "Spores of the hay bacillus, which possess the greatest power of resistance, were killed by 6 per cent. of creolin in six days; phenol failed.

Dr. Washbourn ‡ repeated the experiments of the two previous observers with confirmatory results. He concludes that "creolin is a good antiseptic, certainly superior to carbolic acid in its action on sporeless bacteria, and probably superior also when acting on spores." He finds that 5 per cent. creolin is equal to 1 per cent. of mercuric chloride.

Creolin and Jeyes' fluid have found great favour in hospitals for warm baths in infectious and skin diseases. Their results are certainly very good. But for sewage, fumigation, &c., "disinfection" cannot be maintained, as it is proved by experiments that 5 per cent. is required to destroy all pathogenic organisms, and the cost of this would be almost prohibitive.

Lano-creolin, soaps, gauze, &c., are also made, and "capsules" containing 5 minims each.

"**Smith's Carbolated Fluid**" (Hampton Works, Borough Road, London) turns milky with water, and seems to be of similar nature to the above. So is "Artmann's creolin" (Julius Sommer, Stuttgart) specially used for soaps (Hof & Co., London Agents).

The Strathclyde Chemical Company are manufacturers of a disinfectant which is a residual product of a kind of blackstone shale at the Dorset mines. "This shale is remarkably light, yet it contains oils of a very heavy and volatile character. These oils when distilled are said to possess valuable insecticide and deodorant qualities."§

These shale oils contain a large quantity of the pyridine series of bases to be described later (p. 189).

Essets Fluid is an alkaline solution of higher phenols similar to Jeyes' fluid, giving, like it, a milky emulsion with water. The *Lancet*,

* See *ibid.*, 1891, p. 49, for a confirmatory case. † See *Lancet*, Jan. 5, 1889.
‡ *Guy's Hospital Reports*, vol. xlv., 1888. § *Chemist and Druggist*, 1891, p. 39.

July 1, 1893, pronounces it "an efficient disinfectant and antiseptic." It may be mentioned that the strength of solution recommended to be used for closets, drains, &c., viz., one teaspoonful to a gallon of water, or 1 in 320, is much too dilute to be efficient.

Saprol, introduced by Dr. Nordlinger of Bockenhein, Frankfurt, is a dark brown oily liquid smelling like crude carbolic acid, having a mean specific gravity of 0·990, therefore floating on aqueous solutions.

According to the analysis of Dr. Spindler of Stuttgart, it contains phenol and cresol, 43·0; hydrocarbons, 53·9; pyridine and other bases, 2·8 = 99·7.

When poured into water a separation occurs, the heavier cresols partially dissolving and partially sinking in drops, while an oily scum of the hydrocarbons floats on the liquid. This covering, according to Professor Quincke of Heidelberg, amounts to 0·2 milligramme per square millimetre. Scheurlen* finds that when saprol is thus poured upon water, and left to stand for three or four days, from 33 to 39 per cent. of it dissolves—that is, the greater part of the cresol and phenol, of which it contains 43 per cent. The liquid contained 0·41 to 0·49 per cent. of cresols. He proved that either crude phenol or saprol itself, even if shaken repeatedly for seven days with water, only yielded solutions of 0·45 to 0·51 per cent. of cresols, so that he concludes that 0·5 per cent. is the mean solubility of the cresols, and that the latter, if time be allowed, dissolve just as well when merely poured on water, as when continuously and vigorously stirred. "This fact, applied to the disinfection of fæcal matters, proves that by the use of saprol a mixture of the fæces supersaturated with the disinfectant is obtained." Dr. H. Gross found that the addition of dilute alkalies or acids did not increase the solubility. It is also pointed out that while the uniform coating of saprol entirely prevents contact with the atmosphere, so that no evil-smelling gases can be emitted from the fæces, the usual oxidation process is also checked, while the soluble parts of the saprol gradually penetrate right through the mass.

According to Laser,† a thin layer of saprol kept urine clear, without smell and sterile, for twenty-two days. A thick layer sterilised anthrax cultures in twenty-four hours. Urine, which had been standing under a thin film of saprol for twenty-three days, was filtered and mixed in three glasses with (1) cholera vibrios, (2) typhus bacilli, and (3) *Staphylococcus pyog. aureus*. In all three glasses the micro-organisms were killed. He also made a series of researches with increasing quantities, to ascertain the amount required to disinfect and deodorise urine, and, as a result of his experiments, concluded

* *Archiv. f. Hyg.*, 1893. † *Centr. f. Bacteriologie*, 1892, vol. xii., p. 78.

"that 1 per cent. of saprol is sufficient for the disinfection of fæces and urine."

Scheurlen * confirms these results. It must be remembered that a 1 per cent. solution of saprol is equivalent to about 0·34 per cent. solution of the cresols.

The special claim of saprol is its peculiar physical action—viz., "being a little lighter than water, partially soluble and partially insoluble"—by which it—

1. Forms a complete coating over the substances, so keeping them from the atmosphere, and masking smells.

2. Diffuses gradually and evenly through the putrescent matters, first restraining and then killing the organisms.

3. Acts in less strength (1 per cent.) than phenol (2½ per cent.).

As to cost, it is stated that "1 litre per month, costing 60 *pfennige*, is sufficient for a household of twenty people, or 3 *pfennige* per month per head."

It must be admitted this is a very strong case for saprol. It and lysol are much used in Germany, the former for common, and the latter for surgical purposes. It is to be noted that saprol retards the natural decomposition of sewage by oxidation; unless the excreta be removed quickly they will be liable to grow organisms again, as even with such cheapness it would be difficult and expensive to attain so high a strength as 1 per cent. A similar reservation applies to all this class; they are really more antiseptic than true disinfectants, and their action as deodorants is simply that of a mask.

The presence of pyridine (which is very soluble) must not be forgotten. Neither sulphuretted hydrogen nor ammonias would be effectively absorbed; hence it would be advisable to use one of the chemical absorbents as well.

The flashing point of saprol is 90° to 100° C., about the same as that of phenol, and sufficiently high for safety under ordinary circumstances. Unless heated, a light applied to it does not cause it to inflame.

In some of these preparations containing the higher phenols, ozone is said to be produced when they are exposed to the air.

With Allen's "hygiene disinfecting fluid" this is said to be the case, but as this fluid is recommended to be used at a strength of 1 in 500, and the evidence of all experiments go to prove that 1 per cent. is the lowest effective dilution for any tar preparations, these statements require confirmation.

As to the production of ozone, Dumas † endeavoured to explain the slight deodorant properties of the tars in the light of the experiments

* *Arch. f. Hyg.*, 1893. † *Acad. des Sciences*, July 25, 1859.

of Schönbein on the abundant formation of ozone in air mixed with the vapours of essence of turpentine, but later experiments have shown that in all probability more hydrogen peroxide than ozone is produced by the phenols in the presence of air and moisture.

Izal.—In the process of carbonising coke in close ovens, a tarry oil condenses, which contains some of the higher phenols. From it J. H. Warrall has obtained a clear deep, reddish-brown liquid insoluble in, and of greater density than, water. Its mean boiling point—*i.e.*, it is a mixture—"is considerably higher than that of carbolic acid (400° F.), and it has not the caustic action on the skin as has that antiseptic; moreover, it is non-poisonous to the higher animal life." This insolubility and high boiling point "insures the antiseptic body remaining upon the part requiring disinfecting after it has once been there deposited." It remains permanently suspended in water, forming a milk-white emulsion, and is hence easily distributed by water. "It remains liquid at all temperatures above 32° F., while a temperature of 212° F., instead of deteriorating, only tends to concentrate it. It mixes readily and perfectly with water in all proportions."

It was originally called the "Thorncliffe disinfectant," but is now known under the name of "izal."

Mr. Warrall tried izal on the *Acarus* of the sheep, and found one treatment to effect complete cure, "proving that not only were the parents destroyed, but the antiseptic body remained to destroy also any insects hatched from the eggs which the parents had deposited previous to their death" ("the time of egg-incubation and larva-development is ordinarily fifteen days"). This seems to be a far more legitimate inference than that the eggs themselves had been destroyed.

Klein, after a bacteriological investigation, reported that izal had "a quite remarkable bactericidal effect." According to Dr. Klein, 0·25 c.c. administered to a rabbit, both subcutaneously and by the mouth, had no effect on the rabbit's health or appetite, and Mr. Warrall states that 10 drops have been taken with impunity.

Dr. Klein states that "an exposure for five minutes to izal in the strength of 1 in 200 completely destroys the vitality of the microbes of diphtheria, typhoid, fowl-cholera, swine fever, glanders, cholera, suppuration, erysipelas, scarlatina, and other non-sporing pathogenic and non-pathogenic species."

With reference to spores he continues: "The result of all experiments on inhibition may be briefly summarised for all the twenty-five species tested—namely, (1) spores do not germinate in medicated gelatine or broth if the amount of disinfectant added be 0·1 per cent.; (2) no microbes (*Staphylococcus* and *Streptococcus*) are capable of growing in medicated gelatine or broth of the strength of 0·1 per cent. medication; (3) all non-sporing bacilli and spirilla fail to grow in the above 0·1 per cent. fluid; (4) excepted from this are the *Bacillus prodigiosus* and the bacillus of typhoid; the former shows growth on gelatine medicated 0·1 per cent.; the growth is retarded, and always starts from the superficial layer of the medium; it proceeds considerably slower than on normal gelatine."

Dr. Bruce Clarke, of St. Bartholomew's Hospital, gives a very favourable report of its use in surgery.* With regard to Dr. Klein's exceptions he says that they "obviously do not concern one from a surgical point of view, inasmuch as *B. prodigiosus* is not a pathogenic organism at all, and the bacillus of typhoid fever does not enter wounds."

He also observes that, "being an emulsion and not a clear solution, it is not so easy to see one's instruments when they are covered with it. At the same time it must be borne in mind that the very fact that the fluid is so singularly unable to form chemical compounds with living animal tissues is in all probability highly advantageous from the germicidal point of view. Unlike corrosive sublimate, which speedily loses its disinfectant power by combining with the albuminous substances of the body, izal retains this power in such a remarkable degree because it will not combine with anything. It is also at the ordinary temperature of the body non-volatile, as may be easily seen by placing a few drops on a piece of cotton wool and leaving it several months in an exposed position." It is to be inferred that:—

(1) Izal seems, in a strength of 1 in 200, to be a disinfectant, and in 1 in 1,000 to be more antiseptic than phenol.

(2) Not being volatile it must be strictly local in its action, like chloride of zinc. Hence it is doubtful if to "saturate a sheet and suspend it before the door of a room" has much beneficial action.

(3) The quantities recommended, namely, "for sprinkling rooms, 1 tablespoonful with 5 pints of water," and for sewers and public disinfection, "1 gallon in 100 gallons of water," are higher than those usually proposed for most other "disinfectants," being about 1 per cent. As Dr. Rohe says,† "There can be no partial disinfection of infectious material; either its infective power is destroyed or it is not. In the latter case there has been a failure to disinfect, and the labour and money have been wasted."

As a warning, however, it must be remembered that even the 1 per cent., when used for sewage, becomes considerably diluted; hence a great deal more must be used. Here the expense, as with other disin-

* *Lancet*, July 1, 1893. † *Text Book of Hygiene*, 1890, p. 350.

fectants, become so heavy that, at the risk of repetition, it must be laid down that the practical and complete disinfection of sewage by any agent or process at present known cannot be attained except at great cost.

Lawes' disinfectant fluid and "Odamine" are similar commercial cresol products used as disinfectants and sheep dips.

Europhene, isobutylcresol hydriodide, $(C_6H_3(CH_3)(C_4H_9)OH)_2,HI$, is a product of the action of iodine on isobutyl-orthocresol. It is insoluble in water and alkalies, but soluble in alcohol and ether. It easily decomposes (liberating iodine), and behaves like similar organic iodine compounds.

Resorcinol, or "resorcin," is meta-dioxy-benzene, $C_6H_4(OH)_2$. It is prepared by fusing sodium *m*-benzene-disulphonate with potash or soda and extracting with alcohol.

Resorcinol occurs in minute needles, colourless when pure, but turning reddish in air. It coagulates albumen, forming a white precipitate. It only begins to be toxic in very large doses 10 to 20 grammes per day internally for an adult, while a 2 per cent. solution is highly antiseptic (Vallin).

Andeer * Callias † Dujardin-Beaumetz ‡ Lichtheim of Berne, and others have experimentally demonstrated that resorcinol is a powerful antiseptic. Callias proved that fermentation was prevented, and many animal liquids preserved, by 1 per cent. of resorcinol, while to keep milk required at least 2 per cent.

As to its internal action, Andeer, after a dose of 10 grammes of resorcinol, experienced vertigo, dizziness, loss of smell, and salivation, the symptoms disappearing in 5 hours with no after effects. It is therefore, far less poisonous than phenol. Dr. W. Murrel § has also reported on its internal use.

Dujardin-Beaumetz employed the fine powder in diphtheria and in syphilitic ulcerations with somewhat doubtful results. 1½ per cent. of resorcinol gradually entirely sterilised the bacilli of typhoid.

It is evident that 1 per cent. of this substance is efficiently antiseptic towards most micro-organisms. It has been employed in the treatment of acute fevers, also as spray in diphtheria and whooping-cough. As an antiseptic the dose is 5 to 20 grains.

Andeer's lotion is resorcinol 40 grains, water 1 ounce, as an antiseptic and stimulant for foul sores and to allay chronic eczema and psoriasis.||

* *Ueber das Resorcin*, Wurtzburg, 1880.

† *Resorcin en Thérapeutique*, Paris, 1881.

‡ *Bull. de Thérapeutique*, June and July, 1881.

§ *Med. Times and Gaz.*, 1881, p. 486.

|| Squire's *Companion to the B. P.*, 1890, p. 348.

For rendering rooms antiseptic M. Meillière* recommends the dissipation of phenols, &c., by heat. Naphthalin, anthracene, xylol, ordinary phenol, cresols, naphthols, benzoic acid, oxybenzoic acid, salol, betol, benzonaphthol, chloral, formal, and mercury sulphides and chlorides are indicated as useful for this purpose, but resorcin is particularly recommended. It is best mixed with a little hydrochloric acid, and the mixture should be heated in an open dish. Afterwards it is well to evaporate rapidly 100 grms. of water, either pure or acidulated with acetic or hydrochloric acid.

Pyrocatechol or pyrocatechin, ortho-dioxybenzene, $C_6H_4(OH)_2$, is obtained by fusing iodophenol or iodosalicylic acid with potash. Like almost all products of destructive distillation it is antiseptic, but its properties in this respect do not seem to have been studied. The third dioxybenzene hydroquinone or quinol has also an antiseptic action, but is not much used.

J. R. Duggan† has investigated the relative antiseptic power of the three dioxybenzenes by noting the amount required to prevent *Bacillus subtilis* from developing in beef peptone. Taking phenol as 20, he finds that the ratio of the three compounds ortho : meta : para = 20 : 25 : 30, whilst pyrogallol is represented by 15.

Pyrogallol or "pyrogallic acid" is trioxybenzene, $C_6H_3(OH)_3$. It is obtained by distilling gallic acid. It is inodorous, tastes astringent, and is not corrosive. Its solution quickly turns brown in air, absorbing oxygen; if an alkali be present, the action is almost instantaneous, the solution becoming dark brown. This property leads it to be destructive to "aërobic" organisms—those which live in presence of oxygen. Bovet, of Neuchatel, first examined its antiseptic action,‡ and found that a 2 per cent. solution prevented putrefaction, fermentation, and mould for some months, and that 3 per cent. was capable of killing bacteria. Two per cent. solutions have no injurious local action and disinfect very well; but it cannot be used internally, as it reduces and destroys the blood corpuscles, causing hæmoglobinuria. It blackens steel instruments and stains the hands. The *British Medical Journal* recommends a 2 per cent. solution as an antiseptic (1879, vol. i., p. 278). "A 10 per cent. salve applied with a brush twice a day has been recommended in psoriasis,§ but Neisser records a fatal case where it had been used freely as an ointment.||

* *Journ. de Pharm.* [6], vol. i., p. 82.
† *Amer. Chem. Journ.*, vol. vii., p. 62.
‡ *Revue d'hygiène*, 1879, p. 154.
§ *Journ. of Pharm.*, vol. xxv., p. 377.
|| *Zeitschrift f. klin. Med.*, 1879, vol. i., p. 88; Squire's *Companion*, 1890, p. 27.

WOOD-TAR AND OTHER PRODUCTS.

The substances which are formed during the destructive distillation of wood in closed vessels are very numerous. They vary with the nature of the wood and with the temperature of the distillation, and are gaseous, liquid, and solid. Charcoal, of course, is left behind in the retorts.

It may be mentioned here that the gaseous products of destructive distillation of all organic bodies are antiseptic in nature, and many proposals have been made to utilise them by blowing them through sewage, &c., but the action is not sufficiently energetic.

The liquid portions are partly soluble in water. Wood spirit or crude methyl alcohol, CH_3OH, is obtained from them by distillation; it is strongly antiseptic, but is so volatile and inflammable that it is best used for other purposes.

Pyroligneous Acid (discussed under *Acetic Acid*, p. 225), with methyl acetate and acetone, are also among the volatile products.

The insoluble portion, which consists of wood-tar, is composed of a mixture of various liquids, such as the hydrocarbons, toluene, xylene, cymene, &c. (the same as those from coal-tar, p. 148, but with little or no benzene), the substance called wood-creosote, and solids, such as paraffin, naphthalene, &c. The lower the heat used, the larger is the proportion of oxidised bodies formed, and the smaller that of hydrocarbons and gases. So that various specimens of wood-tar differ in composition.

It is probable that many of the coal-tar disinfectants previously described contain wood-tar products also.

The proportions of the different bodies obtained by distillation of wood are approximately as follow:—

Charcoal,	25
Gases,	22
Wood spirit,	1·0
Acetic acid,	4·0
Tar,	7·5
Water and other bodies,	40·5
	100·0

Stockholm Tar, obtained from the resinous wood of the pine, is extensively used for preserving ropes and sacking. The smell is principally due to the constituents of creosote, notably to the crystalline body called pyroxanthin, which, though only present in small quantity, is said to be one of the best preservatives. Stockholm tar contains much resin, acetic acid, and oil of turpentine. When distilled it leaves a black resinous substance which constitutes ordinary pitch, and has been used in many patents for forming solid block disinfectants. The specific gravity of the ordinary wood-tar of commerce is about 1·04; when poured on water a portion floats and some dissolves, like saprol.

Retinol is simply the product of distillation of ordinary resin. Its antiseptic properties are feeble.

Resol is the name of a disinfectant which has been introduced from Germany. It appears to be similar to creolin. It is made by saponifying 1,000 parts of wood-tar with 9 parts of caustic potash, and adding 200 parts of "an indifferent body such as wood-spirit." (The latter would, on the other hand, add considerably to its antiseptic power and aid in the saponification.) Resol is said to be an active bactericide, killing typhoid, anthrax, and similar bacilli in five or ten minutes with a 3 per cent. solution.

Wood Creosote contains some phenol and cresol, and quantities of oxyphenols like guaiacol, creosol, and a little pyrocatechol. It is more antiseptic than coal-tar creosote, and has a different and more agreeable odour, but a more burning taste. It immediately coagulates albumen. It is not easily inflamed, but when kindled burns with a smoky flame; it has been proposed to mix it with spirit and burn it in lamps for fumigation, but the sooty flame so produced retards its use. If swallowed in doses of more than a few drops it acts as a poison, so that its internal administration must be attempted with caution. Though sparingly soluble in water, the latter acquires from it its peculiar odour, pungent taste, and much of its antiseptic power. Alcohol and acetic acid dissolve it freely, so do the hydrocarbons of tar.

It combines with potash to form a crystalline compound; solutions of soda and ammonia also dissolve it. It is one of the most powerful antiseptics known. Meat that has been plunged into a solution containing 1 per cent. of creosote gradually becomes dry and hard on exposure to air, and acquires the flavour of smoked meat, but does not become putrid. A considerable proportion of creosote (from 1 to 1½ per cent.) is held in solution in the crude pyroligneous acid obtained during the destructive distillation of wood; and on saturating this acid at 167° F. with effloresced sodium sulphate, an oily matter which contains a large proportion of creosote is separated. Crude pyroligneous acid on this account is often employed for preserving hams and salted provisions, to which it communicates the same flavour as if they had been exposed to wood-smoke.

A great many patents relate to the manufacture of a disinfectant by distilling peat; this would be mainly creosote. Unfortunately the yield is small.

Creosote is used for carious teeth, for fœtid ulcers, and in many cutaneous affections, especially those that are parasitic.

J. Sommerbrodt, after nine years' trials, gave a most favourable account of its action in tuberculosis. In doses of 1 to 4 grains per day, in capsules with cod-liver oil, "it is well borne by the stomach and does not decrease the appetite."* If applied to the skin in a concentrated state it produces a white spot like phenol, and the skin peels off without any attendant inflammation. Creosote dissolves many organic bodies, such as camphor, the fatty and volatile oils, and many of the resins. Therefore it has been a frequent ingredient in compound antiseptic preparations. It is much more costly than the coal-tar product, hence could not be employed largely in public sanitation; and its smell in some cases has been known to produce nausea, headache, and vomiting.

Reichenbach in 1830 discovered the antiseptic powers of creosote; after a long period of trial it fell into discredit, and now is only employed for the uses above mentioned.†

Plants watered with creosote solution at once die; hence it cannot be used as a horticultural insecticide. Most micro-organisms are killed by it in a strength of $\frac{1}{3}$ per cent., and their spores are prevented from developing. In very small quantity it prevents fermentation, the action of diastase on starch, &c.

Bucholtz asserts that "1 in 1000 was not sufficient to sterilise vegetable infusions; it required 1 per cent. to completely sterilise germs and bacteria."

Guaiacol, methoxy-phenol or methyl-pyrocatechol, $C_6H_4(OCH_3)OH$, is a colourless liquid, becoming brown in light (therefore should be kept in non-actinic bottles). Its odour and taste resemble creosote, of which it constitutes a large portion. It boils at 200° C. Only $\frac{1}{2}$ per cent. of it dissolves in water, but it is more easily soluble in alcohol, wood-spirit, acetic acid, and in alkalies. Sodium-guaiacol resembles sodium-phenol.

Ferric chloride gives a brown opacity with the aqueous, and a blue colour with the alcoholic solution; hot sulphuric acid gives an orange coloration. On shaking 4 c.c. of guaiacol with milk of lime (10 grammes lime in 10 c.c. of water) white crystals of a lime-guaiacol compound slowly form.

As the antiseptic value of wood creosote is due partly to the guaiacol which it contains, it is important to note that recently this ingredient has been removed from foreign creosotes.

* *Berlin. Klin. Wochenschr.*, Oct. 19, 1891.

† See a monograph by M. Labbée in the "*Dictionnaire des Sciences Medicales*," art. Creosote.

The largest quantity (60 to 90 per cent.) exists in beech-wood creosote, but it also has been obtained by distillation of guaiacum resin, whence the name.

Its physiological value was first pointed out by Seidel in 1880 P. Marfori * finds that 1 part of guaiacol should dissolve in 60 of water, and that impurities render it more soluble. It first excites, then paralyses the nerve-centres, and reduces the temperature. Therapeutically it is similar to phenol and pyrocatechol, but not so poisonous. In a later paper † the same author states that its antiseptic power is greater than that of phenol in the ratio of 5 to 2, and that 0·5 to 1 per cent. destroys *Bacillus tuberculosis* in two hours, while other bacteria are killed with their spores in 20 to 30 minutes.

The hypodermic solutions known as Picot's, Pignol's, and Morel-Lavallee's contain guaiacol.

It has been used for phthisis, administered in cod-liver oil or in weak spirit.

Guaiacol-carboxylate, $C_6H_3(OH)(OCH_3).COOH$, is obtained by saturating sodium guaiacol with carbonic acid, heating, and precipitating by hydrochloric acid. It is, therefore, a methoxy-salicylic acid, and has naturally been credited with antiseptic and antipyretic properties.‡

Creosol, or methyl-guaiacol, $C_6H_3(CH_3)(OCH_3).OH$, is the chief ingredient of ordinary wood-creosote. It resembles guaiacol, but has a higher boiling point, is heavier, and less soluble. Its antiseptic power is said to be a little higher.

A comparative study of creosol, guaiacol, and wood-creosote, with and without the low boiling guaiacol, would be of value.

A disinfecting fluid called "soluble creosote," containing some wood-creosote, is in the market.§

"**Little's Soluble Phenyle,**" made by Morris of Doncaster, was at one time in high repute in the north of England. It is recommended by Dr. Rohe as a good disinfectant at a strength of 2 per cent.|| Prof. Corfield after lengthy experiments spoke highly of it. "It is non-corrosive and non-poisonous. 1 per cent. in water is more powerful than 10 per cent. of the best known antiseptics for wounds, ulcers, and for use at *post-mortems.* The powder is also energetic against vermin." It appears to be derived from wood-tar creosote, and would take rank with the other preparations.

* *Chem. Centralblatt,* 1890, p. 155. † *Ann. di Chimica,* 1891, vol. xiii,, p. 3.

‡ See also *Benzosol,* chap. ix., p. 197. § *Chem. and Drug.,* Oct. 26, 1893.

|| Rohe's *Hygiene,* 1890, p. 326.

NAPHTHALENE DERIVATIVES.

According to Bucholtz, diphenyl compounds or bodies containing two carbon "rings," are more powerfully antiseptic than those containing only one such group. The toxic behaviour of such compounds is also diminished.

Naphthalene itself, $C_{10}H_8$, has been already described (p. 148). It is useful as an insecticide, but is not a disinfectant. It is employed locally in scabies as a 10 to 20 per cent. solution in olive oil. It is to be avoided where large surfaces are exposed. It is also used as an antiseptic for wounds. Dr. Mirovitch considers naphthalene of high value against ascarides and tape-worm, in doses of 15 grains, followed by a large dose of castor oil.*

Some commercial "disinfecting powders" have been proved to contain little else than naphthalene and earthy matters. It is hardly necessary to say they are of little value.

Helbing states † that "the observations of Pavas, Dor, Hess, Magnus, and Kolinski, among others, led to the conclusion that naphthalene is unsuitable for use in medicines. It acts injuriously on the optic nerves and the retina, and upon the kidneys. A small quantity of camphor is said to largely cover its odour without affecting its value as a preventive of moth." ‡ Tidy advocated the presence of naphthalene in the creosote used for preserving timbers.

Naphthalene-sulphonic acids, $C_{10}H_7(SO_2 . OH)$.—By heating naphthalene with concentrated sulphuric acid, two isomeric acids of this formula are obtained. They are deliquescent crystalline substances, soluble in water and strongly acid, and almost inodorous. The α-acid changes into the β-form when further warmed with sulphuric acid. The resulting mass is dissolved in water, saturated with chalk, and the lime salt crystallised (the α-salt remains in solution). Addition of sodium carbonate will then convert it into the sodium salt, which has been occasionally used as an antiseptic.

Naphthols, $C_{10}H_7 . OH$.—Each of the above sulphonic acids, when fused at a moderate temperature with caustic soda, yields the corresponding naphthol. These are purified by pressure, distillation and crystallisation from hot water or petroleum ether.

α-Naphthol resembles the β-form closely, but melts at 95° and boils at 279° C., and with hot ferric chloride gives a violet colour.

β-Naphthol, as being more abundant, is the commercial article. It crystallises in lustrous plates, smells like phenol, and has a hot and tarry taste. It melts at 122° and boils at 286° C., and gives a green

* *Lancet*, 1891. † *Modern Mat. Med.*, 1891, p. 54.

‡ See also Fischer, *Med. Times and Gaz.*, 1881, p. 718.

tint when heated with ferric chloride. Both the naphthols are readily volatile with steam. The crystals should be colourless, should not darken in light, should be neutral, and leave no ash on platinum. It is almost insoluble in cold water, but dissolves in about 11 parts of boiling water, in 2 of rectified spirit, in $1\frac{1}{3}$ of ether, 24 of chloroform, 12 of olive oil, and in 4 of glycerine. It is a powerful antiseptic, and was first proposed for skin diseases by Kaposi in 1881. It has been given internally in diarrhœa in an emulsion with oil, and is very effective in parasitic diseases and in chronic eczema* in ointment form (3 to 10 per cent.), or in alcohol solution (2 to 10 per cent.) (*Helbing*). A daily dose of 38 grains will produce intestinal antisepsis. It has also been used in typhoid fever.† A solution of 1 in 1,000 has been successfully used for preserving anatomical preparations.

Prof. Bouchard, in a report to the Academie des Sciences in 1888, detailed certain experiments on the antiseptic power of β-naphthol. He says that he found 0·4 grm. of it to have the same effect as ·025 grm. of mercuric iodide, 2 grms. of phenol, 1·6 of creosote, 1·27 of iodoform, 2·7 of iodol, or 1·51 of naphthalene.‡ He values it highly for external use. "But what is more important is, that it appears to be the most efficient agent for intestinal antisepsis, on account of its slight solubility, which prevents its absorption, and allows it to remain a long time in the intestine without any poisonous effects. A dose of 1 grm. per kilo. of body-weight may be administered without danger." §

Lesser and Neisser recorded symptoms of poisoning by β-naphthol, which Shoemaker attributed to impurities; a conclusion largely confirmed in 1888 by an exhaustive examination of this drug by Willing.‖

Dr. A. G. Gibson,¶ of the Edinburgh Medical Infirmary, used 2 grains of β-naphthol two or three times a day for the antiseptic treatment of pernicious anæmia. In a large number of cases, improvement was extremely rapid when iron had been used before. Dr. Gibson finds that irritation is sometimes caused by the drug, and to prevent this he administers it together with a bismuth preparation, such as the salicylate.

It has been recently observed that α-naphthol and salol (p. 199) when rubbed together form a liquid. β-naphthol, on the other hand, does not liquefy, but, like many other substances, it becomes a permanent fluid when melted with camphor, so forming "camphorated

* *Med. Times and Gaz.*, 1882, vol. xi., p. 505.

† *Brit. Med. Journ.*, 1888, vol. xi., p. 1226.

‡ The experiments make naphthalene a stronger antiseptic than phenol, *Year Book of Pharm.*, 1888.

§ *Brit. Med. Journ.*, 1888, p. 1185.

‖ Helbing, *Mod. Mat. Med.*, p. 53.

¶ *Edin. Med. Journ.*, October, 1890.

β-naphthol," used, according to Fernet, with great success for boils, coryza, angina diphtheritica, and tuberculosis. Against the latter it was given by injection in doses of 2 grms. mixed with oil.

Reboul cured twenty-one out of twenty-seven cases of tuberculous glands by emptying any abscess formed, and injecting 7 or 8 drops of camphorated naphthol, repeated every two days. Similar results are recorded by Nelaton.*

Betol, naphthol salicylate, $C_6H_4(OH).CO.OC_{10}H_7$, is a white, crystalline, inodorous, and tasteless powder, neutral, insoluble in water and in glycerine, difficultly soluble in alcohol and turpentine. It dissolves in 3 parts of hot alcohol, in ether, benzene, and in warm linseed oil. Melting point, 95° C. Hot acids or alkalies reconvert it into salicylic acid and β-naphthol. It is prepared similarly to salol (p. 199). Antiseptic; now almost disused.

"**Microcidine**," chiefly composed of sodium-β-naphthol, $C_{10}H_7ONa$, also contains phenols. Prepared by the action of soda and heat on β-naphthol. It is more soluble but less antiseptic than the latter, and is somewhat irritant and caustic. It possesses no special advantage.

"**Alumnol**."—By heating the naphthols with sulphuric acid, several naphthol-sulphonic acids are obtained. Certain of these, saturated with aluminium hydroxide, give an aluminium salt to which the above name is applied. Alumnol contains 5 per cent. of aluminium. It is a white stable powder, very soluble in water, and soluble in alcohol with a blue fluorescence. It dissolves in glycerine, but not in ether. It is slightly acid. With albumen and gelatine it forms precipitates which are readily soluble in excess. "Judiciously employed it produces no injurious effects. Very large doses are required to produce any toxic action on animals." †

Prof. Eraud, of Paris, praises it highly as a dressing in simple wounds, in ulcers, and as an injection in gonorrhœa; also the powder as a dry dressing. He finds it to cause neither irritation nor pain.‡ "As a soluble non-toxic astringent, strongly penetrating and antiseptic, it seems to deserve a place. Excellent results have also been obtained by using solutions of ½ to 5 per cent. in laryngitis and pharyngitis. Dr. A. Spengler, of Heidelberg, considers alumnol quite equal to zinc chloride, while it has the advantage of not being unpleasant to use."§

Hydronaphthol seems to be β-tetrahydro-naphthol, $C_{10}H_{12}O$, obtained by the reduction of β-naphthol by sodium. It forms white shining crystals with an odour something like creosote, slightly soluble in water, easily in spirit. Dr. Bryce recommends the external use of 1 part of hydronaphthol dissolved in 10 parts of rectified spirit, to

* Helbing, *loc. cit.* † Heintz and Liebrecht, *Pharm. Centralhalle*, 1892, p. 697.
‡ *Chem. and Drug.*, Jan. 21, 1893. § *Lancet*, April 21, 1894.

which sufficient glycerine is added to make a 1 per cent. solution. "In this form the antiseptic properties are well marked." Dockrell has used it very successfully in a plaster against *Tinea tonsurans*. Mr. M. Clarke found it of great value in enteric fever and diarrhœa. He says that it has a very distinct retarding effect on digestion, but does not much interfere with that of milk.

Hydronaphthol gauze 5 per cent. is recommended as very lasting, and as compatible with albuminous fluids.*

α-Hydroxynaphthoic Acid, called also simply oxynaphthoic acid, $C_{10}H_6(OH).COOH$, is formed by the action of carbonic acid on sodium-naphthol. It melts at 186° C., is sparingly soluble in water, but easily in alcohol, ether, and the alkalies.

Collodion impregnated with ½ per cent. of it has been used as a substitute for iodoform-collodion, as it is non-irritant and more stable.† Ellenberger and Meister established its bactericidal properties. A 5 per cent. ointment is antiseptic in scabies. Its salts are not antiseptic. It has not been determined whether it is completely innocuous.‡

"*Chloronaphthalene*" and "*naphtholeum*" are used for disinfecting excreta in one of the London districts.

CHAPTER IX.

ORGANIC SUBSTANCES (*continued*).

Nitro-Compounds Nitro-Benzene—Nitro-Phenols—Trinitro Phenol or Picric Acid; its value as an insecticide — Nitro-Cresols — Nitro-Glycerine — Nitro-Cellulose — Collodion. **Amido-Compounds** · Ammonia — Compound Ammonias or Amines — Amides — Amido-Acids — Imido-Compounds — Hydroxylamine — Hydrazine — Methylamine — Dimethylamine — *Trimethylamine* — Propylamine — Amylamine — The "Amines Process" — Aminol — *Aniline*—Acetanilide or Antifebrin—*Aniline Dyes as Antiseptics*—Methyl-Violets—"Pyoctanin"—Researches on their Antiseptic power—Apyonin. **Pyrrol-Compounds**: Furfurane—Thiophene—Pyrrol—*Iodol* or Tetra-Iodo-Pyrrol—*Antipyrin* or Phenazone—Salipyrin, &c. **Pyridine Group, &c.**: Conine — Piperine — *Pyridine* — Antiseptic properties of Tobacco-smoke — Nicotine — Various Patents as to Pyridine, &c. — Indole — Tryosine — *Quinoline* or Leucoline — Diaphtherin — Loretin — *Thalline* — *Quinine*—Antiseptol.

NITRO-COMPOUNDS.

THE aromatic nitro-compounds are characterised by their poisonous properties. Several of them have been suggested as disinfectants.

* S. W. Williams, *Chem. and Drug.*, 1893, p. 735. † *Ibid.*, 1889, p. 34.
‡ *Journ. of Soc. of Chem. Industry*, 1888, p. 226.

Nitro-Benzene ("Nitro-Benzol"), $C_6H_5(NO_2)$, is a heavy yellowish oil with an odour like bitter almonds. It is a disinfectant, because it kills bacteria, but its poisonous character and insolubility render it unsuitable for general use. Pettenkofer and Lehmann * state that the vapour of nitro-benzene "even in large quantities had no serious effect;" but many aniline workers have experienced that it is nauseating and narcotic. The same may be said of **Nitro-Toluene**, $C_6H_4(CH_3)(NO_2)$, &c., and the di- and tri-nitro-compounds.

Ortho- and **Para-Nitrophenols**, $C_6H_4(NO_2)OH$, are obtained by acting on phenol with nitric acid. Both are slightly soluble in water, acid, germicide, and poisonous. Their sodium compounds are soluble and antiseptic. There are no records of bacteriological experiments with reference to them.

Trinitrophenol, "picric" or "carbolised acid," $C_6H_2(NO_2)_3OH$, is easily produced by the action of nitric acid on nearly all organic bodies that contain the benzene nucleus. It occurs in pale yellow plates, and is very acid, little soluble in water (about $1\frac{1}{2}$ per cent.), but soluble in alcohol. Its salts are yellow and explosive.

It is a very powerful germicide; it almost immediately combines with albuminoid substances, staining them yellow, precipitating the albumens, and causing the death of protoplasm in exactly the same way as iodine; hence it is rapidly fatal to both bacteria and spores. It does not, however, like iodine, permanently colour starch and cellulose. The aqueous solutions are extremely poisonous, irritant, but not corrosive.

Jalan de la Croix † found that bacteria in white of egg infusions were killed by 1 in a 1,000 of picric acid, but resisted 1 in 5,000. He also points out that a solution of 1 in 200 prevents growth in *bouillon*, while $\frac{1}{2}$ to 1 per cent. was required to destroy the germs; this would be a nearly saturated solution in water. Cheron ‡ disinfected the latrines of a hospital by the use of 10 litres of a saturated solution ($1\frac{1}{2}$ per cent.). He found that it arrested fermentation, and the action of diastase and synaptase. The germination of seeds was also prevented. It hindered the ammoniacal change in urine, even in cases of vesical catarrh, when given to a patient, or injected into the bladder.

Schwartz asserted (1880) that a minimum dose of 1 in 15,000 of picric acid killed the bacteria of tobacco infusions transferred to Pasteur's solution, whereas Kuhn maintained that 1 in 1,000 was necessary, thus agreeing with Jalan de la Croix.

Picric acid is used in histology for hardening and preserving tissues.

* *Acad. d. Wissensch. zu München*, 1887, p. 179.

† *Arch. f. exp. Pathol.*, Jan. 27, 1881. ‡ *J. de Thérapeut.*, Gubler, 1880, p. 121.

Vallin states * that 60 centigrammes per day produce in man, besides a deep orange colouration of the skin and urine, a slowing and weakening of the heart, prostration of strength, vertigo, and stupefaction.

Kinloch has recently patented picric acid as "an insecticide," antiseptic and disinfectant.†

Except as an insecticide, when its staining powers and poisonous action on plants and animals would be against its use, picric acid may be pronounced to be unsatisfactory for disinfection. There is still, however, a possibility of its being of special service in killing those micro-organisms that only mercuric chloride will touch, as Klein has shown, with some difficulty. Further experiments would be desirable.

Potassium Dinitro-Ortho-Cresol, $C_6H_2(NO_2)_2(CH_3)OK$, occurs in yellow needles, inodorous, sparingly soluble in water, poisonous, and explosive by heat. Therefore, it is used as a yellowish paste, mixed with soap and glycerine, and thus dissolves easily in water. It has been lately introduced into this country under the name of "Antinonnin" (F. Bayer & Co., Elberfeld). "Properly diluted it forms an efficacious and safe insecticide, and does not injure plants. Though originally intended to destroy certain kinds of caterpillars it has been found to be fatal to mice, ants, snails, and all kinds of plant-lice, as well as protecting wood from dry rot and fungi. 1 kilo. of antinonnin in 300 litres is found most effective for killing lower plant life and fungi. House and field mice succumb to three-twentieths of a grain, best mixed with flour-paste." ‡ The specification states that "1 in 400 of water kills all insects, also fungi which rot timber; it may even be used more dilute if time be given. Soft soap, $\frac{1}{4}$ part, increases the power."

There are a large number of other nitro-compounds of the aromatic group, of similar properties, but of no special interest.

Nitroglycerine, $C_3H_5(O.NO_2)_3$, is said to be antiseptic when dissolved in alcohol and poured into water.

Nitrocellulose dissolved in ether or acetone is used under the name of *Collodion* for protecting wounds, &c. Being insoluble in water and the blood fluids, it has no antiseptic power.

AMIDO-COMPOUNDS.

Ammonia, NH_3, has been described among the alkalies (p. 109). It, like the other products of putrefaction, is fatal to the bacteria which produce it, and the bactericidal power of ammonia, sulphuretted hydrogen, and even of carbonic acid no doubt materially assist in

* *Désinfectants*, p. 156. † Patent No. 6,243, 1894. ‡ Patent No. 3,301, 1892.

retarding natural decay. Animal matter placed in a 5 per cent. solution of ammonia remains free from putrescence for a long period. When added to gelatin in which putrefaction had been already set up, a 5 per cent. solution caused the putrefaction to cease. In an atmosphere impregnated with ammonium carbonate, meat can be kept for six months, and at the end of the time remain unaltered.

In all these cases it is necessary that the material be kept closed, or the ammonia would rapidly escape. On account of its alkalinity, smell, and irritant action, it has not been much used. The fact that its vapour, which is at first stimulant, soon becomes excessively depressant, also militates against its use for rooms. The compound ammonias, or amines, formed by replacing successively the atoms of hydrogen in ammonia by basic organic radicles, have greater antiseptic properties. Methylamine, $NH_2(CH_3)$, the simplest of these amines, is a gas; others are more or less volatile liquids; while the more complicated organic bases, like the alkaloids, are white solids. They are all alkaline, form salts with acids, and the volatile ones have an ammoniacal odour. As a class they are poisonous, therefore they are antiseptic and may be disinfectant. They absorb sulphuretted hydrogen, but of course do not absorb ammonia.

The acid organic radicles, such as acetyl ($CH_3.CO$), may also replace the hydrogen in ammonia, forming a class of bodies called amides, *e.g.*, acetamide, $CH_3.CO.NH_2$, which are usually crystalline, neutral compounds which are soluble in water and more or less volatile. A few, like acetanilide, are antiseptic.

Hydroxylamine, NH_2OH, has been tried by Bing and others in skin diseases. It acts as a reducing agent and is a strong germicide.

Hydrazine or **Diamine,** N_2H_4, has been found by Loew and Buchner to be powerfully poisonous to animal, vegetable, and bacterial life.

Methylamine, CH_3NH_2, is a gas with a strong alkaline reaction. It is more basic and more soluble in water and in alcohol than ammonia. Its odour is like that of herring-brine, in which it is contained. The hydrochloride, $(CH_3)NH_2.HCl$, crystallises in deliquescent, very soluble plates, which give off methylamine on treatment with potash. The sulphate forms an alum, $(CH_3NH_2)_2H_2SO_4$, $Al_2(SO_4)_3$, $24H_2O$; this is a powerful disinfectant, but has not been much used.

Dimethylamine, $(CH_3)_2NH$, occurs in guano and, in small quantities, in pyroligneous acid. It resembles the preceding. Neither of them seem to have met with any practical application.

Trimethylamine, $(CH_3)_3N$, is a very volatile, alkaline, and inflammable liquid, extremely soluble in water and alcohol. It also has the fishy and ammoniacal odour. It is obtained from herring-brine, and is made in large quantities, with ammonia, dimethylamine, methyl alcohol, and methyl cyanide, by distilling "vinasse," a residue of the beet-sugar manufacture. The source is "Betaine," the internal anhydride of trimethyl-amido-acetic acid, $\overbrace{CH_2.CO.O.N}(CH_3)_3$.

In Patent No. 16,242, 1888, H. Wollheim claims its use "for destroying, in a very short time, the vitality of all germs and spores which can produce disease." Its compounds with acids crystallise well, and resemble the ammonia salts, but are more soluble in alcohol, and are said to be poisonous.

The **Ethyl-** and **Propyl-amines** are similar, but of greater density and higher boiling point. Propylamine, $(C_3H_7)NH_2$, is metameric with trimethylamine, and resembles it.

Amylamine, $(C_5H_7)NH_2$, is contained in the products of destructive distillation of animal matters, such as bone oil. It is a liquid smelling like burnt feathers, is antiseptic, but seems to have no special advantage.

The Amines process for treating sewage consists in the utilisation of herring-brine with lime. This liquid is a mixture of amines, with trimethylamine predominating. Klein and others, who tested the effluent bacteriologically, reported very favourably on the process, asserting that the result was complete sterilisation, that 1 per cent. of trimethylamine was sufficient, and that the operation was easy and inexpensive. Objections were made by others on the score of (1) the offensive odour of the precipitant; (2) its deterioration on keeping; (3) in the case of its application inland, the quantity of salt that must be discharged into rivers; (4) the danger of the effluent being poisonous to river-fish (this is not proved of the small quantity of trimethylamine that would remain as, being volatile, most of it evaporates into the air); (5) the alkaline character of the clarified water; and (6) the difficulty of procuring a sufficient supply of herring-brine.

"**Aminol**" is the name given to the mixture of methylamines obtained by distilling herring-brine with lime according to the patent mentioned above. It is a clear colourless liquid, alkaline and odorous of the bases. It is permanent when kept tightly enclosed, but easily loses strength when opened. Two solutions are applied:—"D" (disinfecting) for general disinfecting purposes, is said to be a "perfect deodoriser, non-poisonous, non-corrosive, and does not stain;" and "R" (Remedial), for medicine and surgery, "efficient remedy in all suppurative, phlegmonous, or fermentative disease processes."

Aniline, $C_6H_5(NH_2)$, amido-benzene, is now made on a large scale by the reduction of nitrobenzene by iron filings and acetic acid. The residue, acetate of iron, is oxidised to "red liquor," ferric acetate, and has been used in France as a disinfectant. Aniline also occurs in bone-oil (p. 190).

It is an oily liquid, colourless when pure, but turning brown in air and light, boiling at 184° C., but easily volatile with the vapour of water. Its melting point is 0·8° C., and specific gravity 1·036. It is soluble in 31 parts of water, very soluble in alcohol, &c., and forms soluble crystalline salts from which the base is again liberated by potash, soda, or lime.

It is poisonous, and hence a germicide. It slowly volatilises at ordinary temperatures, giving a vapour of oppressive tobacco-like odour, which also kills bacteria, but does not easily affect their spores. Pettenkofer and Lehmann assert* that 0·1 per cent. of aniline vapour in air is dangerous to man and animals. From this fact, and the slow rate at which it diffuses, its use for fumigation is negatived.

The salts are antiseptic, and, being acid, absorb ammonia and compound ammonias, but not sulphuretted hydrogen. Angus Smith † places aniline in his sixth class—*i.e.*, as moderately antiseptic. Dr. Fischer has shown that tubercular sputa mixed with ten times its volume of aniline water, is completely disinfected in twenty-four hours. This is equivalent to the action of a 5 per cent. carbolic acid. At the present price of aniline, it seems to be a disinfectant which is worth trying.

Substitution Products.—An immense number of these have been obtained, aniline being much more easily acted upon than benzene. They are generally antiseptic, but have hitherto not yielded any satisfactory results for hygienic purposes, and are less soluble and volatile, and often more poisonous than aniline itself.

Acetanilide, "antifebrin," or phenyl-acetamide, $C_6H_5.NH(CO.CH_3)$, prepared by boiling aniline with glacial acetic acid for several days, is a white crystalline and easily soluble powder. Its melting point is 114° (*Ritsert*), and boiling point 295°. Potash and acids slowly reconvert it into acetic acid and aniline. In 3- to 8-grm. doses it is antipyretic and analgesic in fevers; externally it has been used as an antiseptic for wounds, but 30 grains in twenty-four hours has been found to produce poisonous symptoms. A special therapeutic commission ‡ pronounced it inferior to *phenacetin* and *antipyrin* (p. 189).

Para-brom-acetanilide, "asepsin," or "antisepsin,"

$$C_6H_4Br.NH(CO.CH_3),$$

is said to be anodyne and antiseptic. This must not be confounded with "aseptin."

Aniline Dyes as Antiseptics.—Several of these have long been known to have the power of penetrating into living animal and vegetable

* *Acad. d. Wissensch. zu München*, 1887, p. 179.

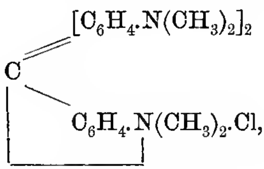
† *Disinfectants*, Edin., 1869. ‡ *Brit. Med. Journ.*, 1894.

structures, different dyes selecting different parts and species; therefore, they are widely employed for microscopic staining. Their action occurs in extremely dilute solutions, and is out of all proportion to their poisonous action on higher animals.

The effect is to lower the vitality of, and, finally, to kill the organisms. Hence it became a matter of interest to see how far they could be used as actual disinfectants.

Koch proved* that a number of the tar dyes were inhibitory to tubercle and other bacilli, both in local and in internal application.

The Methyl Violets are mixtures of hexamethyl-rosaniline hydrochloride—



with the salts of penta- and tetra-methyl rosanilines. They occur in amorphous, dark blue masses (the pure hexa-compound is in large deep violet crystals), soluble in alcohol, sparingly in water, but gives it an intense violet colour.

Professor Stilling, of Strasburg, has experimented on the disinfecting power of methyl-violet, and has found that a paste made with wheaten flour, with a 2 per 1,000 solution of methyl-violet added, does not turn sour, however long it is kept. Milk mixed with the same quantity does not turn sour, butter and bacon soaked in a stronger solution (1 in 500) and dried, become superficially stained, but do not afterwards become rancid. *Mucor stolonifer* was sown upon rolls of bread, some of which were soaked in a 1 in 500 to 1 in 1,000 solution of the dye, and some in water only. On the latter a growth appeared in twenty-four hours, whilst on the former none could be noticed after fourteen days. He has given the name of "pyoctanin," from πυος, pus, and κταος, stain, to methyl violet, and says it can be had absolutely pure from the firm of E. Merck, of Darmstadt. "Certain auramines proved to be the next best, when used in solutions of 1 in 4,000 to 1 in 1,000." †

Dr. C. Prioux ‡ points out that solutions of pyoctanin and gentian violet, 1 in 100 prevent the development of micro-organisms. Weaker solutions (1 in 500, or even 1 in 2,000) arrest the cultures of typhoid and *Bacterium coli communis* (the ordinary microbe of the intestines);

* *Mittheil. a. d. K. Gesundh.*, 1881, vol. i., p. 234.

† *Lancet*, 1890, vol. xi., p. 965.

‡ *International J. of Microscopy and Nat. Science*, vol. iii., part 18.

1 per cent. solutions of safranine (an orange-red dye containing at least three "benzene rings") have also been shown to hinder Eberth's bacillus from developing.

Solutions of blue pyoctanin for general surgery, ointments, powders, and dressings have been introduced.

Dr. Petersen found that these preparations were as effective as those made with iodoform, without the unpleasant odour, and without any bad effects or symptoms of poisoning. Dr. Wanscher strongly recommended a 1 per cent. solution for ophthalmic use and in urethral discharges, as lessening local irritation. They have also been used for nasal and other cavities of the body, to stop suppuration. Von Mosetig treated malignant tumours by injections of methyl violet, and believes that complete cure by this method is possible.

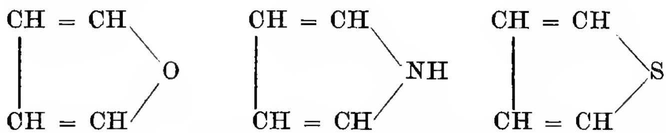
Yellow Pyoctanin is an "auramine," obtained by acting on dimethyl-aniline with phosgene, and then by ammonia; its formula is $C[C_6H_4 . N(CH_3)_2]_2 . NH$. It is a para-derivative of benzophenone, and is specially recommended for ophthalmic practice.

"**Apyonin**" is said to be also an auramine, and is intended for the same purpose as the last.

PYRROL COMPOUNDS.

There are other rings analogous to the benzene ring, but containing 4 or 5 atoms instead of 6. Those with 4 carbon atoms include these three chief compounds:—

Furfurane. Pyrrol. Thiophene.



All three are tar products, are volatile, colourless liquids, with antiseptic characters that have not been well studied.

Furfurane, C_4H_4O, is a mobile liquid with an odour like chloroform, and boils at 32° C. It appears to be present in pine-wood tar, together with methyl-furfurane, or sylvane, $C_4H_3(CH_3)O$, which boils at 63° C.

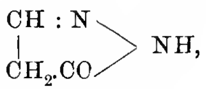
Furfurol, $C_4H_3(CO.H)O$, is the corresponding aldehyde, and is formed by the action of acids on sugar, bran, &c. (*Furfur*, bran).

Thiophene, C_4H_4S, is found in commercial benzene, and smells like it; it boils at 84° C. It is probably an insecticide if not a germicide. It is insoluble in water, but soluble in oil of vitriol, forming a sulphonic acid, $C_4H_3S(SO_3H)$.

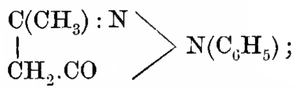
Pyrrol, $C_4H_4(NH)$, is colourless, but becomes brown in air (like most of these bodies). It boils at 133° C., has a specific gravity of 1·077 (*Anderson*), a faint odour like chloroform, and a hot, burning taste. It is insoluble in alkaline solutions, but is slowly dissolved by acids. It is contained in coal tar, but is generally made from bone oil. Alcoholic solutions of pyrrol precipitate mercuric chloride.

"**Iodol,**" tetra-iodo-pyrrol, $C_4I_4(NH)$, is made by the action of iodine and potash on pyrrol. It is a pale yellow, inodorous and tasteless, crystalline powder, almost insoluble in water, soluble in 18 parts of alcohol, 155 of glycerine, 1½ of ether, and in oils. It decomposes at 140° C. with violet vapours of iodine. It gives a black precipitate with mercuric chloride (hence incompatible with it), and is decomposed by hydrochloric acid, iodine being liberated. It is reputed to have antiseptic properties, and is used for the same purposes as iodoform, but has not the objectionable smell, and is not so poisonous, but Riedlin says * that it has no action on cholera or any other bacteria.

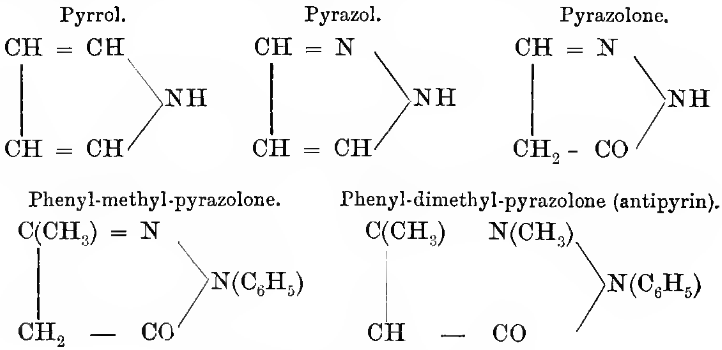
"**Antipyrin,**" $C_{11}H_{12}N_2O$.—By substituting a nitrogen atom for one of the $(CH)^{III}$ groups in pyrrol, the grouping known as *pyrazol*, $C_3H_3.N.NH$, is obtained. A body of ketonic character called *pyrazolone*,



is an oxy derivative of this compound. From it phenyl-methyl-pyrazolone,



and phenyl-dimethyl-pyrazolone or "antipyrin"; abbreviated in the *British Pharmacopœia* to "phenazone" are obtained—



* *Archiv. f. Hyg.*, vol. vii., p. 309.

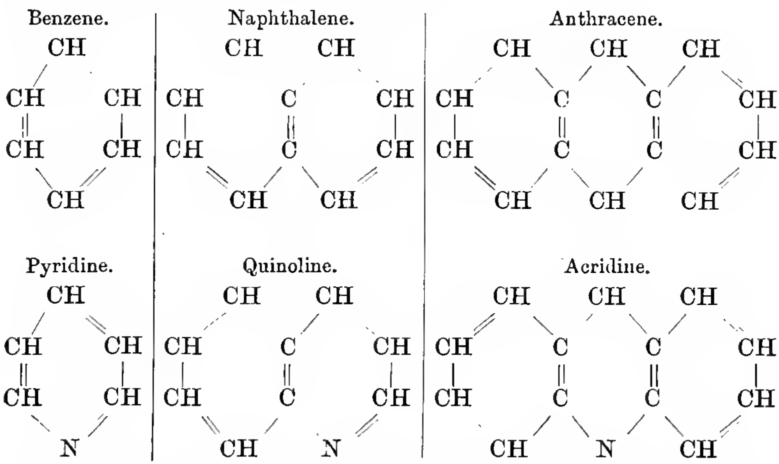
L. Knorr's patent* heats phenyl-hydrazine, $NH_2.NH(C_6H_5)$, with ethyl aceto-acetate, $CH_2(CO.CH_3).CO.O(C_2H_5)$, when water and alcohol are separated, and phenyl-methyl-pyrazolone formed; methyl iodide converts this into antipyrin.

Antipyrin, or "phenazone," crystallises in colourless scales, neutral, inodorous and slightly bitter, fairly soluble in water, alcohol, and chloroform, less so (about 1 in 50) in ether. It dissolves in acids to colourless solutions. Melting point, 113° C. It has been found mixed with acetanilide (p. 185), which is much cheaper; but the detection is easy, as, although the melting point of the latter is also about 113°, a mixture of the two melts about 45° C. It is antipyretic and antiseptic, also an anodyne for neuralgia and gout (see *Antifebrin*, p. 185). Externally, it has found favour as an antiseptic lotion, and as gauze. It is incompatible with tannin, many acids, ferric salts, iodine, and a number of drugs.

Nitro- and "isonitroso"-antipyrin, "salipyrin" (a salicylate), "iodantipyrin" or "iodpyrin," "resopyrin" (a compound with resorcinol) have been prepared.

PYRIDINE GROUP, &c.

If, in the benzene ring, nitrogen be substituted for a CH group, pyridine, C_5H_5N, is obtained. From naphthalene and anthracene, similar nitrogen derivatives are formed :—



Additive compounds, of which piperidine or hexahydro-pyridine, $C_5H_{10}NH$, and nicotine or hexahydro-dipyridyl, $(C_5H_4N)_2H_6$, are examples, are also known. The radicles, methyl, ethyl, &c., can

* Liebig's *Annalen*, vol. ccxxxviii., p. 137.

also replace the hydrogen atoms giving homologues of pyridine, which exist with it in coal-tar, and in larger quantity in bone-oil. They much resemble pyridine in properties, but rise in boiling point and diminish in density as the number of carbon atoms increases, and are more readily oxidised and attacked. The mono-, di-, tri-, tetra-, and penta-methyl derivatives have been obtained by the fractional distillation of bone-oil, the fractions so procured being mixtures of isomerides, which it is impossible to separate by this method. They were discovered by Anderson in 1846, and investigated also by Greville Williams, Ladenburg, and others.

TABLE OF THE PYRIDINE HOMOLOGUES.

Name.	Constitutional Formula.	Empirical Formula.	Boiling Point.	Specific Gravity.
Pyridine, . .	... ...	C_5H_5N	117° C.	·985
Picolines, . .	$C_5H_4(CH_3)N$	C_6H_7N	135°	·961
Lutidines, . .	$C_5H_3(CH_3)_2N$	C_7H_9N	154·5°	·946
Collidines, . .	$C_5H_2(CH_3)_3N$	$C_8H_{11}N$	180°	·944
Parvolines, . .	$C_5H(CH_3)_4$	$C_9H_{13}N$	...	...
Caridines, . .	$C_5(CH_3)_5N$	$C_{10}H_{15}N$	211°	...
Rubidine, . .	?$C_5(C_2H_5)(CH_3)_4N$	$C_{11}H_{17}N$	230°	...
Viridine, . .	?$C_5(C_3H_7)(CH_3)_4N$	$C_{12}H_{19}N$	251°	...

Conine, $C_8H_{17}N$, the volatile alkaloid of hemlock (*Conium maculatum*), is normal-propyl-piperidine, $C_5H_{10}N(C_3H_7)$, (*Ladenburg*).

Piperine, from pepper, is peperyl-piperidine, $C_5H_{10}N$ $C_{12}H_9O_3$, related to pyridine through piperidine (*ibid*).

It will be noticed that aniline, $C_6H_5(NH_2)$, is metameric with the picolines, $C_5H_4(CH_3)N$, of which all the three possible isomerides have been separated from bone-oil.

All these substances are more or less narcotic poisons; hence, would act as antiseptics, and, if in sufficient quantity, would kill bacteria. It has been mentioned that *Saprol* (p. 165) contains pyridine bases: from most coal-tar disinfectants they have been removed together with aniline by treatment with acids, but some of the newer preparations contain appreciable quantities of these bases. The most important is—

Pyridine, C_5H_5N.—When pure it is a mobile, colourless liquid, which does not turn brown in air and light, and is slowly and completely volatile. Its odour is said to be "empyreumatic," but is most persistent and unpleasant. It absorbs water from the air, and mixes with it in all proportions; it is also readily soluble in alcohol. It forms soluble crystalline salts with acids. Commercial ammonia often contains pyridine, and commercial pyridine is sometimes contaminated with ammonia.

Tobacco-smoke, contrary to popular belief, does not contain nicotine, which is decomposed by the heat, but pyridine and its homologues, and the beneficial effect of tobacco in many cases of asthma, must be attributed to these latter, whether as sedative or as bactericide (it must be remembered that very little of the smoke itself gets into the lungs). Pyridine inhalations have been proposed for asthma. "From 1 to 1½ drachms are poured on a plate and placed in a room with the patients. At 68° to 77° F. the above quantity evaporates in about an hour. It is said that after a few minutes' exposure to the pyridine atmosphere the remedy can be detected in the urine. The treatment was well spoken of by Dr. Kelemen, among others, but does not seem to have maintained its ground. Mixed with a little oil of peppermint it has been employed in the treatment of diphtheria with some success, and in aqueous solution (1 in 300) three or four injections have been recently said by Rademacher to be sufficient to cure gonorrhœa." *

It was stated by the Cigar Manufacturers' Association of Hamburg that in the last visitation of cholera there were only eight cases and four deaths amongst a body of 5,000 cigar-makers.

Dr. Burney, the senior Medical Officer of Greenwich Workhouse, asserts that the tobacco-smoking inmates enjoyed comparative immunity from epidemics, and tobacco-smoking is believed to have had a disinfectant action in cases of cholera and other infectious diseases. But Dr. Kerr points out that if a man cannot stand smoking it may depress his heart action and enfeeble his constitution, and so lessen the resisting power to throw off the noxious germs. Pyridine fumigations are also open to the same objection. It is recorded that Tessinari found that tobacco-smoke, on being passed through tubes containing a nutrient gelatine and pathogenic germs for from ten to thirty minutes, destroyed the bacilli of Asiatic cholera and of pneumonia. Pyridine was introduced by O. Fergusson as a horticultural insecticide about 1890, but its odour was against it, although it was most effective. Wynter Blyth exposed the yellow bacillus of nasal catarrh, on threads, to the action of a 1 per cent. solution of a mixture of pyridine, collidine, lutidine, and acridine from bone-oil. After the threads were washed and transferred to nutrient gelatine, there was no growth. In sour milk also, pyridine inhibited growth. Tobacco-smoke passed through water killed the yellow bacillus. These experiments tend to confirm the idea that disinfectant preparations containing the basic constituents of coal tar are to be preferred to those only containing the phenols, also that pyridine being very soluble in water and non-irritant, might be of service in nasal affections.

* Helbing, *Mod. Mat. Med.*, p. 65.

Nicotine, $C_{10}H_8(H_6)N_2$, is an oily liquid which rapidly turns brown in air. It boils at about 250° C., but is readily volatile with steam. It has a well-known stupefying odour, is alkaline, dissolves easily in water, alcohol, and ether, forms crystalline salts with acids, and is extremely poisonous. Its use as an insecticide in gardening is familiar. At Greenwich in 1893 the use of tobacco seemed to be protective in an epidemic of English Cholera.

Nickels* covers the use of shale or bone-oil, or pyridine bases, with resin and soda, as a disinfectant.

Overbeck† proposed the use of pyridine or leucoline (quinoline, see below) with chalk or lime.

Indole, $C_6H_4\langle{}^{NH}_{CH}\rangle CH$, crystallises in plates, moderately soluble in water, easily in alcohol and ether, melting at 52° C., feebly basic, having a peculiar fæcal odour, and giving a red colour or precipitate of nitroso-indole with sodium nitrite and dilute sulphuric acid. It readily volatilises with steam. As a product of putrefaction it has been presumed to be antiseptic, but its odour would preclude its practical use. It has derived a certain importance from the fact that it is constantly formed in the growth of the bacillus of typhoid and the spirillum of cholera. Bujwid‡ first proposed the "indole test," as given above, to distinguish these pathogenic organisms from others that are innocuous. But unfortunately *Bacillus coli communis*, which is commonly found in the intestines and in water contaminated with normal fæces, also forms indole, as might be expected from the latter being always present in small quantity in the intestines.

Tyrosine, $C_6H_4(OH).CH_2(NH_2).COOH$, β-oxyphenol-amidopropionic acid, is also a constant product of the putrefaction of albuminoid substances, and has been said to be strongly antiseptic. It crystallises in minute needles, which are inodorous, almost tasteless, and nearly neutral. It seems to be worthy of experiment.

QUINOLINE DERIVATIVES.

Quinoline, chinoline, or "leucoline," C_9H_7N, is a colourless, highly refracting, oily liquid of a disagreeably pungent and aromatic odour, and a bitter acrid taste. In light and air it rapidly turns brown. It melts below 4° C., boils at 237° C., and has a specific gravity of 1·081.

It dissolves sparingly in water, easily in alcohol, &c., to an alkaline solution, and with acids forms soluble crystalline salts. The salicylate and tartrate have been used in medicine, both internally and externally. Quinoline occurs in coal-tar, &c., with two homologues,

* Patent No. 3,053, 1883. † Patent No. 3,199, 1883.

‡ *Zeit. f. Hyg.*, 1887, vol. xi., p. 52.

lepidine, $C_{10}H_9N$, B.P. 265°, and cryptidine $C_{11}H_{11}N$, B.P. 274° C. Quinoline is incompatible with oxidants, with iodine solutions, and with metallic salts; it is antiseptic, and is the subject of the following patent*:—"It has been proved that quinoline and toluquinoline possess great antibacterial properties, but the complete insolubility of these substances in non-acid fluids presented a serious obstacle to their use. This invention consists of using as a solvent soap in the nascent state," as in creolin, &c., "50 kilos. of castor oil, 50 of quinoline, by the clearing of the liquid, which is then diluted with 85 kilos. of water." Quinoline does not saponify, so that the solution would contain 20 per cent. of quinoline dissolved in aqueous soap, and would become turbid with water like creolin.

"**Diaphtherin**" was introduced by Prof. Emmerich and Kronacher, of Munich,† who, after extended trials, pronounced it to be "equal, if not superior, to previously known antiseptics." It is said to be di-oxy-quinoline phenolsulphonate, $2C_9H_6(OH)N,C_6H_4(OH).HSO_3$. (*Ortho-phenol-sulphonic acid*, or "aseptol," p. 158.) It is a yellow powder, readily soluble in water, decomposed by alkalies and even by blood, with elimination of sparingly soluble oxyquinoline in a fine state of division; hence, when applied to wounds, it does not lose its antiseptic power as some phenolic substances do (it does not coagulate albumen). Emmerich administered 0·25 gramme subcutaneously to guinea pigs, without prejudicial results. "A 1 per cent. solution is sufficient for antiseptic dressings."

α-**Oxy-quinoline** or carbostyrile, $C_9H_6(OH)N$, occurs in white needles, melting at 198°, and is strongly antiseptic. It is the source of:—

"**Loretin**," iodo-oxy-quinoline sulphonic acid, $C_9H_5I(OH)N.HSO_3$, lately introduced as another substitute for iodoform, and reported on by Prof. Schinzinger, of Nuremberg. He showed that its action on granulating and healing processes is a very favourable one, and is superior to that of iodoform, while it is free from objectionable odour, not toxic, and non-irritant, and rapidly removes any eczematous tendency. It is also a good deodorant of purulent secretions and decomposing tissues. "It is very beneficially employed to combat external and parasitic diseases, and as an antiseptic may be blown into cavities for internal affections."

Quinoline when reduced forms a tetrahydride, $C_9H_{11}N$, which is more strongly antiseptic than quinoline.

"**Thalline**" is para-methoxy-quinoline tetrahydride, $C_9H_{10}(OCH_3)N$. According to the specifications (*Skraup*, 1885) it is made like quinoline,

* No. 18,913, 1891; *Lembach, Schleicher, and Wolff.*
† *Munch. Med. Wochenschr.*, 1890.

by heating methoxy-aniline (para-amido-anisol) with glycerine, sulphuric acid, and paranitro-anisol, and then reducing to the tetrahydro-compound. It is an oily liquid, easily frozen, and then only re-melts at 180°, with a strong odour like Tonka beans, and soluble in acids to form crystalline salts. Ferric chloride produces an intense green colour, hence the name (θαλλός, a green twig).

The sulphate and tartrate are found in commerce as yellowish-white crystalline powders, soluble in about 7 and 10 parts of water, sparingly in alcohol. They are acid, fragrant, and bitter, and darken in light.

In a paper by H. Schultz "On the Influence of Thalline Salts on Putrefaction and Fermentation,"* he states that "0·5 per cent. of thalline sulphate in sterilised gelatine prevented the further putrefaction of meat. Yeast fermentation was considerably retarded by 1 per cent. of thalline tartrate; with a less quantity, however, the activity was increased," probably by supplying nitrogenous food to the fungus. It must be observed that the agent would not answer for a food-preservative, on account of its taste, odour, and physiological action. Thalline was at first extolled as a substitute for quinine, 2 to 8 grains of sulphate or tartrate being given in aqueous solution, but the salts are poisonous to the red blood corpuscles and act on the nerve centres (*Brouardel*). As antiseptics they are still occasionally used for injections (4 to 8 grains to the ounce) in gonorrhœa.

Quinine, $C_{20}H_{24}N_2O_2,3H_2O$, appears to be a derivative of a partially hydrogenised di-quinoline, and to have the formula

$$C_9H_6(OCH_3)N - C_9H_{11}(OH)N.CH_3,$$

although it has not yet been synthesised.† Its action against fevers is probably as much due to its antiseptic power as to its effect on the nervous system. The natives of Peru were in the habit of purifying the water of fetid pools by throwing in logs of cinchona (*Humboldt*), but the tannin would also take part in this treatment. Koch observes: "The dose of quinine necessary to destroy the spirilla of relapsing fever would be 12 to 16 grammes, which would kill the host as well as the parasite." A much less dose is sufficient to restrain the spirillum.

Antiseptol, iodo-sulphate of cinchonine, contains 50 per cent. of iodine, and is said by Yvon ‡ to be a powerful antiseptic for surgical use. It must not be confounded with other antiseptics having a similar name.

* *Centr. Med. Wissensch.*, 1886, p. 113.

† Liebig's *Annalen*, vol. cciv., p. 90.

‡ *Amer. Journ. of Pharm.*, Oct., 1890.

CHAPTER X.

ORGANIC COMPOUNDS (*continued*).

ACIDS DERIVED FROM BENZENE.

Benzoic Acid: Its Use as an Antiseptic—Benzo-boracic Acid, &c.—Benzoic Aldehyd, or Oil of Bitter Almonds—Sulpho-benzoic Acid—Benzosol—Benzo-paracresol and Benzo-naphthol. **Salicylic Acid**: Its Three Isomerides—Salicylates—Oil of Wintergreen—Salol—Salophen—Phenosalyl—Antiseptic Value of Salicylic Acid—Patents—"Lactacidine"—The Use of Salicylic Acid for Preserving Food—Objections—Tablets, Gauze, &c.—Anisic Acid—Cinnamic Acid, Styracol—β-Phenyl Propionic Acid—Phenyl Acetic Acid—Gallic Acid—Tannin—Diphenyl Derivatives—Styrone—Sodium Dithiosalicylate. **Thymol, Camphors, and Essential Oils**: The Terpenes, their Properties and Products of Oxidation—Turpentines—Camphors—*Thymol* Aristol—Europhene—Menthol—*Oil of Cloves*, Caraway, Hops, &c.—*Terebene*, Oil of Eucalyptus—*Camphor*, Personal Use—Patents—*Eucalyptol*—Eucalypto-resorcin—Myrtol—Terpin Hydrate—Terpinol—Absynthol—Caryophyllin—Eugenol—Borneol—Various Patents—Camphoid—Combining Disinfectants with Soda Crystals—Bases of Powders—The Oxidising Power of Essential Oils—Ozone Test—*Sanitas*, Sanitas Oil—Value of Sanitas as a Disinfectant—Camphoric Acid—"Pinol."

BENZOIC ACID GROUP.

Benzoic Acid, $C_6H_5.CO.OH$, exists in gum benzoin, balsams of Peru and Tolu, and several aromatic gums that have been used for ages for enbalming. It is made by acting on boiling toluene, $C_6H_5(CH_3)$, with chlorine, and oxidising the benzyl chloride, $C_6H_5.CH_2Cl$, with nitric acid. It melts at 121° C., boils at 250° C., but sublimes slowly with a pungent, aromatic odour, even at ordinary temperatures. It is sparingly soluble in cold water, yielding an acid solution of pungent, disagreeable taste. It acts as a stimulant, expectorant, diuretic, and is strongly antiseptic both as solid, solution, and vapour, and even in its salts.

Salkowski,* in a number of experiments with meat juice inoculated with putrid fluid, showed that benzoic acid, in a dose smaller than salicylic, prevented for a long time the putrefaction of the mixture and the development of bacteria. Bucholtz † found that 1 in 1,000 stopped the growth of micro-organisms. Haberkorn did not succeed

* *Ueber die antisept. Wirkung d. Salicylsäure und Benzoesäure, Berlin Klin. Wochenschr.*, 1875, p. 22.

† *Archiv. f. exp. Pathol.*, 1875, vol. iv.

with the bacteria of urine with less than 1 in 400. Jalan de la Croix,* in seventy-four experiments with varying quantities, showed that the least quantity that would prevent bacterial growth from being inoculated into a fresh liquid (beef tea) was 1 in 2,800. To kill bacteria he required 1 in 410, and to sterilise spores 1 in 50. As regards non-organised ferments ("enzymes"), Wernitz † declares that pepsin is neutralised by 1 in 200, and others by 1 in 300, of benzoic acid or benzoate of soda.

Graham Brown ‡ stated that sodium benzoate was superior to quinine hydrochloride and sodium salicylate in destroying the virus of diphtheria; he believed even that by saturating the human system with benzoic acid by repeated hypodermic injections, it was rendered almost insusceptible of inoculation with diphtheria.

In disorders of the bladder, attended by ammoniacal urine, Gosselin and Robin § proved that benzoic acid taken internally rendered the urine acid, preventing the precipitation of insoluble phosphates, and the formation of carbonate of ammonium and poisonous salts by the urinary bacteria, and also diminished the amount of urea excreted. Therefore, Frerichs introduced it successfully for uræmia. They use 1 to 4 grammes per day dissolved in glycerine and water.

Vallin states ‖ that "in most cases, to destroy definitely and without return germs transplanted from a sterilised liquid into the midst of an appropriate culture fluid, the proportion of benzoic acid should be 1 in 77, or even 1 in 50." This would make it rather more potent than phenol, cresol, or other similar compounds. It is not poisonous; Prof. Senator, of Berlin, gave as much as 50 grms. of sodium benzoate a day to a patient with acute rheumatism, without ill effect. As much as 1 oz. of ammonium benzoate per day can be taken without any noticeable effect, and is excreted as hippuric acid in the urine.

In those cases in which the odour and taste is immaterial, a saturated solution of benzoic acid in water delays the putrefaction of animal matters much more effectively than salicylic. It has less effect on vegetable effusions. It is also useful for preventing fats from becoming rancid. Added to milk, a very small quantity prevents coagulation.¶

Benzoic acid and benzoates are ingredients in many antiseptic mixtures, as, for example, the following complex receipt:—"Antiseptic pastilles for use in diphtheria are made by incorporating boric

* *Archiv. f. exp. Pathol.*, 1881, vol. xiii., p. 175.

† Dorpat Essay, 1880. ‡ Kleb's *Archiv.*, vol. viii., p. 140.

§ *Arch. genérales de Méd.*, 1874, vol. xxiv., p. 566. ‖ *Désinfectants*, p. 202.

¶ Horn, *Zeitschr. f. Chem. Industr.*, vol. ii., p. 329, 1888.

acid and borax, each 20 grms.; citric acid, 12·5 grms.; sodium benzoate, 1 grm., with glycerine and water as solvents, and gum, sugar, and gelatine as bases, and dividing into 500 pastilles." * Dr. Miller states that by using the following mixture he could completely sterilise the mouth and cavities in carious teeth :—"Thymol 4 grains; benzoic acid, 45 grains; tincture of eucalyptus, 3½ drachms; water, 25 ozs." †

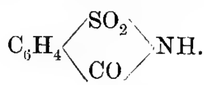
By heating benzoic with boracic, tartaric, or citric acid, double compound acids called benzo-boracic, &c., are formed, which are, of course, antiseptic, and are mentioned in some of the older patents.

Although the benzoic acid is thus rendered much more soluble, and its taste is in great part disguised, it frequently crystallises out, and hence these compounds are now seldom heard of. This separation also makes them irritant to wounds and mucous surfaces.

Listerine contains 2 grains of benzo-boracic acid in each fluid drachm, together with the essential oils of thyme, eucalyptus, *Baptisia*, *Gaultheria*, and *Mentha arvensis*.

Benzoic aldehyde, or benzaldehyd, $C_6H_5 . CO . H$, occurs with hydrocyanic acid in oil of bitter almonds. Angus Smith ‡ considered it a little below phenol in antiseptic power. It readily oxidises to benzoic acid, is sparingly soluble (1 in 30), and is of no hygienic use except in ointments, when the crude oil is very effective against eczema, irritation, and parasites, partly on account of the prussic acid it contains. Obviously the skin must not be broken.

Sulphobenzoic acids, $C_6H_4(HSO_3)(CO.OH)$, of which there are three isomers, made by the action of oil of vitriol on benzoic acid, are very soluble, and have an acid and bitter taste. They and their salts are antiseptic.§ The derivative "**Saccharin**," benzoyl-sulphonicimide, is also sometimes used as a preservative. It has the constitution,



The mixture of sodium salts are met with as an antiseptic under the name of **sodium sulphobenzoate**.§

Benzanilide is a weak antiseptic used as an antifebrile.

"**Benzosol**," or benzoyl-guaiacol, $(C_6H_5)CO.O(C_6H_4.OCH_3)$, is obtained from benzoyl chloride and sodium guaiacol. It is a crystalline powder, colourless, almost free from taste and smell, insoluble in water, easily soluble in alcohol, and melts at 50° C. It is said to combine the effects of guaiacol (p. 175) and benzoic acid without any disadvantages, and to be very useful in tuberculosis, facilitating expectoration and

* *Year-Book of Pharmacy*, 1889. † *Chem. and Drug.*, 1887, p. 83.
‡ *Disinfectants*, Edinburgh, 1869. § *Journ. Soc. Chem. Ind.*, 1888, p. 226.

rendering the sputum free from bacilli. Prof. Sahli, however, remarks that the commercial article is of varying composition, that he found some specimens inert, and that "as the effect of guaiacol and creosote were due to local antiseptic action in the stomach, benzosol could not take their place." It is used largely in diabetes mellitus.

Benzo-paracresol, $C_6H_3(C_6H_5.CO)(CH_3).OH$, is an antiseptic prepared by the action of sodium benzoate on paracresol (p. 164), in presence of oxychloride of phosphorus. It occurs as a crystalline powder almost insoluble in water, but soluble in alcohol (0·15 per cent.). It melts at 71° C.*

Benzo-naphthol, $C_{10}H_7O.CO(C_6H_5)$, from β-napthol, melts at 110° C., and has also been proposed for internal antisepsis.

SALICYLIC ACID.

There are three isomeric oxybenzoic acids, of which only the ortho-compound, called salicylic acid, $C_6H_4(OH).COOH$, is of practical importance. It is met with in minute white needles or prisms, of pungent odour and sweet taste (inodorous when pure, *Charteris*), soluble in 500 parts of cold, and 15 of boiling water, in 7 of alcohol, 3 of ether, and 50 of glycerine. When heated quickly it breaks up into phenol, which distils, and carbonic acid. The same decomposition occurs in the human system, as phenol appears in the urine. It is antiseptic and antipyretic.

J. B. Duggan found that it was twice as powerful an antiseptic as the corresponding para-oxy-benzoic acid, whilst the meta-acid had intermediate properties.†

"Artificial" salicylic acid (from sodium phenate and carbonic acid) is somewhat more toxic in its action than the pure "natural" acid obtained from oil of wintergreen. This is due to two foreign acids, isolated by Williams in 1878, and found by Dunstan and Bloch ‡ to be ortho- and meta-cresotic acids, $C_6H_3(CH_3)(OH).COOH$, derived from the cresols contained in the crude phenol from which the salicylic acid had been prepared. Schering and others now prepare a pure artificial acid from pure phenol, which is free from these impurities, and acts in the same way as the natural acid. It melts at 156·7° C. It gives a purple colour with ferric salts, therefore cannot be prescribed with them. It is not corrosive, and does not coagulate albumen.

The salicylates are much more soluble. Salts of nearly every metal have been prepared and recommended for various uses; but sodium salicylate, $C_6H_4(OH).COONa$, is the most usual one.

* *Revue de Chim. Industr.*, April 15, 1893. † *Am. Chem. Journ.*, vol. vii., p. 62.
‡ *Journ. Chem. Soc.*, April, 1891.

Oil of Wintergreen, *Gaultheria procumbens*, is methyl salicylate, $C_6H_4(OH)COO(CH_3)$. It is a colourless, fragrant liquid, sparingly soluble in water, but easily in alcohol, and also in alkalies. Specific gravity, 1·18; boiling point, 222° C.

Perier, of the hospital of St. Antoine, Paris, substituted this oil for phenol in surgery, using a mixture which was perfectly miscible with water:—Oil of Wintergreen 30 grammes, tincture of quillaia 6 grammes, water 1 litre. Gosselin and Bergeron* found that the oil, both as a solution and as vapour, hindered the putrefaction of blood, and that it was neither irritant, nor of disagreeable odour. It is still used in France for dressings, but is inferior to phenol and other agents in power. It does not coagulate albumen, and is not poisonous.

"**Salol**," Phenyl salicylate, $C_6H_4(OH).COO(C_6H_5)$, is made from sodium phenol and sodium salicylate by heating with phosphorus oxychloride. It is a white crystalline powder, melting at 42° C., with a faint aromatic odour, practically tasteless, neutral, insoluble in cold water, soluble in 15 parts of rectified spirit, in 3 of ether, and very soluble in chloroform and in oils. Antipyretic and antiseptic, it passes through the stomach unchanged, to be decomposed in the duodenum into phenol and salicylic acid.† It is used in diarrhœa, dysentery, cholera, &c., as an internal antiseptic, also as an injection in gonorrhœa and cystitis. It has been employed externally as a substitute for iodoform in skin and nasal diseases. Löwenthal ‡ has shown that salol will kill cholera bacilli in a paste containing pancreatic juice. Spirituous solutions (5 per cent.) are employed with various flavouring agents for mouth-washes and dentifrices, toilet-powders, and soaps. When melted with camphor, salol, like many other substances, forms a permanent liquid which has also been used to replace iodoform.§

"**Salophen**," $C_6H_4(OH)(COO.C_6H_4.NH.CO.CH_3)$, an imido-compound formed by heating salicylic acid with phosphorus oxychloride and para-nitrophenol, reducing and acetylating, resembles the preceding in properties, but is said to have rather stronger antiseptic power. M. P. 188° C. It has not been much used, and is expensive.

Cresyl Salicylates.—The three cresols form corresponding salicylates, and have been proposed as internal antiseptics.

Betol, salinaphthol, or naphthosalol, is a β-naphthol salicylate, and has already been described under **Napthol** (p. 179).

Salbromanilide is said to be a mixture of bromacetanilide and salicylanilide.

Salipyrin is a compound of antipyrin and salicylic acid.

* *Arch. général. de Méd.*, 1881, p. 16. † *Brit. Med. Journ.*, 1887, vol. xi, p. 1438.
‡ *Comptes Rendus*, vol. cvii., p. 1169. § *Répertoire*, 1889, p. 185.

Phenosalyl is a mixture of phenol, salicylic, benzoic, and lactic acids, made by heating them together at 140° C., adding menthol and eucalyptol, and, after, cooling, adding four times the volume of glycerine. It is a clear, syrupy liquid, of sweetish taste. It is easily miscible with water or alcohol, is not poisonous, and has a pleasant and non-persistent odour, which does not cling about the hands and clothes. The solutions have no corrosive action on the skin, the mucous surfaces remain smooth and slippery, and do not become dried up, as is the case after washing with carbolic acid or "corrosive sublimate." Of course, this latter advantage belongs to the glycerine, and would equally pertain to phenol or mercuric chloride in the same medium.

Prof. Fränkel,* in a series of bacteriological trials, found that phenosalyl possessed an antiseptic power superior to phenol in dealing with the micro-organisms of cholera, anthrax, pneumonia, typhus, diphtheria, tuberculosis, *Bacillus pyocyaneus,* and *Staphylococcus pyogenes aureus.* "It is well known that the last-mentioned bacterium is one of the most resistant, but even a 1 per cent. solution of phenosalyl is sufficient to kill it, while to produce the same effect with carbolic acid one must use a $2\frac{1}{2}$ per cent. strength, and the exposure or contact must be continued for a longer period." Phenosalyl has been used by Duloroy in the sterilisation of instruments, of gauze, and of different organic substances like blood, as well as decomposing urine and the saliva of consumptives with most encouraging results. It does not corrode nor discolour metals under ordinary circumstances of contact.

This is an example of a mixture which seems to present great advantages. Of late years there has been a tendency to use complicated compounds, most of them only soluble in alcohol, which, apart from expense and other faults, is inadmissible as a medium for many purposes. It should be noticed that while in mixtures the properties of the ingredients are mostly retained, in many of these compounds not only are the properties lost, but frequently new and objectionable ones are developed. For example, the desire to avoid the unpleasant odour of iodoform has led to the introduction of many "substitutes" which are costly, unstable, uncertain, and even dangerous in their action.

However, phenosalyl may be reckoned as a convenient preparation of the above aromatic acids dissolved in lactic acid and glycerine, and scented with menthol and eucalyptus. The name is rather an unfortunate one, as leading to a wrong idea of its composition.

Salicylic acid is by no means an innocent remedy. In fact it can be a powerful poison, as it has a disintegrating action on the blood corpuscles. The salts cause albuminuria, hence, must be irritating

* *Bacterienkunde*, Berlin, 1890.

to the kidneys, probably through phenol being formed.* The acid, in strong (alcoholic) solutions, or in ointments, is so caustic that it is the basis of most of the popular cures for corns.† As to dilute solutions, Dr. Bond, of Westminster Hospital, states that "when in the country he has been in the habit of taking 10 grains daily for a month without bad effect," obviously as an anti-malarial. The official dose of the acid is 5 to 30 grains. Dr. Brouardel has noticed daily doses of 2 grammes to produce grave symptoms of intoxication and poisoning. Kolbe ‡ first drew attention to the antiseptic properties of salicylic acid. He showed that it prevented the action of enzymes (unorganised ferments), like diastase, emulsin, and that of mustard, also gastric digestion, fermentation by yeast, ammoniacal fermentation of urine, and the germination of seeds. H. A. Weber § and Leffman and Beam || proved that a solution of 1 in 420 of salicylic acid, completely checked salivary and pancreatic digestion of starch, and that even 1 in 840 had a marked depressing influence.

As to the strength required for killing bacteria, it has been variously given by different observers. Ratimoff ¶ uses 1 in 400, practically a saturated solution in water and a little spirit; Jalan de la Croix,** 1 in 200 for milk, and more than 1 in 35 for germs in meat juice; Bucholtz,†† 1 in 362; and Kühn, 1 in 200 for germs in albumen solution. As to salicylate of soda, the necessary dose is stated as 1 in 100 by Miquel, and 1 in 161 by Bucholtz.

Vallin ‡‡ points out that "this action on ferments and microbes is often only temporary; the ferments and bacteria rapidly become used to their new surroundings, and the generations that succeed resist doses that had been fatal to their ancestors, and the work of fermentation goes on again at the end of a few days. Neubaur and Bechamp have specially proved this curious phenomenon of the habituation of ferments to progressive doses of phenol and salicylic acid. It follows that, to obtain a durable antiseptic effect, we must at frequent intervals add new and increasing doses of the agent. For this reason, in alcoholic beverages, which can only be preserved by the aid of salicylic acid, the dose of this substance sometimes reaches as much as 1·5 grammes per litre. Even then experience has shown that poor wines and ciders soon undergo fresh fermentation of acid or putrid character.

* See a paper by Dr. Squire on the "Physiology and Therapeutics of Salicylic Acid," *Lancet*, Dec. 20, 1879.

† Whelpley, *Chem. and Drug.*, Aug. 16, 1890.

‡ *J. für Pract. Chem.*, 1874, vol. x., p. 89.

§ *Journ. of Amer. Chem. Soc.*, 1892, p. 4.

|| *Journ. Soc. Chem. Ind.*, 1888, p. 582.

¶ *Bied. Centralblatt*, vol. xiv., p. 360.

** *Arch. exp. Pathol.*, 1881.

†† *Ibid.*, 1875.

‡‡ *Désinfectants*, p. 182.

Salicylic acid, then, is a convenient antiseptic, but it gives no absolute guarautee, and its power is limited."

The very sparing solubility of salicylic acid in water has led to a variety of devices for increasing it. Alcohol is in many cases unsuitable; glycerine only dissolves 2 per cent.; alkalies form salicylates, which, although soluble, have only about one-third the antiseptic power of the free acid. Borax solution dissolves a large quantity of salicylic acid, forming a loosely-combined crystalline compound, inodorous, neutral, and of little taste, called borosalicylate of soda. It is much more soluble, and is more antiseptic than either of its components (see under *Boric Acid*, p. 102).

Offen and Moore,* "to prevent the second fermentation of yeast or other ferment when combined with wheat or other cereal for food," use 10 parts of salicylic acid, 3 of boric, and 4 of borax, dissolved and mixed with the grain either whole or ground; "yeast is then added, and the dough baked as usual."

Lactacidine solution contains 2·65 per cent. lactic acid, and 0·35 per cent. salicylic acid, "to which other materials, such as sugar or glycerine, may be added." It is used for preserving articles of food—*e.g.*, butter. It may be removed by washing before use.†

Salicylic acid is largely used for preventing loss of material, and consequent annoyance with fruit; 4 to 8 grains of the acid to the pint or lb. prevent fermentation in saccharine liquids; and jams, preserves, &c., can be kept for years. "As a preservative it is best applied in process of preparation. It is advisable to gradually introduce it in the solid state into the boiling mass" (but it somewhat readily volatilises with the vapour of water), "constantly stirring, or the acid may be rubbed down with the fruit juice, and then added. In any case the finished product ought not to show any white flocks." Another mode is to pour over the cold uncooked fruit the cold salicylated juice of the same fruit, so that the fruit is entirely covered. A cold juice may be made by pressing the fruit, adding to every pound 15 grains of the acid, heating the juice, and allowing to cool. In this way, cherries, plums, &c., can be preserved all the winter uncooked, and are then suitable for pies. The last of the above processes seems better than the others, since almost all the salicylic acid can be removed by washing the fruit before cooking.

Salicylic acid is very largely used for perishable articles of food. Many preparations, more particularly of salicylic and boric acids, are sold as "lard bleachers," and "fruit, wine, and cider preservatives." Most authorities agree that it is a most objectionable preservative, especially in milk which is destined for young children. Powdered

* Patent No. 16,592, 1887. † *Grosfils*, Patent No. 2,235, 1887.

salicylic acid, that has been used for hams, fish, &c., is mostly washed off, but when mixed with, or allowed to penetrate the food, chronic dyspepsia and other symptoms would certainly be caused by the relatively large quantities that would accumulate in the system. There seems evidence to show that, like lead and arsenic, it has a cumulative action. Vallin,* in an exhaustive discussion of this point, shows that if a man consumes an average quantity of salicylated foods and drinks as met with in France (he gives tables of the amount customarily added to a number of foods) he would absorb per day 3 grammes of salicylic acid. He observes that it is nefariously used to secure the disposal of inferior articles that would not otherwise be saleable. In 1880 the French Committee of Public Hygiene, after the matter had been fully reported upon by M. Dubrisay, passed, on Feb. 7, 1881, the following edict which is still in force :—

"*Est interdite la vente de toute substance alimentaire, liquide ou solide, contenant une quantité quelconque d'acide salicylique ou d'un de ses derivés.*"

At the present day, food arriving at the city barriers, if it should be adulterated, and especially with salicylic acid, is seized, and its owner punished.

K. Portele says † that salicylic acid cannot be considered a success as a preservative either for butter or milk, as it gives to them an unpleasant sweetish odour, which increases until decomposition takes place.

H. A. Weber ‡ and Dr. H. Vogel § strongly condemn the practice of adding preservatives to food, proving that it interferes with digestion. Nessler observes that "salicylic acid is not a natural constituent of any food, and its addition is a fraud on the quality." He, with Vogel, Pasteur, and others, demanded that the addition of any quantity of this acid to wine should be mentioned on the bottle. The German Government seem to be yet undecided.

In England, although a few trifling increases of fine have followed the finding of salicylic acid by public analysts in milk where there was added water also, it seems to be recognised as a customary addition to syrups and to "British wines." In a test case at the Great Marlow Petty Sessions, a grocer was prosecuted for selling raspberry wine adulterated with salicylic acid. For the defence two analysts swore that salicylic acid "was absolutely necessary to preserve the wine," and that it was "quite innocuous." In the result the case was dis-

* *Désinfectants*, pp. 189 to 193.
† *Landw. Versuchs. Stat.*, vol. xxvii., p. 143.
‡ *Journ. Amer. Chem. Soc.*, vol. xiv., pp. 4-14.
§ *Deutsche Viert. f. öff. Ges.*, 1880, p. 402.

missed. If wines be carefully made, they can be sterilised without any drug, and will keep for a reasonable time after opening.

Among special salicylic acid preparations the following may be noticed:—

Solution for Local Antisepsis.*—Water, 1,000; boric acid, 12; salicylic acid, 2.

In Patent No. 15,564, 1887, Boake and others show that "sodium sulphite dissolves one-sixth of its weight of salicylic acid;" they propose to make such solutions with any alkaline sulphites or bisulphites for antiseptic purposes.

"**Stroch's Antiseptic Paper.**"—See p. 142.

Antiseptic Tablets.—"(1) For Thiersch's solution, much used in many modern operations, Adolph Levy, of Brooklyn, N.Y., recommends 14 grains of 'resublimed' salicylic acid and 84 grains of pure boric acid, to be compressed into a tablet, which is dissolved when required in 16 ounces of hot distilled water.† (2) Warner & Co. make pastilles of sodium bicarbonate, biborate, benzoate, and salicylate, with menthol, eucalyptol, and oil of wintergreen. One of the pastilles gives 2 ounces of a solution to be applied as spray in nasal catarrh." "Strongly deodorant as well as antiseptic."‡ (3) Sacker, 79 Fenchurch Street, make tablets of similar composition, "to be each dissolved in two quarts of water."§

Salicylated Gauze.—Gauze washed with soda to remove grease, then in succession with water and acidulated water, then bleached by chloride of lime and weak acid, and finally well washed with water and dried. Next soaked in a solution of salicylic acid, 5·6 parts; glycerine, 15; rectified spirit, 50; distilled water up to 100 parts; drained, nearly dried by a current of sterilised warm air, rolled or folded by machines previously made aseptic. The finished gauze is packed in cylinders freshly lined with melted paraffin sterilised by heat. The gauze is thus kept permanently slightly moist.|| Contact with iron must be avoided, or purple stains result.

Anisic Acid or para-oxymethyl-benzoic, $C_6H_4(OCH_3)COOH$, occurs in colourless prisms, melting at 175° and distilling at 280° C. The sodium salt was recommended by Curci in 1887 as antiseptic and antipyretic, in doses of 15 grains. It was said to be analogous in action to sodium salicylate, but without disturbing influence on digestion.

Cinnamic Acid, $C_6H_5.CH:CH.COOH$, also met with in prisms, is

* Carcano and Cesares, *Revue de Chim. Indust.*, April 15, 1893.

† *Chem. and Drug.*, vol. xxxviii., 1891.

‡ *Lancet*, vol. xi., 1890.

§ *Lancet*, vol. xi., 1889, p. 174.

|| Seward Williams, *Chem. and Drug.*, May 27, 1893.

more soluble; melts at 133°, boils at 290° C. It is somewhat strongly antiseptic.

Styracol or cinnamyl-guaiacol, $C_6H_5.CH:CH.COO(C_6H_4.OCH_3)$, occurs in needle crystals; is said to be a strong antiseptic in catarrh of the bladder and intestines, and in phthisis; soluble in alcohol.*

β-Phenyl-propionic Acid or hydrocinnamic acid, $C_6H_5.CH_2.CH_2.COOH$, is formed in the decay of albuminous matter, and, like other similar products, is a bactericide. It forms fine needles, moderately soluble, melting at 47° and boiling at 280° C. Klein regards this and phenyl-acetic acid, $C_6H_5.CH_2,COOH$ (sparingly soluble pearly plates, melting at 76°, boiling at 262°, strong odour of burning urine), as among the strongest of disinfectants. Laws has studied the next acid in this series (see p. 159).

Gallic Acid, trioxybenzoic, $C_6H_2(OH)_3,COOH$, is astringent and feebly antiseptic. It occurs in sparingly soluble inodorous needles.

Tannin, gallotannic acid, $C_{14}H_{10}O_9,2H_2O$, is an amorphous powder, usually brownish, very soluble, and strongly astringent. It is well known to precipitate gelatin, and to form a compound with skins which is imputrescible (leather). It also coagulates albumen. Therefore it is, in some sense, antiseptic, but Gosselin and Bergeron,† having added to 2 grammes of fresh blood 8 drops of a 10 per cent. aqueous solution of tannin, saw vibrios appear in the mixture on the fourth or fifth day—that is to say, almost as soon as they would without any antiseptic. Gubler and Bordier ‡ state that a horse which for many days had received doses of 20 grammes of tannin, remained with its blood unputrefied till the fifth day after death.

There are many varieties of tannins from many different plants, but none of them have even the power to preserve their own solutions.

Styrone forms silky white crystals of a sweet taste, and having an odour like hyacinths. It is soluble in 12 parts of water, and easily in alcohol. The saturated aqueous solution has been recently found in America to be a perfect deodoriser of a foul ulcerated surface, and to cause no irritation. As an antiseptic it is said to exceed thymol. This explains the healing properties long attributed to tincture of benzoin, of which liquid storax is a constituent.

Sodium Dithiosalicylate "No. 1," $\begin{array}{l} S.C_6H_3(OH).COOH \\ | \\ S.C_6H_3(OH).COOH \end{array}$, has only recently been brought under notice as a powerful antiseptic. In a 15 per cent. solution the most resistant bacilli are easily destroyed in from twelve to fifteen minutes. In a severe case of ozœna it effected

* A. Haas, *Sudd. Apoth. Zeit.*, 1891, p. 55. † *Arch. de Méd.*, 1881, p. 16.
‡ *Bull. de Thérapeut.*, 1873, vol. lxxxiv., p. 265.

a complete cure in a relatively short time. In 2½ to 5 per cent. solution this preparation is reported to have yielded most strikingly beneficial results in the treatment of foot-and-mouth disease, in which its further trial would seem to be very desirable.*

THYMOL, CAMPHORS, AND ESSENTIAL OILS.

From the time of the ancients it has been known that this class of aromatic bodies had a prophylactic action against fevers, and were of value in purifying air, and as insecticides. Precious woods were those which contained essential oils, like sandal-wood and cedar; they were used in constructions wished to be imperishable, and for boxes to contain valuable tissues and documents. They were burnt for fumigations to drive away diseases, they were carried about the person, they were thrown as logs into water, and mixed in wines and possets. The ancient classic wines had generally a strong resinous flavour, due to the admixture of herbs, and even to a trace of wood-tar purposely added to the grapes to check objectionable fermentation, also to bitumen on the stoppers, so that, apart from the agreeable odour, there was also a real sanitary use for perfumes. A large number of patents for disinfection contain aromatic gums and resins as adjuncts. It is well known that these were used with bitumen for embalming, and bodies have been preserved in this way. The result, however, was in great part due to desiccation and protection from the air.

Musk, which seemed to give some relief in plague cases at Hong Kong, has been successfully used in large doses for cholera by Monsiorski.†

These odorous principles are divided into two classes:—

CLASS I.—HYDROCARBONS, composed of carbon and hydrogen only. They mostly belong to the terpene group, $C_{10}H_{16}$, or derivatives of it. This formula includes the liquid portions of the oils of thyme, orange, lemon, savine, turpentine, juniper, hop, cloves, camomile, and the majority of others. It will be noticed that the use of condiments may be explained on the assumption that they are all (including salt, mustard, and vinegar) antiseptic and preventive of fermentation, hence germs in the alimentary canal have their action arrested. Oils of capivi and cubebs, probably affecting micro-organisms in the urinary tract, have the polymeric formula, $C_{15}H_{24}$, as proved by their vapour density. Cedrene, from cedar, is said to be $C_{16}H_{26}$, hence would not be a terpene. Menthene from peppermint is $C_{10}H_{18}$. The cause of the differences in odour of these different compounds of the same formula is not yet entirely known, but in many cases the difference is due to physical isomerism. All are liquids with boiling points much

* Helbing, *Med. Materia Medica*, p. 90. † *Prov. Med. Journ.*, Feb., 1894.

higher than that of water (mostly 160° to 180° C.), yet they emit at ordinary temperature minute quantities of strongly scented vapour, and are readily volatilised with steam. Their specific gravity is usually less than that of water (0·83, orange, to 0·94, caraway), and they are almost insoluble in it; they are readily soluble in alcohol, forming "essences," and in other hydrocarbons and in fatty oils. When fragrant plants are distilled with water the essential oils float on the surface of the distillate, while a small proportion dissolves to form the "distilled waters" of pharmacy, all of which are mildly antiseptic.

Both the essential and the fatty oils produce a greasy spot on paper, but the spot produced by the former gradually disappears, whereas that of the latter remains fixed, so that the presence of adulteration can be easily detected.

The essential oils neither combine with, nor dissolve in, alkalies; yet, if they be present when resins or fat are saponified, a large proportion remains dissolved in the soap, and is only liberated on dilution with water, when an emulsion similar to those obtained with tar oils is formed.

Chlorine, bromine, and iodine act on most of the essential oils (iodine at first merely dissolves), giving compounds in which the halogen displaces one or more atoms of hydrogen, at the same time the odour is much affected, becoming gradually pungent. Excess of chlorine breaks them up entirely into hydrochloric acid and carbon. Therefore they are not suitable for use with the halogens. The antiseptic or disinfectant properties of substituted essential oils are not well known, but there is no evidence to indicate their utility.

The terpenes rapidly absorb dry hydrochloric acid gas, yielding compounds called artificial camphors; some of them are crystalline, and in appearance and properties much resemble natural camphors. Patents have been taken out for these products, but they have not hitherto been of much value. The artificial camphor obtained from oil of turpentine is the best known.

Artificial camphors are only formed from the terpenes by slow combination with water.

Turpentines.—When an incision is made in a pine tree, a resinous fluid flows out, which is mainly a solution of various resins in the hydrocarbon, $C_{10}H_{16}$, called "oil or essence of turpentine." "Common turpentine" comes chiefly from *Pinus abies*, "Venice turpentine" and "Bordeaux turpentine" from *Pinus maritima*, and "Chian turpentine" from *Pistacia lentiscus*. They are somewhat different in antiseptic value, but different specimens vary among themselves.

By distillation with water, about one-fourth (the essence) passes over with the steam, while three-fourths remain behind as rosin. The latter has no antiseptic power, but is used as an adjunct or medium in a large number of organic disinfectants (Jeyes, &c.).

"Camphine" is the oil of turpentine from *Pinus australis.* Letheby found that 1 in 4,000 of oil of turpentine in air prevented necrosis.

CLASS II.—OXIDISED COMPOUNDS, such as camphor, thymol, &c., are crystalline solids, existing dissolved in the natural oil, from which they either separate spontaneously or by refrigeration. They were formerly called *stearoptenes.* Some of them have been formed by oxidation of the hydrocarbons, others are of a different constitution, such as—

Thymol, propyl-methyl-phenol, or propyl-metacresol, $C_6H_3(CH_3)(C_3H_7)OH$. By cooling oil of thyme, crystals of thymol separate, while the liquid portion consists of thymene, $C_{10}H_{16}$, boiling at 165° C. Oil of thyme contains about equal proportions of thymol and thymene; both have the pleasant odour of the plant and a hot aromatic taste.

Thymol is easily fusible (melting point, 44° C.), lighter than water, in which it is very sparingly soluble (3 parts in 1,000), and is easily soluble in alcohol. It does not readily combine with, or dissolve in, alkalies, and is insoluble in acids, except sulphuric, with which it unites to form thymolsulphonic acid, in almost inodorous soluble crystals whose physiological properties do not seem to have been examined.

Dr. Paquet first* recommended thymol as an antiseptic in surgical dressings, and as an inhalation in pulmonary gangrene. Jalan de la Croix † found on an average that while 1 in 1,000 prevented bacteria from growing, 1 in 100 was necessary to kill them, and as much as 1 in 20 to destroy the germs. Miquel ranks it as strongly antiseptic, since 2 grammes "neutralised" a litre of beef tea. Other observers found the following strengths necessary to prevent the development of bacteria; in urine, 1 in 3,000 (*Haberkorn*); in infusion of peas, 1 in 3,027 (*Kuhn*); in tobacco infusion, 1 in 2,000 (*Bucholtz*). Wernitz states that a saturated aqueous solution (3 in 1,000) arrests pancreatic digestion. Kobert, Kohler, and Stern used it to preserve vaccine lymph, as while it prevented it from putrefying, it only slightly diminished its activity. Koch mentions it as specially inhibitory to tubercle. Ratimoff ‡ puts it fourth in his list of disinfectants, arranged in order of potency (mercuric chloride, silver nitrate, iodine, thymol), saying that "1 in 35,000 killed putrefactive bacteria."

* *Bull. général de Thérapeutique,* 1868.

† *Archiv. f. experim. Pathol.,* Jan. 20, 1881.

‡ *Bierdermann's Centralblatt,* vol. xiv., p. 360.

Thymol in a saturated solution in water arrests fermentation and putrefaction better than carbolic or salicylic acids.* Thymol gauze is used in surgery, and an ointment has been made with lanoline. It is, however, too expensive for use on the large scale.

"**Listerine**" is a mixture of the essential oils of thyme, eucalyptus, *Baptisia*, *Gaultheria*, and *Mentha arvensis;* each fluid drachm also contains 2 grains of refined and purified benzo-boracic acid.

The action of iodine on thymol is of interest. The action may be represented as follows:—

$$2C_6H_3(CH_3)(C_3H_7)OH + 3I_2 = \begin{matrix} C_6HI(CH_3)(C_3H_7)OH \\ C_6HI(CH_3)(C_3H_7)OH \end{matrix} + 4HI$$

This compound is di-iodo-di-thymol, and is known commercially as

Aristol or **Annidaline.**—It is a white solid, melting at 60° C., insoluble in water, soluble easily in alcohol and ether. Like most iodine compounds it turns brown on exposure to light and air, liberating iodine. It is said to be strongly antiseptic.

Menthol.—Oil of peppermint contains a hydrocarbon, menthene, $C_{10}H_{18}$, boiling at 163° C., together with a white crystalline solid obtained by cooling it, menthol, $C_{10}H_{18}H_2O$. Menthol melts at 34° C., and boils at 213° C. It smells of peppermint, and has antiseptic properties.

Peppermint from very early ages has had an immense repute as an arrester of fermentations. Several medical receipts for "plague water" have peppermint as a basis. In a recent cholera scare there was a strong demand both in Germany and England for peppermint herb, and for the oil and water. W. L. Braddon † directs attention to the antiseptic properties of oil of peppermint in diseases in which antisepsis is the best mode of treatment. Angus Smith spoke highly of it.‡

It was ascertained by Koch that 1 part of the oil in 300,000 arrested the development of spores, and that the vapour from warm oil of peppermint quickly killed both spores and bacilli. Dr. A. Macdonald found that the power of menthol is about double that of phenol—"1 in 500 kills bacteria."§ Both it and oil of thyme seem to be useful antiseptics.

Oil of Cloves.—This is extensively used for preserving paste, gum, &c., and for carious teeth ("Bunter's Nervine"). It is heavier than most essential oils (specific gravity 0·918), rather more soluble in water, and more volatile (boiling point 143° C.). All these peculiarities increase its value as an antiseptic. It consists chiefly of a liquid terpene, $C_{10}H_{16}$, holding in solution eugenic acid, $C_{10}H_{12}O_2$

* *Brit. Med. Journ.*, 1875, vol. i., p. 680.
† *Year-Book of Pharmacy*, 1888.
‡ *Disinfectants and Disinfection*, 1869.
§ *Edin. Med. Journ.*, 1880, p. 121.

(*Ettling*), with an isomer eugenin, and a variety of camphor called caryophyllin, $C_{10}H_{16}O$.

Oil of Caraway is yet heavier (specific gravity 0·938). It contains a hydrocarbon carvene, $C_{10}H_{16}$, isomeric with thymol—specific gravity 0·953, boiling point 225° C. (*Voelcker*). The latter yields with an alkaline solution of ammonium sulphide a peculiar substance named carvol hydrosulphide, $(C_{10}H_{14}O)_2H_2S$, in yellowish crystals sparingly soluble in alcohol, almost insoluble in water, but slowly decomposed by it. It has an unpleasant odour, and is strongly antiseptic, but hardly available on account of cost, insolubility, and poisonous character. Jalan de la Croix * states that 1 in 1,000 of carvol destroyed the bacteria of tobacco infusion, while 1 in 360 was required for those of urine.

Oil of Cinnamon is considered by Lucas Championnière to be superior to even corrosive sublimate as an antiseptic. Oils of verbena and geranium have similar properties.†

Essence of Hops is a powerful agent in checking fermentation, hence its former universal use in brewing. It readily absorbs oxygen, being converted into an acid resinous mass containing valerianic acid, $C_5H_{11}.COOH$. The main constituents are a terpene, $C_{10}H_{16}$, and valerol, $C_6H_{10}O$.

All the other essential oils are more or less antiseptic, but their general use is negatived by (1) their cost; (2) sparing solubility; (3) their persistent odour, which becomes after a time insupportable; (4) their want of energy in terminating, as distinguished from restraining, putrefaction and fermentation changes; (5) internally, their injurious action on digestion. Their chief value, beyond that due to their odours and flavours, consists in their general property of hindering fermentation in the alimentary canal. They are largely used for mouth washes, tooth powders, &c.

Terebene, $C_{10}H_{16}$ (specific gravity, 0·86; boiling point, 160° C.), is a liquid obtained by acting on turpentine with about one-twentieth of its weight of oil of vitriol, and distilling. It has a strong odour resembling that of thyme and pine-wood, oxidises less readily than turpentine, and is only slightly soluble in water, but easily in alcohol and oils. Some years ago it was extensively commended as a "disinfectant;" it has now almost fallen out of use except in "Terebene Soap," which is a pleasant preparation of some antiseptic power, containing 1 to 2 per cent. of terebene.

Prof. Maclean, of Netley, reported favourably on its use for surgical and sanitary purposes.

Camphors.—These are oxidised essential oils.

* *Archiv. f. exp. Pathol.*, Jan. 20, 1881. † *Rev. Thérap.*, 1893, p. 290.

Ordinary or Laurel Camphor, $C_{10}H_{16}O$, is a white solid of specific gravity ·996. About 1 per cent. dissolves in water, communicating to it, as "camphor water," its odour, with its stimulant and antiseptic properties. It is very soluble in alcohol; the tincture in moderate doses is an irritant poison. Dr. Rubini in Naples used it largely in cholera and diarrhœa.

Camphor has some repute as a personal prophylactic, but it is obvious that there cannot be sufficient of the vapour to disinfect the air. It is irritant to the skin. It burns with a luminous sooty flame; but when burnt, either alone or with spirit, the products of combustion contain little or no camphor. Spirit lamps containing this and essential oils in spirit have often been proposed for fumigation, but are obviously of little value.

There are numerous inventions relating to camphor. "Sanoscent" is a block disinfectant containing camphor, eucalyptus, pine-oil, "and other germ-killers." The basis of most of the cakes or blocks commonly met with is either naphthalene, paraffin, or plaster. "Hebden's Camphortar" is camphor, eucalyptus, and tar distillates, similarly made into blocks for lavatories, &c., and also recommended to be grated among clothes for insects (see under *Naphthalene*, p. 148).

A mixture of equal parts of camphor and animal (vegetable?) charcoal is recommended by Barbocci for preventing the offensive odour and removing the pain (?) of old excavated ulcers.*

Kyle † has shown that camphor combines in molecular proportions with menthol. Symes ‡ has made a similar compound with menthol. These compounds, like that with phenol, are generally liquids. Hille § suggests its use with magnesium or calcium chloride for drains and for dressing vines.

Bromo- and iodo-camphor are strongly antiseptic, but irritant.

Eucalyptol, or eucalyptus camphor, $C_{10}H_{18}O$, was first isolated by E. Jahns from the essential oil of various species of *Eucalyptus*. Since then it has been detected in numerous other oils. Besides six species of *Eucalyptus* there are 15 plants which yield it. It is a colourless liquid, smelling like camphor, of specific gravity 0·930, boiling point 176° C., and crystallising point − 1° C. It is practically insoluble in water, but is miscible with alcohol, ether, chloroform, and fatty oils. The *Eucalyptus* trees have long been famous for their anti-malarial action, and are largely planted on the Continent in marshy districts. According to Cloez, the half-dried leaves contain 6 per cent. of the oil. It is used in the antiseptic treatment of atonic

* *Chem. and Drug.*, 1887, p. 373.
† *Am. Journ. Pharm.*, 1885, p. 429.
‡ *Pharm. Journ.*, 3, vol. ix p. 598.
§ Patent No. 6,411, 1889.

ulcers, gangrene, &c., internally and by inhalation for pulmonary affections.*

Candles containing 5 to 10 per cent. of oil of eucalyptus or cajeput with or without a little phenol were patented by Wright.† In all these fumigating appliances the greater part of the organic matter is destroyed in burning, only a fraction being volatilised unchanged, while the peculiar odour becomes after a time sickly and insupportable. All fumigating candles, except the so-called "sulphur candles" (p. 93) and some bromine and iodine forms (p. 73), are therefore unsatisfactory. Tablets containing eucalyptus oil and chalk, which have a powerful and pleasant odour, have been introduced for domestic use.‡

Eucalypto-resorcin is a hard amorphous mass obtained by mixing eucalyptol with excess of resorcin in the cold. It crystallises from chloroform, is insoluble in water, but very soluble in alcohol and in ether. It is said to have some advantages as an antiseptic.

Myrtol, from essence of myrtle, is a clear liquid of pleasant odour, boiling between 160° and 180° C. Eichorst recommended it as an internal antiseptic. It is a mixture of dextro-pinene (the main hydrocarbon of turpentine, juniper, eucalyptus, and sage oils, &c.) with eucalyptol, and would be advisedly replaced by the latter (*Jahns*).

Terpin Hydrate, $C_{10}H_{18}(OH)_2,H_2O$, is prepared by the interaction of a mixture of 4 parts of oil of turpentine, 3 parts rectified spirit, and 1 part of nitric acid in shallow porcelain dishes during some days. It occurs in large colourless and inodorous crystals with a faint aromatic taste. On warming there is a separation of the water and formation of terpin, $C_{10}H_{18}(OH)_2$. The development of tubercle bacilli is arrested by a 0·25 per cent. solution (*Colpi*). It has been used internally in lung and kidney diseases (*Manasse and Talamon*).

"**Terpineol**" is the product obtained by boiling terpin or terpin hydrate with dilute mineral acids. According to Wallach it is a mixture in variable proportions of terpineol ($C_{10}H_{18}O$) and several terpenes. Guelpa and Morra have proposed it as an antiseptic in cases of bronchitis.

Absynthol is an isomer of camphor from oil of wormwood.

Caryophyllin, $C_{20}H_{32}O_2$, is a polymer from oil of cloves; **Eugenol**, $C_{10}H_{12}O_2$, an unsaturated compound, being the chief constituent of the oil.

Borneol or Borneo camphor, $C_{10}H_{18}O$, from *Dryobalanops camphora*,

* See Gimbert, *Eucalyptus globulus, and its Importance in Agriculture, Hygiene, and Medicine* (Paris, Delahaye, 1870). Demarquay in 1872 recommended eucalyptol in surgery. Sir J. Lister has used it as a substitute for carbolic acid.

† Patent No. 11,963, 1884. ‡ *Lancet*, vol. xi, 1890, p. 724.

is a white crystalline solid with an odour like pepper, resembling ordinary camphor in properties. It is slightly more antiseptic than camphor (*Selmi*).

An "Improved Disinfecting Fluid" * consists of 28 lbs. chloride of lime, 14 lbs. of camphor, and 50 gallons of "black varnish" (a coal-tar product) mixed together. "After standing for eight days the resulting substance is ready for use in urinals, &c."

Camphoid, though in itself only feebly antiseptic, is a useful vehicle for applying more active agents to the skin, and forms a protective coating. It is a mixture of camphor, pyroxylin, and alcohol. Several so-called disinfectant washing powders have been patented. These usually consist of a mixture of disinfectants with soda crystals. R. P. Hicks † makes a saturated solution of sodium carbonate in boiling water, and then on cooling, as it crystallises, a mixture of diamylene (or decylene, $C_{10}H_{20}$), camphene (one of the terpenes, $C_{10}H_{16}$), menthene, terebene, cymol, thymol, and sometimes phenol is added.

Many of the essential oils are used as disinfecting powders. Under phenol (p. 154) the bases of the most common powders have already been mentioned. Lime, magnesia, and alkaline bases unite with the disinfectant when it has acid properties. The volatile oil is then only slowly evolved by the action of the carbonic acid of the atmosphere. Sand is too coarse for general use, but infusorial earth and artificial silica (*Calvert*), being inert bases, give off the volatile matters completely. For use in wet places, such as urinals, inorganic bases are the best; while for stables, rooms, &c., sawdust and peat are most serviceable. Plaster of Paris and cement are sometimes used; whilst dry earth and burnt clay are suitable for rough work.

The Oxidising Power of Essential Oils.—Sanitas.—Schönbein first observed that in all slow processes of oxidation a small quantity of the oxygen is converted into ozone. This is the case in the slow burning of phosphorus. If any organic matters be present, they are rapidly oxidised by the ozone formed. He remarked that oil of turpentine and other essential oils were specially active in this way, and that ozone, probably from being continually re-formed, was permanently present in small amount as long as any oxygen was left.

He attributed the purifying action of perfumes entirely to this ozonising effect. But Angus Smith ‡ proved by experiments that the explanation was not sufficient, and that their antiseptic action must also be taken into account. He suspended ozone paper (blotting-paper dipped in potassium iodide and starch paste) in a large flask containing a thin layer of the essential oil, and judged the amount of

* Lees, Patent No. 1,738, 1893. † Patent No. 6,209, 1887.

‡ *Disinfectants*, Edinburgh, 1869, p. 118.

ozone by the degree of blueing of the paper, taking 10 degrees as an arbitrary maximum. He gives the following table:—

	Degree of Blueing of the Ozone Paper.			
	After 18 hours.	24 hours.	48 hours.	72 hours.
Oil of Orange-peel, .	Considerable.	Strong Colour.	9	10
Essence of Turpentine,	Feeble.	Distinct.	7	9
Oil of Juniper, . .	Considerable.	,,	5	5
,, Cumin, . .	None.	None.	2	2·5
,, Lavender, .	,,	,,	2	2·5
Cresol, . . .	,,	,,	2	2
Phenol, pure, . .	,,	,,	None.	1
Creosote (Wood), .	,,	,,	,,	None.
Pyroligneous Acid, .	,,	,,	,,	,,
Camphor, . .	,,	,,	,,	,,
Oil of Thyme, . .	,,	,,	,,	,,
Naphthalene, . .	,,	,,	,,	,,

This test is not very delicate, as there is no doubt that traces of ozone are produced with all the above compounds except naphthalene. Other observers have found oil of thyme to give more than cresol. Yet the fact is obvious that the antiseptic action is not proportional to the small quantity of ozone formed, though the slight disinfectant power may be. Although, relatively, there is only a mere trace of ozone, amounting perhaps to 1 in 1,000, nevertheless it may form a considerable quantity in a large volume of air.

Scoutteten * found that ozonised air rapidly removed the odour of foul manure; Richardson and Wood, that of putrid blood that had been kept in a flask for two years. Bond attributed the disinfecting action of permanganate to its production of ozone.† Boillet proved that ozone not only destroyed a putrefactive odour already formed, but actually prevented putrefaction.‡ Chapuis collected the germs and dust from contaminated air by filtering it through cotton wool; he then submitted some of the wool plugs to the action of ozonised air. On then placing the wool in a nutrient solution (wort), the untreated plugs caused rapid turbidity and growth, the ozonised ones remained clear for twenty days.§ From the known fact that the hygienic condition of a locality varied with the proportion of ozone in the air as shown by test papers, and that several epidemics had been preceded by a sudden fall in ozone, he very naturally argued that ozone must have the power also of destroying pathogenic organisms.

Miquel asserts that ozone attacks gaseous emanations before it acts

* *L'Ozone*, Metz, 1856.

† *Brit. Med. Journ.*, 1875, p. 239.

‡ *Comptes Rendus*, 1875, p. 1258.

§ *Bull. Soc. Chimique*, 1881, p. 290.

on bacteria or spores. Subsequent investigations have shown that it does attack the latter (see *Ozone*).

Thenard was one of the first to show, and Ireland,* Barlow,† and others to confirm, that this gas is a poison, and was capable of causing asphyxia and fatal bronchitis, and that even a very minute quantity was irritant to the mucous membranes.

These facts have a direct bearing on the claim of many advertised "disinfectants" to give ozone. The odour of turpentine, the smell of a newly-painted house, even the proximity of a pine forest, though supposed to be good for consumption and pulmonary complaints, undoubtedly cause in many people considerable irritation of the eyes, nose, and lungs. Still, in most cases, the freedom of the air from germs produces manifest improvement.

C. T. Kingzett, about 1874, noticing that in presence of excess of warm water, peroxide of hydrogen, which is not irritant, is produced in solution rather than ozone, together with oxidation products of the terpenes, which acted as strong antiseptics, introduced a new disinfectant under the name of "Sanitas."

In the first patent ‡ turpentine oil is floated to a sufficient depth on the surface of warm water in large jars called oxidisers, and currents of warm air or oxygen are forced through the mixture continuously for seven to ten days, maintaining the temperature constantly at 60°. The proportions used are 9 parts of turpentine oil to 1 of water.

Berthelot has also shown that oil of turpentine is capable of dissolving from 3 to 5 per cent. of oxygen. The action in the presence of water is, therefore, of a dual character, the atmospheric oxygen molecules simultaneously producing molecules of peroxide of hydrogen, H_2O_2, which dissolve in the water and oxidise the turpentine, yielding camphors, camphoric acid resins, minute quantities of formic acid, cymene, &c., and a substance named by Kingzett "camphoric peroxide." Part of these dissolve in the water, part remain in the oil. The products are :—

1. "Sanitas fluid," of a light straw colour and pleasant aromatic odour. It contains camphoric acid, camphoric peroxide, and gives a distinct purple reaction with sulphuric acid and potassium bichromate, showing the presence of hydrogen peroxide, amounting, according to the *Lancet*, to such a proportion that twice its volume of oxygen is given off when it is decomposed.

2. "Sanitas oil," a brown syrupy liquid, lighter than water, and insoluble in it, but soluble in alcohol, and having a similar odour to

* *Annales de Hygiène*, vol. xix., p. 439. † *Journ. of Anat. and Physiol.*, 1879.
‡ No. 274, 1876.

that of the liquid. When shaken with water, the latter acquires a peroxide of hydrogen reaction which is not so strong as that produced by the fluid.* It burns like camphor with a sooty flame.

Patent No. 5,572, 1882, added resin and resin oil, and camphor or thymol. Turpentine, oil of eucalyptus, and "camphor oil" are also among the ingredients used.

The "Sanitas air purifier" consists of fine wood flour impregnated with camphoric peroxide. A Sanitas toilet soap is made, and soft soaps, veterinary washes, and emulsions of the oil with gums, &c. Patent No. 1,589, 1890 (*Kingzett*), refers to "oxidised turpentine mixed with soft or hard soap." In patent No. 276, 1887, it is proposed to use:—

1. Tin instead of earthenware for storing, as Sanitas is not corrosive to metals.

2. Sea water instead of ordinary water, as the hydrogen peroxide keeps better in a saline solution.

3. "One or more antiseptics added before or after oxidation."

Horgreaves† mixes Sanitas oil and other disinfectants with laundry blue for linen.

Dr. A. B. Griffiths, in testing the germicidal powder of the various Sanitas preparations, and particularly of "Sanitas oil" as liquid and vapour, on the bacilli of diphtheria, tuberculosis, glanders, cholera, typhoid, and scarlet fever, found that:—

1. "One-tenth per cent. of the oil was incapable of destroying the microbe of typhoid in *bouillon*, but 1 per cent. prevented its development."

2. "One-quarter per cent. completely destroyed *Micrococcus scarlatinæ* in nutrient gelatine, $\frac{1}{2}$ per cent. prevented its development (six tubes in each case)."

3. "Eight tubes, each containing 100 c.c. of nutrient gelatine, were inoculated with *Bacillus diphtheriæ* from pure sub-cultures of the microbe; and after three weeks' incubation at 20° C., $\frac{1}{2}$ c.c. of Sanitas oil was added to each tube, and the incubation continued four days. As a result, the microbes in all the tubes were found to have been destroyed, as animals susceptible to diphtheria on being inoculated were unaffected."

4. "The bacilli of tuberculosis and of glanders were destroyed respectively by 1 per cent. in six, and by $\frac{1}{2}$ per cent. in seven days."

5. "The spirilla of Asiatic cholera (*Koch*) in ten tubes of *bouillon* (slightly alkaline) were killed in five days by 1 per cent. of the oil. It was further demonstrated that it is quite impossible to inoculate gelatine plate cultivations containing 1 per cent. of Sanitas oil with

* *Lancet*, vol. i., 1890, p. 809. † Patent No. 2,524, 1883.

the microbe of cholera; although when Sanitas was absent the microbes gave rise to colonies."

6. An apparatus was fitted by which the vapour of Sanitas oil from a flask heated to 100° C. in a water bath was passed into test-tubes containing nutrient media in which the above-mentioned organisms were growing. They were all destroyed in from four to fifteen minutes. From this it is concluded that the vapour itself possesses genuine germicidal powers, and should be of service in the treatment of diseases of the throat and lungs. It must be remembered, however, that these are not quite the conditions under which the agent would be employed in practice; the bacterial growths seem to have been at or near the surface of the nutrient gelatine, instead of having penetrated deeply into the tissues. No mention is made as to whether any water was placed in the flask with the oil; the vapour of a fluid with so high a boiling point as Sanitas oil seems hardly likely to pass over at the temperature of boiling water except in the presence of steam.

Dr. Bond, of Gloucester,* Dr. Poehl,† and Mr. Kingzett himself‡ have placed "Sanitas" and its varieties in the very first rank of disinfectants.

On the other hand, Vallin§ says that the statements should be accepted with reserve, admitting, however, that "this product, being unknown in France, we have not been able to experiment on its efficacy." Harding Crowther‖ points out that equal parts of vaccine lymph and Sanitas fluid did not prevent the inoculation succeeding. It might therefore be used as a preservative.

Tripe and Stevenson¶ and Longstaff and Hare,** after numerous experiments, arrived at the conclusion that "the Sanitas fluid and powder do not disinfect better than slaked lime;" they recognise, however, that this substance retards putrid decomposition, but that "it is little active in deodorising substances already putrid."

It is obvious that Sanitas, like some other preparations, has suffered by being over extolled; its chief points of interest are:—

1. The "fluid" is non-poisonous, non-corrosive, and does not stain.

2. It certainly oxidises most organisms and their products when in sufficient quantity and strength, say 1 or 2 parts per 100.

3. In antiseptic power it is about equal to the cresol preparations and superior to the carbolic; over both it has the advantage, shared

* *Brit. Med. Journ.*, 1875, p. 239. † *Revue d'hygiène*, 1879, p. 510.

‡ *Sanitary Record*, 1879, p. 370, and 1880, p. 348.

§ *Désinfectants*, 1882, pp. 177 and 316. ‖ *Med. Times and Gaz.*, 1879, p. 361.

¶ *Med. Times and Gaz.*, 1880, p. 51, "Disinfectants in contradistinction to Deodorants and Antiputrefactive agents."

** *Sanitary Record*, 1878, p. 353.

with permanganate and the halogens, of chemical destruction of the microbes and of exhalations.

4. Its action on sulphuretted hydrogen is not great, that on ammonia is almost *nil*. It can, however, be used with an absorbent like chloride of zinc, but not with ferrous sulphate, sulphurous acid, or other reducing agents.

5. Its price is decidedly higher than some other disinfectants if quantity required be considered. A "Sanitas water-cart block, consisting of Sanitas in a highly concentrated (solid) state," intended to be placed inside the cart for disinfecting streets, has been proposed, but it is more than doubtful whether this could be done efficiently except at a prohibitive cost.

6. It is valuable for toilet use when a persistent odour is not an objection. Many people find it very agreeable. It ranks about equal to sodium hypochlorite (liquor sodæ chlorinata, p. 63).

7. More evidence as to its stability or constancy of composition is required.

8. Further independent investigations as to its efficacy in epidemics like typhus, cholera, &c., as to the poisonous dose of "Sanitas oil," and whether it has irritant external effects, seem also desirable.

Kingzett calculates that the eucalyptus forests of New South Wales and South Australia alone contain, at any moment, sufficient oil in the leaves, ready to be evaporated into the atmosphere under the agency of warm winds, to form no less than about 93 million tons of peroxide of hydrogen, and 507 million tons of camphoraceous principles.*

A fluid called "Pinol" is advertised, derived from *Pinus pumilo*. It resembles other terpene preparations, but is somewhat more pleasant in odour. We have no experience of its efficiency.

The Wandsworth Chemical Works manufacture "the Pineotas series," including fluid, oil, sawdust, and soap, also carbolic preparations, sheep dips, &c.†

* *Social Science Congress, Manchester*, 1879; also see the same author's *Nature's Hygiene*.

† For further chemical information as to the terpenes and their derivatives, see O. Wallach, Liebig's *Annalen*, vols. ccxxvii., ccxxx., ccxxxix., ccxlvi., &c., also on essential oils, &c., *Journ. Soc. Chem. Ind.*, 1888, p. 226.

On cresols, Frankland and Ward's Second Report, abridged in *Journ. Soc. Chem. Ind.*, 1893, pp. 1,051-3.

On phenol and camphor in antiseptic dressings, see Gosselin and A. Bergeron, *Comptes Rendus*, Sept. 29, 1879, "Experiments on the Behaviour of Blood mixed with known quantities of Phenol, Alcohol, and Camphorated Spirit."

CHAPTER XI.

COMPOUNDS RELATED TO THE ALCOHOLS.

Methyl Alcohol: Wood Spirit—Methyl Chloride—Chloroform—Methene Dichloride. **Formic Aldehyde or "Formalin"**: its Properties and Disinfectant Value—Action on Bacteria—Other Aldehydes. **Ethyl or Ordinary Alcohol**: Not a Reliable Antiseptic except when Concentrated—Higher Alcohols—Acetone. **Formic Acid and Sodium Formate. Acetic Acid**: Aromatic Vinegar—Acetic Acid as a Poison—Pyroligneous Acid—Acetates. **Glycerine**: its Uses—Glycerine Soaps—Preservation of Food. **Oleic Acid, Oils, and Fats**: Lanolin. **Petroleum**: Hexane—Vaseline. **Vegetable Acids**: Tartaric, Citric, Malic, Oxalic, Succinic.

Methyl Alcohol, $CH_3.OH$, is a colourless liquid closely resembling ethyl alcohol, but boiling at a lower temperature, 66° C. In the crude form of wood spirit it has long been used to preserve anatomical specimens, owing its efficiency in great part to the creosote, &c., it contains. It is fatal to insects and micro-organisms in the moderate proportion of about 5 per cent., and were it not for its volatility and the fact that its vapour when mixed with air is explosive as well as narcotic, it would take a high rank as an antiseptic. Its relative cheapness makes it a better vehicle for those aromatic antiseptics which are insoluble in water than ethyl alcohol, which is commonly used.

Tollens has devised a lamp for the slow combustion of methyl alcohol, forming formaldehyde, and thus ensuring aërial disinfection.*

Methyl Chloride or monochlormethane, CH_3Cl, is a colourless gas of sweetish odour, soluble in water, and neutral, compressible by a pressure of 3 to 7 atmospheres into a colourless liquid, boiling at 21° C., in which state it is sold in commerce in iron cylinders. Its vapour is antiseptic, but no experiments are extant as to its relative value.

Methene or Methylene Dichloride, CH_2Cl_2 (boiling point, 42° C.), is very similar to, but less powerful than, chloroform.

Chloroform, trichlormethane, $CHCl_3$, has already been referred to (p. 76).

Formic Aldehyde, Formaldehyde, or "Formalin," H.COH, is only known in solution and in a state of vapour, since if an attempt be made to condense it, it polymerises to a white crystalline solid called para-formaldehyde, $C_3H_6O_3$. Formaldehyde is readily soluble in water, giving, if perfectly pure, a neutral solution; commercially it is always slightly acid, from the presence of a little formic acid. The odour is

* *Ber. d. deutsch. Chem. Gesells.*, 1895, vol. xxviii., p. 261.

very pungent, causing irritation to the eyes and nose. It is not a poison. The aqueous solution is stable when kept in well-closed bottles, but loses some of the gas on exposure. Loew and Fischer, in 1886,* discovered that it possessed powerful antiseptic properties; Trillat, in 1888, showed that the presence of a minute quantity of this substance in urine effectually preserved it from putrefying. In a further paper he remarks that "hitherto it has been thought that the most powerful antiseptic bodies belonged to the hydroxyl compounds of the aromatic series of hydrocarbons (the phenols) and to the metallic salts. Formaldehyde is, however, a very powerful antiseptic, being actually superior to bichloride of mercury in this respect. The result is quite unexpected, as acetic aldehyde does not possess this property."† It is prepared by passing methyl alcohol vapour mixed with air over a red hot platinum spiral or heated platinised asbestos, condensing and purifying the vapours.‡

Buchner,§ Aronsohn,‖ and F. Cohn¶ have investigated the properties of formaldehyde, while Lehmann, Gegner, and Blum** have examined its value as a general disinfectant, and Stahl,†† Hauser,‡‡ and Liebreich§§ have reported on its suitability for special purposes. All these writers are agreed in attributing to formaldehyde powerful antiseptic and deodorant properties. Blum, however, points out that micro-organisms are only killed in somewhat strong solutions (2 per cent.). A recent paper by C. Slater and the author confirms Blum's statements.‖‖

With reference to the antiseptic power of formaldehyde, Trillat states¶¶ that "the addition of 1 to 50,000 to meat extract had a decided preservative action, while with 1 in 25,000 no change could be noticed in the extract after the lapse of four days. Mercuric chloride in these proportions has no effect, the extract showing change in twenty-four hours. With 1 in 12,000 the extract is kept good for several weeks, while change occurs in five days when using an equal weight of mercuric chloride. Several kinds of bacilli are destroyed by a solution of 1 in 25,000, such as that of the saliva, &c." For the preservation of meat, Trillat tried (1) immersion in the solution, (2) exposure to the vapour, (3) wrapping the goods in coverings soaked

* *Journ. f. praktische Chemie*, vol. xxxiii., p. 221.

† *Moniteur Scient.*, 1892, p. 490.

‡ Trillat and Berlioz, *Compt. Rend.*, vol. cxiv., p. 1,278; cxv., p. 290; cxix., p. 563.

§ *Münch. Med. Wochenschr.*, 1889, No. 20. ‖ *Berlin Klin. Woch.*, 1892, p. 749.

¶ *Botan. Centralblatt*, 1894, p. 573. ** *Münch. Med. Woch.*, 1893, p. 32.

†† *Pharm. Zeit.*, 1893, p. 22. ‡‡ *Münch. Med. Woch.*, 1893, pp. 567 and 655.

§§ *Therap. Monatschrift*, vol. iv., p. 183. ‖‖ *Lancet*, April 21, 1894.

¶¶ *Moniteur Scientifique*, 1892.

with the aldehyde solution. One hour's soaking in a 1 in 500 solution preserved the meat for twenty-five days; five minutes with a 1 in 250 solution kept it for twenty days, when exposed to air at 23° to 30° C. "The vapour was found to stop all decomposition, keeping meat fresh for months and stopping fermentation in organic liquids."

Cambier and Brochet have shown that by heating dioxymethylene, the vapour of formaldehyde produced effects the complete sterilisation of household dust.*

Slater and Rideal's re-examination,† in which formaldehyde was added to tubes of *bouillon* in proportions varying from 1 in 1,000 to 1 in 20,000, the tubes then inoculated with vigorous cultures of different micro-organisms, and placed in an incubator, showed the following results for inhibitory action:—

Organism.	Proportion of Formaldehyde Inhibiting Growth.	Proportion allowing some Growth.	Remarks.
Staphylococcus pyogenes aureus,	1 in 5,000	1 in 10,000	Growth poor—1 in 10,000, and much delayed 1 in 20,000.
Bacillus typhosus,	1 in 15,000	1 in 20,000	Very scanty growth.
,, *coli communis*,	1 in 7,000	1 in 10,000	After seventy-two hours' incubation.
,, *anthracis*,	1 in 15,000	1 in 20,000	Scanty growth on sixth day.
Spirillum choleræ,	1 in 20,000	...	... ...
Bacillus mallei,	1 in 20,000	...	... ...
,, *pyocyaneus*,	1 in 7,000	1 in 10,000	On the third day.
,, *lacticus*,	1 in 20,000	...	... ...
,, *butyricus* (Hueppe),	1 in 20,000	...	... ...
Micrococcus prodigiosus,	1 in 20,000	...	... ...

The authors remark, "This would place formaldehyde among the first three or four antiseptics in Koch's tables. It is to be noticed that even when the proportion is too small to prevent growth, the cultures then obtained are scanty, and their development is long postponed. The fact that growth does not take place in the *bouillon* is not proof that the microbe has been killed. Thus *Bacillus mallei*, which showed no growth after four days' incubation in a 1 in 15,000 strength, when transferred to a fresh nutrient solution, gave rise to a culture normal in all respects, except in requiring an unusually long time to develop. Blum has shown with regard to anthrax that exposure to the antiseptic does not cause attenuation." As to commercial yeast, 1 in 2,500 of wort was required to prevent fermentation. In lesser quantity the rapidity was diminished, but the final amount of

* *Compt. Rend.*, vol. cxix., p. 607. † *Lancet*, April 21, 1894.

alcohol was the same as if no antiseptic had been added. Hence formaldehyde might be useful to arrest secondary fermentations in alcoholic liquids.

To determine the amount required to kill microbes, sterilised silk threads were soaked in cultures of the various micro-organisms and then transferred to the antiseptic. After exposure for various periods the threads were withdrawn, well washed in sterile water, transferred to *bouillon* tubes, and kept at 37° C. for more than eight days. The tubes in which no growth took place were tested by inoculation in order to determine whether they were still suitable for growth of the microbes or whether the sterility was due to transferred antiseptic. They all yielded copious growth on second inoculation. Control experiments were made in all cases. The results obtained were :—

"Time required to kill the microbes with a 1 per cent. solution. *S. pyogenes aureus*, between 50 and 60 minutes ; *B. typhosus*, 40 to 50 ; *B. coli communis*, 30 to 40 ; *B. anthracis* and *S. choleræ*, less than 15 minutes.

"With a 1 per 10,000 solution (threads examined every half hour, at first, then hourly, then every twenty-four hours), *B. anthracis* (no spores) killed in thirty minutes ; *S. choleræ* in two hours ; but putrefaction organisms were not killed after twenty-four hours. Experiments were made to see how far these solutions might replace the 1 or 2 per cent. solution of carbolic acid frequently used for the disinfection of soiled linen before washing. Soiled clothes from the *post-mortem* room and sterilised clothes soaked in cultures were left for from twenty to twenty-four hours in 1 per cent. and 1 per mille solutions of formaldehyde. After washing in sterile water they were examined by cultivation :—

	1 per cent. solution.	1 per 1,000.
Clothes from *post-mortem* room, . .	Sterile.	Not Sterile.
Clothes soaked in *B. typhosus*, *Spirillum choleræ*, or *St. pyog. aureus*, . .	,,	Sterile.

"The solutions are without any ill effect on clothes, and are efficient as antiseptics, more especially the 1 per cent. solution, and the more so as in practice the adherent formaldehyde solution would not be removed." It seems especially suited for the disinfection of leather goods and general articles, like combs and brushes, which cannot be satisfactorily sterilised in other ways.

The action of the vapour evolved at 19° C. from a 40 per cent. solution was examined by exposing to it glass slips of dry *bouillon* cultures under a bell-jar for ten minutes, *B. typhosus* and *coli* ; *M. prodigiosus* and *Sp. choleræ* were killed in less than ten minutes ; *S. pyogenes aureus* in twenty ; *B. pyocyaneus* in thirty minutes. As to the disinfection of rooms, 1½ ounce of 40 per cent. formaldehyde was evaporated by a spirit lamp in a room of 1,548 cubic feet (about 11½ feet side). The dust was disturbed by vigorous sweeping, then examined bacteriologically. After four hours' exposure to the vapour, the dust was again disturbed, and a sample examined. In other experiments threads soaked in various cultures were suspended at different heights and at about 3 to 5 feet from the source of the vapour. The results were not decisive, but showed decided effects of the vapour. There is no reason why much larger quantities of the antiseptic should not be used. The air before disinfection contained 429 organisms for 10 litres, afterwards only 71.

The threads after disinfection in all cases produced more scanty cultures and more slowly. Some of those impregnated with *B. typhosus* and *coli* were sterile.

It seems also to be possible to sterilise the skin with formalin, and as it does not hinder the formation of a lather with soap, as mercuric chloride does, it seems a desirable substitute.

Trillat states that formaldehyde precipitates the tannin and colouring matters of urine. It is also incompatible with ammonia, forming with it a non-volatile crystalline compound. It is of course a reducing agent.

In commerce it is found as "Formalin," a solution in water containing about 40 per cent. of formic aldehyde with a minute trace of formic acid, made by Schering of Berlin. A "formalin" dusting powder is also available.

Berlioz and Trillat say that the vapour can be inhaled or injected in throat and lung disease with marked benefit and without toxic effects.* J. Stahl generally confirms the value of formaldehyde.†

Ethyl aldehyde and paraldehyde seem to be useless as antiseptics. Chloral has properties similar to those of chloroform.

Alcohol, $C_2H_5(OH)$, coagulates albumen, hardens animal tissues, and renders them imputrescible, hence it is used for preserving anatomical specimens, bodies, &c. For this purpose the old form of "methylated spirit," containing 10 per cent. of crude wood spirit, is better and cheaper. The new form, mixed with petroleum, is not available, as it becomes turbid with water; for other antiseptic purposes, however, it is equally serviceable.

Bucholtz observed that a 1 in 30 solution of alcohol did not prevent the development of vibrios.‡ Calvert and M'Dougall found that 1 in 20 prevented the putrefaction of beef-juice and egg-albumen for six days. Wernitz established the fact that 1 in 3 to 1 in 10 destroyed

* *Comptes Rendus*, vol. cxv., p. 290. † *Pharm. Zeit.*, 1893, p. 173.
‡ *Archiv. f. exp. Pathol.*, 1875, p. 159.

the activity of non-organised ferments (ptyalin, &c.).* Jalan de la Croix † found that it required a solution of 1 in 21 to prevent the growth of adult bacteria transferred into *bouillon*, but the organisms were not killed below 1 in 4·4, or 22 per cent., and the germs not below 1 in 1·18, or 83 per cent. Meat broth freely exposed to air remained free from bacteria when the proportion was 1 in 11, Gosselin and Bergeron ‡ exposed fresh blood in vessels covered with folds of muslin to the vapour of strong spirit under a bell-jar. Putrefaction was deferred to the eighth day by six drops of alcohol, whereas naturally it would have appeared on the third or fourth day. Miquel's statement is that "95 parts of alcohol neutralised 1 litre of beef tea," about 10 per cent.§

It has been suggested that the gradual re-appearance of bacteria when the solutions are exposed to air is due to the loss of strength by evaporation of the alcohol. But Geissler has disproved this, finding that open tubes containing a mixture of water and alcohol at the end of seventy-two hours still contained 32 per cent. of alcohol, the original amount having been 33 per cent. So that, as with other antiseptics, the bacteria have the power of slowly becoming accustomed to their environment.‖ With alcohol this toleration appears to be very marked.

Alcohol, therefore, in itself is not a reliable antiseptic, although it has been found useful for washing open wounds and even cavities. Here of course its absorption and stimulant action must be taken into account. With water, it is chiefly used as a vehicle for other compounds, to whose efficacy it adds. Indeed, in some cases it probably takes the principal part, the other materials, such as essential oils, &c., being in such small quantities as to act mainly as scents.

Dr. J. J. Ridge ¶ describes the effect of minute quantities of alcohol on cell protoplasm, and points out that it causes a shrinkage of the protoplasm, by withdrawing water, slowly hardens and thickens the walls and hinders nutrition.** To these phenomena must be attributed its inhibitory action on bacteria, and its destruction even of germs, when the solution is strong. Minute quantities have no action in preventing putrefaction. Wines, for example, if of weak alcoholic strength, become sour, and even putrid. A mixture of acetic ether and alcohol, with or without acetic acid, constitutes the antiseptic and preserving agent called "Salubrine." ††

* *Wirkung der Antiseptica*, 1880.

† *Archiv. f. exp. Pathol.*, 1881, p. 175.

‡ *Arch. de Méd.*, 1881, p. 16.

§ *Org. viv. de l'Atmosph.*, 1883, p. 289.

‖ See *Salicylic acid*, p. 201; Watson Cheyne, *Med. Times and Gaz.*, 1879, p. 561.

¶ *Brit. Medical Association*, 1890.

** *Brit. Med. Journ.*, vol. i., 1891.

†† Hakansson, Patent No. 10,465, 1893; *J. S. C. I.*, 1894, p. 898.

Formic Acid, H.CO.OH, resembles its homologue acetic acid. Its antiseptic power is less than that of acetic and propionic acid, and according to Duggan,* in the series of fatty acids the antiseptic power is proportional to the molecular weights. Sodium formate, H.COONa, is a soluble salt resembling the acetate, but possessing reducing properties; it has the advantage of dissolving many compounds which are sparingly soluble in water alone, such as arsenious, boric, and salicylic acids, and it does not favour the growth of moulds like sodium acetate; consequently it has been incidentally mentioned in several patents, as, for example, No. 3,153, 1882, "Boric acid melted with sodium phosphate and formate, can be cast into homogeneous solid cakes, which are inodorous, very soluble and almost tasteless; to be used by dipping or soaking to preserve provisions." It would leave a white efflorescent crust, which would undoubtedly be antiseptic, and could easily be washed off.

Acetic Acid, CH_3,CO(OH), in the pure state or "glacial," is a crystalline solid melting at 17°, and boiling at 118° C.; specific gravity 1·055. It has a strong pungent odour, and is very caustic. The "strong acetic acid" of the *British Pharmacopœia* contains about 30 per cent. of real acid; vinegar from 3 to 5 per cent.

A more or less concentrated acid, scented with spices, was much used in the middle ages under the name of "aromatic vinegar," to drive away plague. Glacial acetic acid dissolves considerable quantities of camphor and essential oils, and does not wholly deposit them on dilution.

Acetic acid is the chief product of the action of *Mycoderma aceti* on alcohol. When it has reached a certain amount, it checks and finally stops this fermentation, and, if sufficiently strong, it inhibits the growth of all bacteria, hence its use for pickles, &c. But, as is well known, if the vinegar be weak, it turns cloudy, and itself undergoes a putrefactive change. The old idea that vinegar is an antiseptic is, therefore, only a question of degree, inasmuch as most micro-organisms thrive best in a neutral or alkaline medium; any acid whatever will act as a restrainer of their growth (see *Hydrochloric* and *Sulphuric acids*, pp. 69 and 97). Calvert and M'Dougall say that 10 per cent. of acetic acid was necessary "to prevent animalcules in beef-juice and egg-albumen for six days. The effect of 10 per cent. on animalcules in already putrid beef-juice was none." Liebig defended the popular opinion by pointing out that it fixed ammonia and the organic bases accompanying fermentation.†

"Aromatic vinegar," diluted with water, is frequently used to bathe the bodies of patients in typhoid fever and scarlatina; it certainly

* *Am. Chem. Journ.*, vol. vii., p. 12. † Vallin, *Désinfectants*, p. 155.

assists desquamation, acts as a cooling tonic to the skin, and removes or hides any offensive odours. It lends itself admirably to mixing with resorcin or a sulphocarbolate (p. 158); so yielding a powerful and efficient antiseptic. The acetates are not antiseptic.

Pyroligneous Acid, or crude vinegar, is used in curing hams and fish. It owes its undoubted antiseptic power chiefly to the creosote it contains.

Propionic acid, C_2H_5COOH, has been tested by Duggan on *B. subtilis*.*

Glycerine, $C_3H_5(OH)_3$, is a colourless, inodorous, and neutral syrup, of specific gravity 1·27, boiling with partial decomposition at 290° C. It is miscible with water and alcohol, and dissolves a large number of salts and organic compounds. Under ordinary circumstances it is not fermentible. Strong solutions are antiseptic, but weaker ones undergo fermentation, yielding butyl alcohol, caproic and butyric acids, and other products of very disagreeable odour. It has been used for the following purposes:—

1. On account of the sweet taste, non-fermentibility, and antiseptic tendency, it is largely used *for sweetening* wines, temperance drinks (*e.g.*, "Hygeia"), syrups, artificial cordials, and "British wines," and for the preservation of beef-juice extracts. On this subject Lehmann remarks†: "An addition of glycerine, as it can be practically applied, should not be pronounced hurtful, for, even if large quantities of glycerine taken at once act as a purgative (say 15 to 30 grammes), and if very large quantities have an action resembling that of alcohol, there is no doubt that the addition of a few grammes of glycerine (5 grammes per litre) is perfectly harmless in such dilution. Experiments on the guinea-pig, a very susceptible animal, prove $\frac{1}{2}$ gramme daily per kilogramme of body weight can be mixed with food without injury." Miquel ‡ says that to prevent putrefaction of *bouillon* it is necessary to add 225 grammes of glycerine of specific gravity 1·25 to a litre—a very large dose, which implies that an amount to preserve food would also confer a penetrating and unpleasant sweetness. It has also been employed instead of sugar in beverages for diabetic patients, but causes purgative and griping effects. No prosecution is recorded under the Food and Drugs Acts.

2. In surgery, *to keep the skin pliable.* It does not maintain the surface moist, as, being very hygroscopic, it acts as a drier; on this account its habitual use for the hands or face is well known to make the skin transparent, thin, and wrinkled. Bacteria and insects are killed by undiluted glycerine, since, having very low diffusive power,

* *Am. Chem. Journ.*, vol. vii., p. 62. † *Hygiene*, 1893, vol. xi., p. 247.
‡ *Org. vivants*, chap. 9.

it causes death by desiccation. Germs, with thicker envelopes, resist it indefinitely, and on dilution commence growing rapidly. Its chief use has been as a medium for other medicaments, which it keeps liquid and allows to readily diffuse. It is largely employed in suppositories.

3. *Glycerine soaps* do not enjoy the same repute as formerly, on account of the above-mentioned objectionable action on the skin if their use is long continued. "Glycerinum saponatum" is largely used by Prof. Hebra in his clinic at Vienna by reason of its rapid solubility in cold and warm water, and its advantageous property of dissolving a large number of substances and of holding other pulverulent insoluble substances in suspension.* It is a faintly yellowish, more or less elastic mass, perfectly inodorous, and melting at the body temperature. Its composition varies from 80 to 92 per cent. of glycerine, with 20 to 8 per cent. of a neutral cocoa-nut oil soda soap.

4. Hams and dried fish have been soaked in 20 per cent. glycerine with the idea of preservation.

Boroglyceride has been described at p. 101.

Oleic Acid, the fats, "Lanolin," &c., have no antiseptic power in themselves, but act as convenient vehicles for the application of antiseptics. Oleates of mercury, zinc, &c., have, within late years, been found to possess a rapid absorption, to be more powerful than simple ointments, and to be less irritating. It has been pointed out (p. 151) that "carbolic oils" are less efficient than aqueous solutions.

Oils and ointments when applied to the skin may prevent infection by the exclusion of the germs, but Vicario has observed that the fixed oils may contain germs, and that both they and any solutions to be mixed with them must be sterilised by heating to 100° C., or preferably to 120° C., in a digester, especially in the case of hypodermic injections of guaiacol, iodoform, and eucalyptol with olive oil, for phthisis, &c.†

Petroleum Jelly and the paraffins, although almost insoluble in water, are used diffused through it or through soap and water, as insecticides in horticulture. Under the name of vaseline it is used as a medium for antiseptic compounds.

Marco Polo, in the thirteenth century, said that petroleum from the Caspian Sea was used "to anoint camels that had the mange."‡

Vegetable Acids, like tartaric, citric, and malic, have the general power of inhibiting bacteria which prefer a neutral to an acid medium, but their effect is much less than that of mineral acids, and, as is well

* *Pharm. Zeit.*, July 19, 1890; *Pharm. Journ.*, 3rd series, vol. xxi., p. 1,040.

† *American Druggist*, June 15, 1891.

‡ *Encyclopædia Britannica*, vol. iii., p. 259.

known, their solutions quickly become covered with mould in warm weather. Reinsch * states that ·028 per cent. of tartaric acid in water "began to diminish the bacteria, and 0·2 per cent. killed them."

Patent No. 1,297, 1893, proposes the use of tartaric acid for purifying water, and a filter has been devised to carry out this idea. Many patents use tartaric and malic acids to increase the solubility of boric acid and borax (*q.v.*, p. 102); it would seem as if they would rather diminish the efficiency by providing nutrient material, as exemplified by Pasteur's solution, which is used for growing organisms.

Oxalic Acid is an irritant and corrosive poison, and is said to be antiseptic. Its solutions certainly do not develop organisms; even the oxalates only allow their growth slowly. But in practice they are inapplicable. Succinic acid is slightly antiseptic.

CHAPTER XII.

PRACTICAL METHODS.

Towns: Limited Areas—Administration. **Sewers and Drains**: Ashpits and Dust-Holes. **Houses**: Walls and Wall Papers—Furniture and Wood Work—Sinks. **Sick Rooms**: Isolation—Clothing—Excreta—Removal—Light and Air—Spray—After-Disinfection—Phenol—Sulphurous Acid—Chlorine—Liquid Disinfectants by Spraying—Hot Solutions—Cisterns—Water-Closets—Earth-Closets—Middens—Cesspools—Infection by Flies—Automatic Distributor—Wood Paving—Urinals—"Urinal Cakes"—Stables—Pigstyes and Cowsheds—Cattle Markets and Fairs—Slaughter-Houses—Dairies—Bake-houses—Pigeon and Fowl Houses—Rabbit Hutches—Cats and Dogs—Vehicles—Skins, Furs, Wool, and Hair—Rags. **Disinfection of Air**: Impurities—Sewer Gas—Vaporisers and Filters for Air—Water and its Purification. **Preservation of Timber**: Copper Sulphate—Creosote Oils.

In early times it was almost considered presumptuous to combat by natural methods the great plagues which frequently devastated the country, and only trifling efforts were made to control the ordinary infectious diseases that are always with us, such as diphtheria, typhoid, and other fevers. It is true that vinegar, camphor, and perfumes were used to protect the person from contagion, and that fumigation with aromatic woods was sometimes employed, but these, as has already been shown, have only feeble powers in this direction. As the population increased, and overcrowding in towns became general, the fatality from epidemics became excessive. Amulets of all kinds were the only remedies relied on. Even now, in the bubonic plague which was

* *Centralbl. f. Bakteriol.*, 1891, vol. x., p. 415.

recently raging in Hong Kong, the faith of the people in charms, and their opposition to sanitary measures, was so intense that it was only under military force that the work of sanitation could be undertaken. Yet it is scarcely open to doubt that this plague, identical in its symptoms with the great plague of 1666 and other years, as shown recently by Kitasato, and is still endemic in certain parts of the East, the Black Death, and the Sweating sickness, and, to a great extent, the cholera, are only kept out of Europe by modern applications of sanitary science. Harvey in the sixteenth century, and Bishop Berkeley in the eighteenth, seem to have been the first to advocate the combating of disease from the outside. England was the first nation to organise a systematic campaign against infectious diseases. After the great outbreak of cholera in 1832, Parliament energetically resolved to frame regulations for public health. These emanated from the elected authority, and not, as in other countries, entirely from the police. The Public Health Act of 1848 constituted the Local Government Board as the executive sanitary power. Statistics were collected. The country was divided into limited areas, which were distinguished as Urban and Rural Sanitary Districts, each with its Local Board of Health. The Urban districts included all towns except London, which has a special sanitary organisation. Scotland and Ireland also have in part their own laws. The Urban authority centred in the Town Council. In rural districts the Board of Health and the Guardians are now merged in the Rural District Councils. Each body sends an annual report to the Local Government Board, which from time to time sends out recommendations in the form of a circular to the Local Authorities. Measures of disinfection are performed, superintended, or directed by the Sanitary Officer (Inspector of Nuisances) under the control of the Medical Officer of Health.

Sewers and Drains.—It has already been pointed out that the old system of pouring large quantities of liquids, like carbolic acid, sulphate of iron, or permanganate down the drains with the object of disinfecting the sewage, is really useless, inasmuch as the reagents are practically lost in the immense volume of water, and fail to reach a proportion sufficient to destroy the bacteria, although they may partially remove the smell. If an attempt is made to hermetically close the sewers, as was formerly supposed to be the best method for preventing a nuisance, the sewer gas, by backward pressure of rains or tides, passes through any form of trap into the houses, and, although sewer gas has been proved, probably owing to subsidence in the quiet atmosphere, to be almost free from germs,* yet there can be

* *Journn. Soc. of Chem. Ind.*, 1888, p. 911; also J. Parry Lawes' *Report to the L. C. C.*, 1893.

no doubt that it has a depressant effect, and lowers the vitality in such a way that men subjected to its influence are therein predisposed to infection. The fact that a few germs may be present must also be borne in mind. Consequently, the modern system is mainly confined to ventilation and flushing. Charcoal and disinfecting ventilators are elsewhere discussed (p. 246). Drs. Arthur and Illingworth have recently proposed a new system of sewerage in which the side drains enter at the bottom of the main sewage.*

In workmen's dwellings it is customary in London for the gratings of the house drains to be daily sprinkled with some disinfecting powder. M'Dougall's, Calvert's, or a pine-oil powder such as Sanitas, are commonly used. In a number of experiments on this practice, gratings were selected which evolved a distinct quantity of sulphuretted hydrogen, as proved by lead paper 1 foot over the drain being in most cases discoloured. After sprinkling with either of the powders, the fetid odour, both of sulphuretted hydrogen and of sewage, seemed to be actually removed, and not merely disguised, as the lead paper was no longer affected. The effect, however, only lasted from an hour to an hour and a-half; after this the smell was as strong as ever, and the lead paper was again discoloured. The odour was most powerful in the mornings, or on the approach of a thunderstorm. It may be mentioned that in this instance several cases of diphtheria had occurred, and a general cachexia was noticed in the inhabitants, in all probability attributable to this sewer gas. Yet in many of these places, when a complaint is made, a roadman is sent with disinfecting powder, and the nuisance is temporarily abated, instead of the defect in the drain being seen to by the sanitary inspector. So that this method of disinfection is not only useless, but is positively to be condemned, as it leads to a false idea of safety, and hinders genuine sanitation. Sanitary inspectors should always visit these places in the early mornings before the roadmen have sprinkled the disinfecting powder.

Chloride of lime retains its power for a very much longer time, on account of the gradual evolution of chlorine by the action of the carbonic acid of the atmosphere. But even this is inefficient. Its smell to most people is exceedingly unpleasant, and the gratings and pipes are quickly corroded; hence its general abandonment for this purpose. A daily flushing of the drains, except in rainy weather, with water seems to be one of the best methods for preventing a nuisance. It has been proposed in several recent patents to suck the smoke from house and other fires into the sewers, not only to get rid of the soot, but with an idea of disinfection, but as it is necessary for workmen to

* *Sanitary Record*, 1894.

enter the sewers, it is not easy to see how the smoke could be temporarily suspended.

As to **Ashpits** and **Dust-holes**, if they are frequently emptied, and care is taken to burn putrescent matter and not to throw it into these receptacles, there is not much danger. Portable ash-bins of galvanised iron are much used in London. To sprinkle disinfectants over the refuse is futile, though they may be used with some advantage in the empty dust-bin after removal, and over the contents of the dust-carts in their passage through the streets. Stingl and Neuman have a patent* for an improved refuse collecting van, with double dust closure and an automatic disinfecting device. A portable petroleum destructor for house refuse has also recently been advocated for this purpose. Most urban authorities have now a difficulty of disposing of their refuse, and many refuse-destructors and cremators are now on their trial.

Houses.—Fresh air, light, and frequent cleansing seem to be the essentials to be aimed at in thickly-populated districts. In washing floors a strong carbolic soap, or better, a cresylic preparation, are very useful. Curtains and bedding must be occasionally brushed and shaken in the open air. When sweeping floors and carpets, tea-leaves or damp sawdust should be used to prevent the diffusion of germs in the dust. Oil paint, or a well-varnished paper, are preferable for walls, as they can easily be washed. Flock papers have become obsolete, from their forming such a favourable nidus for the growth of organisms. Ordinary wall-papers can be cleansed down with the crumb of bread, which mechanically removes any bacteria.

Hygienic Wall-papers prepared with various disinfectants incorporated in the pulp have been suggested. Mercuric chloride has even been proposed to be introduced, but its use should not be permitted on account of the danger of its being evolved in the dust. Resorcinol, 1 in 2,000, is patented by Sinclair and Brown for this purpose.† Salicylic acid is non-volatile and inodorous, but it is doubtful if it would be efficacious. It has been proposed to incorporate it with the plaster coating of walls (p. 198). It always communicates a pinkish colour, owing to the presence of iron salts. Herr Kosinski of Warsaw has invented a machine for drying and disinfecting walls. It is a portable air-heating chamber with pipes to the outside of the room, capable of heating surfaces of about 108 square feet by an air-blast directed by radiating pipes on to the wall or other surface. The air is mechanically renewed at the rate of about 1,000 feet a minute. It is also intended for large disinfecting chambers, in which the rapidity with which the air passes, combines with the high tempera-

* No. 47, Jan., 1894. † Patent No. 12,217, 1886.

ture (stated in the report to be 660° F., but this is obviously an error) in bringing about the desired result. It is also suitable for warming buildings, and for removing vapour and moisture from crowded rooms —*e.g.*, in a theatre, after the exit of the audience, to prevent the condensation and settlement of injurious moisture and dust. An official commission at Warsaw proved that a private house, the building of which was commenced in May, 1882, with the capacity in ground floor and first storey of 7,000 cubic feet, was completely dried in fourteen days, and severe sanitary inspection proved the building to be completely sterilised.

Furniture and Woodwork can be washed and scrubbed, or, in special cases, should be washed with 1 in 1,000 mercuric chloride (in a few instances this may cause discoloration). Beeswax and turpentine are better than the common furniture polishes for polishing, as the surface is to some extent disinfected and rendered non-absorbent. All cracks and crevices should be carefully filled up with putty to prevent the lodgment of vermin or germs.

Sinks, if made of stoneware, can easily be cleaned. Here Condy's fluid (permanganate) is serviceable, but strong soda is ordinarily better. For toilet utensils sodium hypochlorite (chlorinated soda) in 5 per cent. solution should be occasionally used, also for milk cans and pails. In the case of metal baths it should not be used too strong as it removes paint. Bedsteads, in addition to scrubbing with soap and water, can be afterwards washed with chloride of lime and water, 10 per cent., and left in the air till the odour has almost disappeared. Paraffin oil is sometimes used, but its odour is very persistent. Polished floors are to be recommended in preference to porous floors and carpets.

Sick rooms cannot be disinfected in presence of human beings. All placing of saucers with chloride of lime, permanganate, &c., under the bed, or about the room, all hanging up of sheets dipped in disinfectants, are simply illusory. Similarly fumigation by medicated lamps or candles, burning pastilles, or brown paper, are useless. Sufficient of the disinfectant to kill the micro-organisms of the air would make the air unfit to breathe. The following precautions, however, will be of service.

1. *Isolation.*—If possible, the other inmates of the house should live on a different floor. Where this, on account of poverty or other cause, is unattainable, contact should be carefully avoided.

2. *Clothing.*—The attendants should wear cotton and linen, not woollen, garments. This is now compulsory in hospitals and most institutions. The greatest personal cleanliness should of course be observed. The following is the best way of removing soiled clothing

from the room:—At the bottom of a large air-tight tin trunk, such as is used for travelling to India, is placed a piece of felt or blanket, or three or four thicknesses of flannel. This is sprinkled with crystals of carbolic acid, and covered with a linen cloth. The crystals will soon deliquesce, and soak into the stuff. The lid should never be left open. The soiled clothing is put in, and when full it is left for an hour for the phenol vapour to penetrate, and then carried out into a yard, where it is filled with boiling water containing soda, and washed as soon as possible. The washing must never be done, nor the clothes hung out to dry, on the same day as the ordinary house washing, nor should they be ironed or starched in the same room or with the same utensils. This dry method of removal of clothing is probably better than the usual one of plunging into a disinfectant solution (phenol or mercuric chloride), as it is easier, and the weight of the water and constant carriage are avoided.

3. *Excreta*, vomit and sputa should be received into about a pint of mercuric chloride solution, 1 per mille, with 10 per mille of common salt and 1 per mille of hydrochloric acid, and coloured with indigo to avoid mistakes. A large quantity of such a solution should be kept ready. (See also p. 141.) Dr. Fischer recommends aniline water as the best disinfectant for tuberculous sputa (p. 184). "Five per cent. phenol did the same in twenty-five hours; mercuric chloride, 1 in 500, failed. Dry heat of 100° C. sometimes failed, though it acted for sixty minutes. Boiling ten minutes, or steam for fifteen minutes, succeeded."* Disinfected excreta must not be thrown away before the agent has had time to penetrate. If disease begins in houses where the sick person cannot be properly accommodated and tended, medical advice should be taken as to the propriety of removing the patient to an isolation hospital. Where dangerous conditions of residence cannot be properly remedied, the inmates, while unattacked by disease, should remove to some safer lodging.†

4. *Light* and air should be freely admitted. Vallin strongly recommends the use of water spray in the room, as he says that the water entangles the bacteria and dust, and the dissolved oxygen in the water destroys them. He also approves the use in the water of a small quantity of resol (dimethyl-resorcin), a body proposed by M. Pabst, as agreeable and non-corrosive. A 1 per cent. solution of peroxide of hydrogen, or a preparation like Sanitas might also be employed for the same purpose. The sick person should be protected by a screen from this process, from draughts, and from too much light.‡ It is well known what benefit is derived in some lung diseases from the

* *Mittheil. Kais. Gesundh.*, 1884. † *Circular of Med. Off. Local Gov. Board.*
‡ *Désinfectants*, p. 407.

common bronchitis kettle. Dr. W. Ferguson has suggested its use as a fumigator in pneumonia and diphtheria by the following simple modification:—"Take an ordinary bronchitis kettle, remove the first joint, and replace it by a common tin funnel loosely filled with tow. Pour on the tow 1 drachm of pure phenol, and at intervals more. The steam carries off the phenol."* Curtains, hangings, carpets, and all unnecessary furniture should be removed.

After-disinfection.—Phenol, chlorine, and sulphurous acid have each had their advocates.

(*a*) *Phenol.*—Pouring strong carbolic acid on a hot shovel is dangerous to the operator. Calvert manufactures a perforated iron cylinder delivering a mixture of 2 parts phenol and 1 part water on to a red-hot iron heater; the whole is compact and can be carried by a hook. There is also Savory and Moore's vaporiser, in which phenol falls on a hot plate; and many others. But phenol is not reliable as a disinfectant (*Miquel* and others), and the smell remains persistent.

(*b*) *Sulphurous Acid.*—After the removal of such articles as are best disinfected by heat, and the closure of windows and crevices, the gas in ample quantity should be evolved, the doors being closed for six hours or more. The amount of gas required for the disinfection of a moderately-sized room can be obtained by burning 1½ lbs. of roll brimstone in a pipkin over a small fire placed in the middle of a room, with an old tray or the like to protect the flooring. These processes should be effected by skilled persons acting under the directions of the Medical Officer of Health. All wall-paper should be stripped from the walls and burned, and the same room ought to have its ceilings and walls thoroughly washed and lime-whited.† Boake's liquid sulphurous acid, bottles or tins, are much more convenient in careful hands (see p. 92).

(*c*) *Chlorine.*—3 lbs. of good chloride of lime and 3 lbs. commercial hydrochloric acid should be used for every 1,000 cubic feet. This quantity should be divided into several parts and placed in deep vessels as high as possible (since chlorine gas is heavier than air), and the acid allowed to drop in gradually by a funnel partially blocked by a cork pierced with a small hole (try the dropping rate beforehand with water). The room should then be closed for twenty-four hours. Before opening, cover the mouth and nostrils tightly with a towel soaked in weak solution of ammonia, ½ to 1 per cent. Close the other doors of the house and open the windows. Sprinkle a little strong ammonia in the passage around the room door. Now open the sick-room door, rapidly throw the windows wide open, and as quickly retire. Another person similarly protected should be at hand in case

* *Lancet*, 1880, vol. xi., p. 757. † *Circular of Med. Off. of Health, L. G. B.*

of accident. If the eyes are affected, wash them with luke-warm water, without any ammonia. In case any irritation remains in the lungs or nose, inhalation of the vapour of ether will afford relief. With these precautions the operation is perfectly safe. All metal fixtures should be removed beforehand; if this is not possible, they must be well rubbed over with vaseline or lard. This is undoubtedly the most thorough method of disinfection. In both processes, however, there is a common omission. Inasmuch as neither dry chlorine nor sulphurous acid will act, it is necessary to generate steam by a boiler or large kettle over a good fire for some hours before commencing, so as to make the whole room and the air thoroughly damp. Then put out the fire, close the chimney, and proceed to the disinfection.

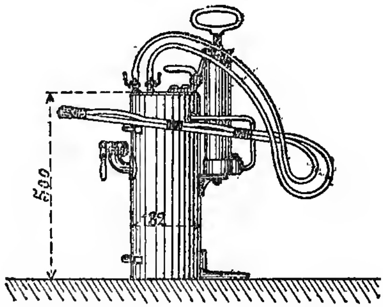


Fig. 20.—The Equifex disinfectant sprayer.

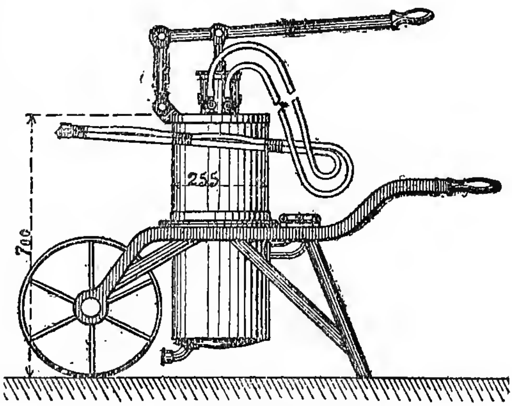


Fig. 21.—The Equifex disinfectant sprayer (another form).

(*d*) *Non-volatile disinfectants* can be applied by mechanical means. Thus bleaching powder can be used as a wash, and the walls, floor, and ceiling coated by means of a brush. Mercuric chloride solution and formalin, or, in fact, any liquid disinfectant can be sprayed into the room. The Equifex sprayers have been specially devised for this work. Two forms are shown in Figs. 20 and 21. The spray is so constructed that the fineness of division and the force and velocity of projection can be varied at will. For this purpose the channel for the disinfectant is arranged to reduce the velocity of the liquid at the point of delivery to a rate which is very small, and capable of being exactly controlled by turning a cock. For a given velocity of air, regulated by another cock, the force of projection will therefore be determined by the velocity of the air, which is controlled by the pressure to which the pump is worked, and the degree to which the air cock is open. The importance of a fine division of liquid depends on the fact that it enables the work to be done with the minimum useful amount of disinfectant, saving the expense and inconvenience of waste liquid.

The parts containing the disinfectant are lined with ebonite, so that these sprayers may be used with any liquid disinfectant without any risk. The cost will vary slightly with the disinfectant used. Taking perchloride of mercury 1 in 1,000 solution, it is found that an ounce of salt disinfects more than 3,000 square feet of surface. The time occupied in the operation is about an hour per 1,300 square feet.

Clothes, bedding, mattresses must be removed at once in a closed van to a disinfecting station, to be treated with superheated steam. Dry hot air is now only used in special cases (books, leather, and some other materials), and in practice the apparatus is no longer constructed (see p. 27). Occasionally, however, a baker's oven may serve, if not for the destruction of the spores of splenic fever, for killing the non-sporiferous bacteria of cholera, typhus, and diphtheria, and especially of animal vermin (*Klein*). The bodies of persons who have died of infectious diseases should be at once wrapped in a cloth soaked in 1 per cent. solution of mercuric chloride prior to burial or cremation. Adolf and Heider find that hot solutions of disinfectants are much more active than cold.* In Belgium infected clothes are boiled in a solution of zinc chloride, or with a mixture of 240 grammes zinc sulphate and 120 grammes salt dissolved in a pail of water. Commercial zinc salts cannot be used, as the presence of iron salts causes them to produce stains on linen.

In *Hospitals* special precautions are obviously necessary, and it is natural to expect in them the most improved methods of disinfection. Most of the larger hospitals in England are now fully equipped with modern steam disinfecting plant for bed-linen, clothes, and the like, and, in one or two, special cremating apparatus are in operation for the destruction of infectious stools, bandages, dressings, and valueless articles. The floors of the wards are preferably of polished wood, and they and the walls near the beds may be mopped with 1 in 20 carbolic acid solution from time to time. The bedstead and bedding may be conveniently disinfected by sulphurous acid, and the smaller wards may also be disinfected by this gas. Carbolic acid, 1 in 20, can be used in bed pans, spittoons, and other dejecta receptacles. For surgical dressings, diluted liquor soda chlorinate or carbolic acid

* *Arch. f. Hygiene*, vol. xv., p. 55.

(1 in 40) are generally employed. Eucalyptol is still frequently used in bronchitis kettles for diphtheria and pulmonary diseases. In the operating theatres and obstetric wards mercuric chloride 1 in 1,000 finds most favour. In London the Metropolitan Asylums Board has been constituted a Local Authority under the Diseases Prevention Act, 1883 and 1885, and in 1891 its powers were increased so that it is enabled to secure accommodation for cholera patients in the event of an outbreak. The arrangements in 1892 provided for 1,700 beds, not including 250 available at the Board's Hospitals. These cholera beds were secured partly by the acquisition of sites for temporary huts, and partly by special arrangements made with the larger hospitals, infirmaries, and workhouses. This constitutes the first line of defence in London in the event of an outbreak.

Cisterns for drinking water must not, obviously, be connected with the water-closet tanks. They must be occasionally scrubbed out, every three or six months, according to the quality of the water. If made of lead, care should be taken not to expose the metallic surface, or lead may get into the water. If any foul deposit, or confervæ, have collected on the sides, the cistern should be brushed over repeatedly with a solution containing 5 per cent. permanganate crystals and 5 per cent. sulphuric acid. Householders can have a quart of this solution made up at a chemist's (water 1 quart, potassium permanganate crystals 2 ounces, sulphuric acid 2 fluid ounces; cost about 6d.). The solution should be used till the pink colour of the permanganate remains for an hour, then it should be well flushed till all colour has been removed. A slight brown coating of peroxide of manganese on the walls will be advantageous, by serving as an oxidiser, and preventing further growth. Several inventions have been introduced for allowing a small quantity of permanganate solution to be constantly admixed with the water, but any admixture of a chemical, except a minute quantity of slaked lime, properly used as in Clark's process (p. 15) would be injurious; they are, however, of service in small cisterns used for closets and urinals. One of these inventions places the crystals in a horizontal bottle with a narrow tube, another in tablets,* a third is a closed porous pot hung in the cistern.† Straling's sanitary tube is somewhat similar. When a rain supply is used for drinking in cottages in remote parts, care must be taken that the water-butts are kept very clean. Iron tanks are better than wooden barrels.

Water-Closets should be of modern patterns, admitting of washing, flushing, and proper cleaning of walls and pans. The walls should be of cemented tiles or lime-washed. The solution of acid permanganate

* Symonds, Patent No. 8,351, 1885. † Austin, Patent No. 4,981, 1885.

should be used occasionally to cleanse the pans. Chloride of lime should not be used, as it corrodes the metal fittings, and has often caused serious mischief by eating holes in lead or iron siphon traps. Mercuric chloride also corrodes lead pipes. The flush of water at each using should be preferably 3 gallons. A valve closet, though rather expensive, seems to be the best form for indoor use.

Earth-Closets are daily diminishing in number, owing to the fact that the rapid and inoffensive removal of excreta is most economically effected by the water-carriage system. The mass of water with which each excretal mass is mixed, the perpetual movement of water in the sewers, and the low temperature in them, are unfavourable to bacterial development. Pathogenic microbes soon die in a mass of water owing to their conflict with non-pathogenic microbes and perhaps also as the result of other unrecognised factors. The system is, however, objectionable, because of its fouling so large a mass of water. It is nevertheless a mistake to suppose that fæces pollute sewage any more than any other waste matter discharged into the sewers.

It was with the object of saving the manure, as well as the immediate disinfection of the fæces, that Moule, in 1863, introduced the earth-system of closets. Earth is popularly believed to be a universal disinfectant, yet it abounds in microbes, some of which are pathogenic (*Koch*). Indeed the very nitrification, upon which the purifying action of earth is so largely dependent, is in great part due to the life and growth of microbes. The earth should be dried or, preferably, baked before using. In some districts this is done every day over the oven; it could also be baked in larger quantities over a baker's oven or in a special furnace. So dried the earth is very absorbent, and instantly removes all odour when only a light covering is spread over the excrement. But its effective use is ruined by the discharge of urine at the same time; if this could be kept separate and used for agriculture, the process would be excellent. Unfortunately the manure is of hardly any value, on account of the rapid loss of ammonia. Dr. Rolleston showed that as the earth became damp, this gas was evolved. Success depends more on the quality than on the quantity of earth. Sand and gravel are inert, chalk feeble and dry clay good, whilst garden soil, loam, and peat give the best results;* 2 lbs. of dried earth at least are required for each evacuation. At Wimbledon camp in 1869, when 140 tons of dry earth were used in a fortnight for 30 tons of excreta the deodorisation was complete.† Green and white moulds destroy the fæcal matter, and in 5 or 6 weeks it is undistinguishable from

* Buchanan and Radcliffe, *Report* of 1869. † *Lancet*, July 24, 1869.

ordinary earth, so that it can be safely spread on gardens or on land, provided that it is ploughed or dug in. Although of so little manurial value, containing only about 0·1 per cent. of nitrogen and 0·5 per cent. of phosphoric acid, it has been found beneficial for soils. Although pathogenic organisms are not killed by the process, they do not in practice escape, and there is no record of epidemics having been caused. For places without a copious water supply, this system is better than pails, and much superior to privies. Dr. Poore has recently advocated an earth system for rural sanitation.

The Goux-Thulasne Method is a combination of the earth and the pail systems. In an iron barrel with handles a slightly conical core is held, and the intervening space packed with dry earth or a pulverulent disinfectant. When the core is withdrawn, a cavity of the same shape is left. These are carried round on a dray and left at the houses. At the end of a few days they are collected, shaken so as to cover the excreta with powder, and covered with an air-tight iron lid before removal. They must be kept from the rain. There should be urinals in the neighbourhood, or a funnel can be arranged in the front part of the closet opening to collect the urine separately, so that the earth or powder is not wetted. This is an excellent mode of disinfection of fæcal matters, especially in sick rooms when the excreta must remain all night in the room.

A Self-acting Earth-Closet has an upright box at the back containing the dry earth, &c. By a rack-work and lever worked by a handle in the ordinary water-closet fashion, a valve at the bottom of the box is opened, allowing a certain quantity of earth to fall on the fæces at each evacuation. The receptacle is a large ordinary zinc pail. Or the arrangement may be made automatic by a hinged seat. By Norris's patent,* the solids are separated by a grating and mixed with earth, the liquid portions pass down the drain, which is ventilated by a current of fresh air and connected with an ordinary ventilating shaft.

Pail System.—In villages and some towns on the Continent the excreta are discharged into pails, which are collected at night-time, and the contents, with or without a perfunctory disinfection, emptied into ditches or pits, which when full are covered up with earth. From this primitive and dangerous practice, the material has come to be called night-soil. Even this is, however, preferable to the old system still surviving in English country districts, and even improperly permitted in some towns (but not in London)—namely, that of

Privies, wherein the fæces and urine fall into a brick well, which is cleared out at intervals. The soil is infiltrated, and the infected drainage has often penetrated for years into wells used for drinking

* No. 20,726, 1891.

water, and has been the cause of numerous epidemics. At Rochdale an improved pail system is giving good results. The excreta and ashes are collected separately and the former converted into dry manure, whilst the latter yields fuel for a refuse destructor and steam production.*

Cesspools can only be dealt with by pumping out the contents and distributing them over land. They cannot, obviously, be disinfected.

S. von Gerloczy,† in an investigation of disinfectants at the Pesth Hygienic Institute, found that a practical disinfection of night-soil was all but impossible. Even 2½ per cent. of mercuric chloride was insufficient to render it germ-free (costing £9, 10s. per cubic yard). Complete disinfection resulted when 4 per cent. of cupric sulphate was used, but the cost of it would also be prohibitive. In sewage matter 1 per mille of copper sulphate destroyed all germs and rendered it clear and inodorous.

According to the model bye-laws of the Local Government Board, the occupier of any premises shall cleanse every earth-closet on his premises, or fixed receptacle, at least once every three months (this interval is found sufficient for sanitary purposes, as under the proper use of dry earth the stools and even the paper become disintegrated and disappear without fœtor in the compost—*Newsholme*); those with a movable receptacle at least once a week (so that the pails may be manageable during scavenging); privies and ashpits once a week; and cesspools every three months; and that between 6 and 8.30 a.m. in summer, and 7 and 9.30 a.m. in winter.

One of the great dangers of leaving fæcal matter exposed is the visits of flies. The bacteria of tubercle, splenic fever, typhus, and European cholera pass through the digestive organs of flies, and reappear in their excrements with unabated virulence.‡ They are also carried adhering to the feet and legs of these and other insects. A covering of chloride of lime or of a coal-tar powder has the merit of keeping them away. There is a vast number of patents having for their object the introduction of disinfectants into the pan or into the flush water of closets. Cakes of naphthalene, tablets of plaster of Paris mixed with manganate or permanganate, zinc sulphate, thymol, &c., are of little value. Automatic distributors designed to keep the drains flushed with liquid disinfectants give better results. The construction of Jeyes' model is easily understood from the appended illustration.

The contrivance is filled by removing the screw seen in the front,

* *Journ. Soc. Chem. Ind.*, 1895, p. 340.

† *Deutsche Vierteljahresb. öff. Gesund.*, 1889, p. 433.

‡ *Centralblatt f. Bacteriol.*, 1888, vol. iv., p. 486.

then filling the receiver. After the screw has been tightly replaced, the machine is raised to a vertical position and suspended inside the water waste-preventor in the water-closet. On the water rising, the ball acts on the lever, moving the plug, which pressing into the well, as is seen in the figure, expels the fluid in the trough, which falls over the sides and mixes with the waste water. Each discharge of water from the cistern, followed by its refilling, automatically mixes a portion of the fluid with the water for use. Panario* and Skudder† have also invented similar contrivances. In the latter the flush passes through a perforated tube containing the disinfectant in the upper portion. Similar devices for automatically discharging permanganate have been proposed (see under *Cisterns*, p. 237). To continually supply sufficient of a disinfectant to a closet would, however, be very expensive.

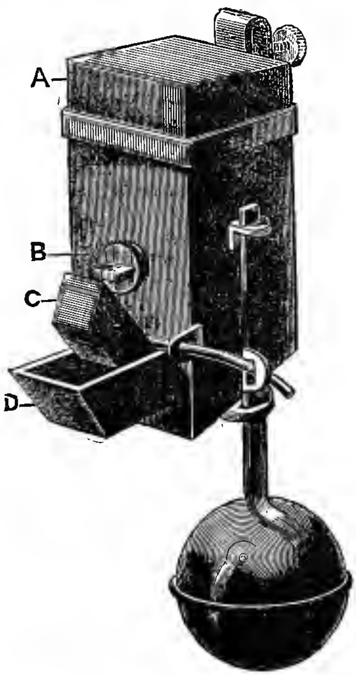


Fig. 22.—Jeyes' Automatic Disinfectant Distributor.

Sanitary officers must proceed with caution in disinfecting private dwellings, and must give proper notice, as it has been proved that an action for damages can be maintained unless the disinfection is legally carried out.‡

Streets are watered and cleansed by the Vestries and Local Boards. It is important to remove refuse and animal excreta immediately, as the surface, even when paved, is porous, and the soil is a very favourable nidus for the growth of micro-organisms, which escape in the dust (p. 223). Mixing disinfectants with the water in the carts is of doubtful utility, as the chemical must be much diluted, and the area to be covered is often large. It is of course impossible to disinfect the open air. Such a procedure may perhaps offer a certain restraining influence on the microbes, but, as ordinarily done, it is often a waste of public money. The main work must be done in houses, and in narrow streets and courts. It would be better if these latter were

* Patent No. 4,287, 1891. † Patent No. 10,301, 1885.

‡ For particulars of such a case at Filey see *Lancet*, April 10, 1880.

paved with asphalt or some similar non-porous material. An asphalt pavement made properly is aseptic, and to a certain extent antiseptic. For disinfecting courts and streets a distributor like Bishop's or the Equifex sprayers (p. 235) would be of service. The former consists of an ordinary rose-jet capable of attachment to an india-rubber hose or to the cock of the water supply. A vessel at the side holds a supply of disinfectant, which is drawn through a tube into the current of water and ejected in spray through the rose. By measuring the relative volumes of water and disinfectant passing through in a given time and regulating the stopcocks, a perfect mixture in any required proportions can be delivered. It is usually made to work with 1 in 40, 1 in 80, or 1 in 160, by marks on the top, which can be set by a key. Such an arrangement is also well adapted for urinals, ships, stables, &c.

Corrosive disinfectants, such as acids or chloride of lime, could not be used with this apparatus. The most suitable would be one of the cresol or pine-oil class (see p. 160 *et seq*).

Wood Paving, although it is cleaner than macadam, and less dangerous to horses than asphalt, has been seriously objected to for sanitary reasons by Mr. Isaacs.* The same view is taken by Mr. Morgan in a recent report to the Liverpool Engineering Society. As the blocks are almost non-porous, and do not readily decay, the objection to their use is not general; no increase of illness in wood-paved as compared with other districts has been noticed.† A creosoted wood paving is now largely used. J. Tottrell ‡ proposes to mix disinfectants, such as carbolic acid, carbolates, sulphites, or bleaching powder, with the ordinary cements employed in paving roads, basements, walls, &c. The cost would be immense, and the utility seems doubtful.

Urinals require somewhat different treatment, on account of the deposit (containing *Bacterium ureæ* and other organisms) which forms from the urine and promotes ammoniacal fermentation. Their sides should be made of slate, or of enamelled, not painted, iron; then they can at intervals be washed down with a solution of sulphuric acid $2\frac{1}{2}$ per cent., and permanganate 2 per cent.; this, of course, must not be put into metal pails unless they are tarred. The sides have been sometimes constructed of glass, but they are too liable to fracture, and then the urine penetrates, and putrefies at the back. Well-tarred iron is the next best material, but is easily scratched, and then rusts into holes.

One form of urinal-cakes consists of sulphates of copper, iron, zinc, and soda, with some alum, heated with resin, and pressed. They

* *Q. J. San. Institute*, June, 1894. † *Lancet*, July, 1894.

‡ Patent No. 8,317, 1884.

absorb ammonia, and are, of course, locally disinfectant, but would not supersede cleanliness and the process just mentioned. Naphthalene tablets are almost useless (p. 148). Disinfecting powders are only temporary in their action.

Stables, pig-styes, and cowsheds require to be regularly cleaned, and to be periodically disinfected, like rooms, with removal of the animals, to prevent disease occurring. Some varieties of antiseptic litter have already been mentioned (p. 12). It is of little use to be perpetually deodorising with powders. Dryness, ventilation, and cleanliness are better safeguards.

For Cattle Markets and Fairs a cresol disinfectant is probably the best. A description of the chief ones is given at p. 165.

Slaughter-houses are particularly difficult to disinfect on account of the large amount of albuminoid matters present. It has already been noted that it is almost impossible to sterilise blood. Mercuric chloride cannot be used because of its action on albumen (p. 137). Phenol is inapplicable for the same reason. Copper sulphate is one of the most useful agents in these places. Chlorine and sulphurous acids are rarely to be recommended. Cleanliness and rapid removal of offal are the first considerations. Cunliffe and Barlow * subject the refuse to heat and destructive distillation. Wood charcoal only serves to deodorise, and does not destroy. Slaughter-houses for infected or suspected animals are usually situated near seaports, and require special methods of isolation, and extra precautionary measures to be adopted.

Bakehouses.—There has been much agitation lately with reference to their insanitary condition. Under the Factory and Workshops Act, 1891, local authorities have power to act, but the recommendations of the London County Council on the bill of 1894 have not yet become law.

Dairies and the Milk Trade will be alluded to under *Food*, p. 272.

Pigeon and Fowl Houses, Rabbit Hutches, &c., often become very offensive, and are dangerous breeding houses of disease. Legislation with regard to them is difficult and hazardous, but at least more attention should be given to secure that, especially in crowded neighbourhoods, they are kept in a sanitary condition. They should occasionally be disinfected with sulphurous acid, the animals being removed. This is only a partial precaution, as their feathers and hair are likely sources of infection. Some effect is produced by dusting them with flowers of sulphur. Poisonous disinfectants obviously cannot be used.

Cats, from their prowling habits, have been proved to frequently

* Patent No. 19,967, 1890.

carry infection, especially of diphtheria. Dogs are more easily kept clean. Rats, as coming from the sewers, and even mice, are sources of infectious danger.

Vehicles.—The following is from the *Report of the Society of Medical Officers of Health*, Nov. 19, 1886, on a communication addressed by the Commissioner of Police to the Metropolitan Sanitary Authorities. In cases of supposed infection, Sanitary Inspectors are authorised to disinfect without charge, and give a certificate. "I hereby certify that cab . . . has been this day disinfected by me after the manner prescribed by the Medical Officer of Health. Signed . . ."

The cushions, and as much of the internal fittings as are movable, should be taken out and put in a disinfecting oven, where such is available. If not, they are well beaten and dusted, returned, and placed on end so as to expose both surfaces to disinfection. All exposed woodwork is washed with carbolic soap, and carbolated oil is smeared over metal work with the view of disinfecting it and also protecting it from chlorine. The chlorine is evolved inside (see p. 57), and the vehicle shut and left so for an hour.

A process was patented for enclosing vehicles in a kind of chamber made of tarpaulin, and then injecting steam or disinfecting spray, but it does not seem to have come into use, being cumbrous and expensive.*

Skins, furs, wool, and hair are constant sources of infection. Wool-sorter's disease, anthrax, charbon, and splenic fever, was many years ago proved by Pasteur to be due to *Bacillus anthracis*. Machines are now devised for carrying the dust away by fans, and for disinfecting by steam; the trouble is, that the wool will not bear a temperature sufficient to kill the anthrax spores, which are, moreover, very highly resistant to chemical agents (see *Mercuric chloride*, p. 136). So that the only means practicable are cleanliness on the part of the workmen and the use of fans. Arsenic is used in the preparation of furs and skins, but of the chemical disinfectants, formalin seems to be the most suitable for general disinfection of such articles.

Rags are exceedingly dangerous, because they often come from fever-stricken districts, and convey bacteria as well as vermin. Their importation in cholera times is generally prohibited, but as they carry other diseases besides cholera, they are at all times to be regarded with suspicion. It is difficult for steam or heat to penetrate the tight bales into which they are compressed by hydraulic pressure.

Parker and Blackman† force hollow screws into the bales by means of suitable machinery, and then introduce a disinfectant through the screws, and afterwards air, which displaces any noxious smell. This apparatus is used in America. An improved process has been devised

* Patent No. 5,434, 1883. † Patent No. 16,539, 1884.

by Paton and Ransom.* Conical perforated pipes are first driven into the bales, and then hot air is forced into the bales to heat the interior and prevent the steam which is subsequently introduced from condensing. Steam at 10 to 25 lbs. to the square inch is then forced in for fifteen to twenty minutes, succeeded by hot air for ten minutes to remove moisture, and cold air for about the same time to finally cool the mass. It is adapted for cotton and textile goods as well as rags. The disinfection of rags is now necessary under the new Act of the United States Legislature. All rags used for paper-making must, prior to shipment, be disinfected by one of the following methods:—First, boiling the unbaled rags in water for half an hour; second, exposing them to the action of steam between 100° C. and 115° C. for a similar period; third, exposing them for six hours in an atmosphere of sulphur dioxide, made by burning 3 lbs. of sulphur to every 1000 cubic feet of space; fourth, exposing them six hours in an atmosphere containing 3 per cent. sulphur dioxide gas liberated from liquid sulphur dioxide. By the third and fourth methods the rags must not occupy more than 50 per cent. of the total cubic space.

Disinfection of Air.—This is impossible except in confined spaces. The germs of cholera and of a large number of other diseases are known not to be carried by air, as an exposure to free oxidation in the atmosphere (possibly to ozone in addition to common oxygen) and to light soon destroys the majority of bacteria. In still air the organisms sooner or later settle, especially if the air is damp and the walls are moist. The number of microbes is least in pure external air. It is greatest in places where the population is dense and the ventilation defective. In inhabited houses the impurity is due to the products of combustion and respiration. S. Merkel† states that air expired from man and from animals even in a good state of health contains a minute quantity of a volatile organic base, poisonous in a free state, but losing its toxic effect when combined with acids. Brown Sequard, Arsonval, and Wurtz‡ found that (*a*) vapour expired is alkaline; (*b*) its toxicity is *not* destroyed by heating in a closed retort; hence they conclude that the "*esprit de corps*," as it has been facetiously termed, has the characters of an alkaloid. Animals confined in a space from which the carbonic acid produced by respiration is continually removed die long before the oxygen is consumed, although nitrogen is not poisonous.

In inhabited districts the air contains, in addition to micro-organisms, fragments of carbon, of hairs, fibres of tissues, particles of starch, pollen granules, epithelium, &c. These can be removed by filtration through cotton wool, also in great part by passage over damp surfaces, or by

* Patent No. 7,735, 1894. † *Archiv. f. Hyg.*, vol. xv., p. 1.
‡ *Acad. des Sciences*, Jan., 1888.

subsidence. Breath is ordinarily free from microbes, and sewer gas contains exceedingly few. In both these cases the freedom from germs is due to the subsidence on the damp surfaces present.

Prof. Klebs remarks* that the cause of malaria is probably a specific organism. From the air of malarial districts aspirated through suitable apparatus he obtained organisms about 0·95 micro-millimetre in diameter, capable of producing malarial fever on inoculation. He proposes the name *Bacillus malariæ* for them. They are developed in the presence of free oxygen, hence are aerobic. The subject has been more recently studied at some length by North. In addition to the apparatus for the disinfection of air already alluded to, there are a very large number of other inventions, of which the following is a summary :—

For Sewer Gas.—Keelin's apparatus: the air is passed through gas furnaces.† Recent experiments with refuse destructors have, however, established the fact that, although a comparatively low temperature is sufficient for killing micro-organisms, a temperature of at least 1250° F. is essential for entirely destroying any noxious vapours.

Vaporisers.—1. In M. Godin's vaporiser the fluids are poured on a porous stone on a stand heated by a lamp.‡

2. An inlet ventilator in the wall of a room 6 ft. from the ground; the air entering horizontally is deflected through a short tube into a well containing a disinfectant; and the charged air then passes upwards into the room.§

3. Strips of linen are stretched on a series of frames radiating from a central hinge, and are syringed with a disinfectant (or it is simply poured on them) so as to expose a large surface. The whole apparatus is enclosed in a case for carriage.||

4. Barlow's exhausting ventilator ¶ is similar, but contains filters of antiseptic wadding, and heating chambers for sterilising the air at the outlets.

5. Bristow Hunt ** draws the ventilated air through a coil heated by an ordinary stove. This apparatus is recommended for sewers, cesspools, holds of vessels, &c., but is open to the following objections :—(*a*) If the air passes rapidly, there is danger that the central parts of the current will pass without being sterilised, on account of the bad conducting qualities of air; (*b*) the air so treated is rendered unfit to breathe; (*c*) the coils, if narrow, become clogged and coated; (*d*) they are uncertain in action, depending on the working of the

* *Atti della R. Acad. dei Lincei*, vol. vii., 1879.

† *Lancet*, 1888, vol. i., p. 486.

‡ *Chem. and Drug.*, vol. xxv., p. 89.

§ *Brit. Med. Journ.*, 1889, vol. xi., p. 771.

|| *Lancet*, 1889, vol. xi., p. 121.

¶ Patent No. 194, 1878.

** Patent No. 1,321, 1878.

stove; (*e*) if made of firebrick flues or fireclay tubes, instead of iron, they are easily broken in stoking, stirring, or cleaning; (*f*) they have been known to cause fires by passing near woodwork. Nevertheless, a method of this kind is cleaner, cheaper, and more effectual than any chemical disinfection for constant use.

6. Water or a disinfecting fluid flows in a thin film over rods or metal-gauze tubes into a lower receiving tank from which the liquid is pumped up again into an upper receptacle. The air to be purified is guided by louvre plates or shutters over the wet surface.*

7. J. S. Mur † draws the air through revolving drums with opposing slots, dipping into disinfecting fluid.

8. J. F. Johnson ‡ proposes to use a rapidly revolving fan which, by means of peculiar paddles, disperses the disinfectant as spray through the current of air. This is a good apparatus where the motive power can be obtained.

9. C. C. Leathers § also by means of a fan draws air through sawdust, tow, &c., impregnated with disinfectant.

10. W. H. Spencer || suggests the use of an open water-bath carrying a porcelain pan containing eucalyptus or other oils which is heated by a lamp underneath, and adjustable as to height above the flame.

11. Mr. W. Key's screen ¶ is formed by stretching thousands of cords of suitable material from ceiling to floor, interlaced with horizontal copper wires stretched tight so as to form a flat surface like coarse cloth. Water trickling down washes the air which passes through the minute holes in the screen. Experiments done in a dense fog showed that no fog passes through, and that the air thus purified is bright, clear, and free from odour. In the case of dust the results were not so satisfactory. A non-corrosive disinfectant or deodoriser could be added to the water. If all the air could be made to pass through such screens in sufficient volume, it would probably be one of the best methods.

12. Kingzett ** suggests a wick with one end embedded in a block of plaster or other absorbent substance, the other dipping into a reservoir of a disinfectant so that the evaporating surface is increased. This device is also suggested as a means of supplying liquids to surgical dressings or bandages.

Water for drinking and cooking is in London and several large towns supplied of very indifferent quality. As obtained from deep wells it has been naturally filtered, is free from germs, and almost

* J. Stanley, Patent No. 3,705, 1880.

† Patent No. 2,781, 1883.

‡ Patent No. 5,379, 1883.

§ Patent No. 22,258, 1881.

|| Patent No. 8,629, 1891.

¶ *Hygiene*, May 13, 1893.

** Patent No. 3,830, 1893.

devoid of organic nitrogenous matter (which has been oxidised into nitrates), but is of considerable hardness. River water is stored in settling tanks, where, by oxidation and subsidence, the microbes are mostly removed (see p. 15); then it is filtered by two methods—(1) Natural filtration; large reservoirs are dug parallel with the banks of the river, being filtered through the ground in transit. (2) Artificial filter beds, composed of layers of sand, gravel, and stones, through which the water passes into the mains. In most districts it is intermittently delivered into house cisterns; some have a constant supply (see p. 237).

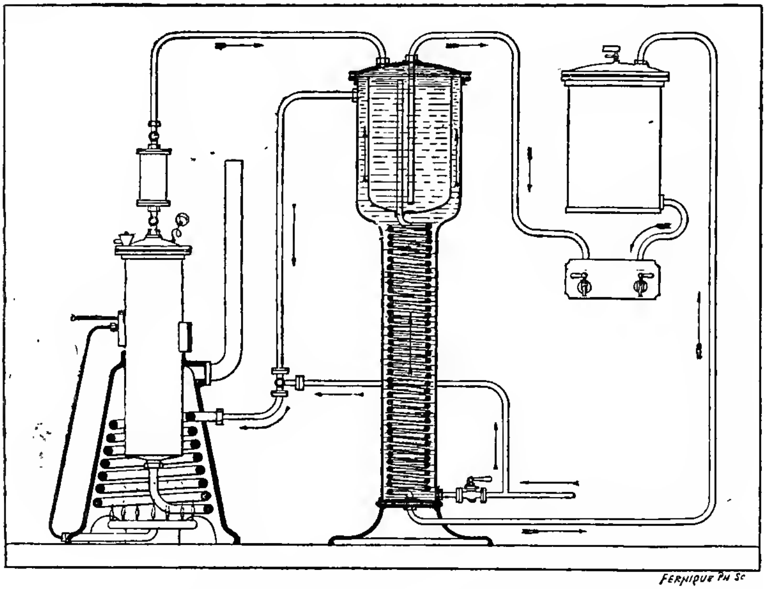


Fig. 23.—The Equifex Water Heat-steriliser.

Occasionally the water supplied is turbid, showing that the filter-beds are not acting properly; it always contains micro-organisms, greatly reduced in number, and usually non-pathogenic. It may also be contaminated on its way to the consumer, from the ground through leaky joints in the pipes (even full pipes carrying a current of water will draw in surface drainage from the soil) or from the atmosphere in the cisterns. Absolute safety can only be attained by boiling, or by filtration through a Pasteur-Chamberland filter. A temperature of 100° C. does not kill all the germs (*Tyndall*, *Koch*, and others) unless continued for a long time; hence it has been proposed to sterilise water by heating under pressure.*

* Société Geneste, Herscher & Co., Paris. J. Y. Johnson's Patent No. 2,051, Feb., 1891. Also *J. Soc. Chem. Ind.*, May 31, 1892.

Under the name of Equifex water heat-sterilisers, the Geneste-Herscher patent has been recently introduced into this country. It is shown in Fig. 23, and continuously sterilises water, and cannot work unless the temperature for which it is set is applied for the necessary time.

This control is effected by means of a valve which only lifts and permits the passage of sterilised water at the necessary pressure and temperature. The sterilising vessel is kept for fifteen minutes at the required temperature, and by means of a cock the discharge pipe is then opened. The capacity of the sterilising vessel and its discharge orifice, and the pressure for which the safety valve is set, determine the minimum time in which the vessel can empty itself; and the control valve ensures that no part of this time can be occupied in passing water below the desired temperature.

By allowing the sterilised water to heat the incoming water, economy is effected, and the sterilised water may be delivered within 2° to 3° C. of the temperature of the service water. The high pressure at the same time prevents the loss of dissolved gases, except in so far as they re-act with dissolved organic matter on the water, and reduces to some extent the precipitation of dissolved salts. The sterilised water is passed through sand, and is discharged from the apparatus cool. The course taken by the water is shown in the diagram, in which tbe feathered arrows represent sterilised, and the others unsterilised, water.

The form shown in the diagram is that of an apparatus used in the operating rooms of hospitals, and supplying about 8 gallons cold and 8 gallons hot sterilised water per hour. When heated by gas it consumes about 45 cubic feet of gas per hour.

Kühn of Paris uses a similar sterilising plant for beer and other organic liquids.*

Boiled water is not palatable; filtration afterwards aërates it and restores the proper taste; hence, as it is proved that boiling does not completely sterilise, boiling first and filtration afterwards through a good and clean filter may be recommended. Water after boiling must be kept in very clean vessels, and should not be exposed to air long before drinking, as the multiplication of bacteria goes on far more rapidly even than in unboiled water.† Boiled water may be artificially aërated with carbonic acid in a gazogene apparatus. Dr. Altehoefer's suggestions as to the use of hydrogen peroxide have been already referred to (p. 85). Water in cisterns with constant supply lying stagnant while families are away for the holidays may be a source of danger.

* *Journ. Soc. Chem. Ind.*, 1894, p. 1133.

† Miquel, *Analyse Bactériol. des Eaux*, Paris, 1891, p. 146.

The recent report of the Royal Commission on Metropolitan Water Supply (1893) has drawn attention to the present unsatisfactory nature of our bacteriological knowledge of river waters. Although there are abundant opportunity for pathogenic organisms to enter the Thames, hitherto investigators have failed to detect their presence in the water supplied by the London companies. This result may be partially due to the filtration which the water receives, but is probably mainly to be attributed to their rapid attenuation and death when introduced into a river water containing numerous non-pathogenic organisms. It must not, however, be forgotten that the fate of these pathogenic organisms has not been properly studied, and it is quite possible that they may be present in such filtered water in a modified form, and capable of giving rise to the original pathogenic forms so soon as they are brought into a suitable medium. It seems, therefore, essential that adequate precautionary methods of boiling and filtration should be adopted by householders in towns possessing a river-water supply, especially in warm weather and when there are any indications of epidemic disease.

Preservation of Timber.—Although not strictly hygienic, attention may be drawn to the use of antiseptics for preventing the decay of wood. Two methods are in use: in the first, hydraulic pressure is employed for injecting the preservative liquid into the lower end of the log; in the second, the liquid is drawn in by vacuum pumps at the upper end, the logs being encased at the end by india-rubber or leather. These processes equally saturate the tissues, if thoroughly carried out, with the antiseptic, and prevent the penetration of the disintegrating mycelium of fungi such as *Merulius lachrymans* (dry rot). The first method is the quicker. Either of them presupposes the driving or sucking out of the natural juices, and replacement of them by the antiseptic solution. Both of them are analogous to the injection of corpses by preservatives.

Copper Sulphate (Kyanizing) was the earliest agent used, and is still found effectual, although the corrosion by galvanic action of any iron nails, screws, or bolts embedded in the wood is a serious disadvantage. Mercuric chloride is precluded by the expense.

Creosote Oils are now commonly used. Well-seasoned timber is placed in a vessel so constructed that a more or less perfect vacuum can be obtained by an air-pump. The creosote oil, previously heated from 35° to 50° C., is allowed to enter the exhausted receiver, and pressure is then applied by pumps in order to effect the better penetration of the antiseptic fluid. In S. B. Boulton's improved process, the exhaustion is continued after the entrance of the creosote, which is heated to a temperature somewhat above 100° C. By this method the moisture contained in the pores of the wood is volatilised and removed by the pump, and the oil subsequently penetrates the wood very thoroughly. A great advantage of this process is that wet timber can be at once treated without being previously seasoned. The amount of creosote oil taken up by the timber varies considerably, but is usually about 1 gallon per cubic foot of wood. The smell of creosote oil is much disliked by the lower animals (white ants, &c.), while certain of the constituents have a powerful antiseptic action. S. B. Boulton and Coisne, on behalf of the Belgian Government, have proved that in the course of a few years the tar-acids (phenol, &c.) in railway sleepers, &c., completely disappear by dissolving and by volatilisation, whereas the semi-solid constituents, such as naphthalene, and the higher boiling oils (above 315° C.) remained, and could preserve the wood for sixteen to thirty-two years.* Hence the phenoloid bodies of high boiling point and slight solubility are probably of more value for creosoting timber than carbolic or cresylic acids themselves. But the lower phenols are doubtless of value in coagulating the organic matter present in the sap, and should be present in creosote oils in sufficient quantity to effect this.

* Allen's *Commercial Org. Analysis*, 1886, vol. xi., p. 552; S. B. Boulton, *Proc. Inst. Civ. Engineers*, May, 1884.

CHAPTER XIII.

PERSONAL AND INTERNAL DISINFECTION—FOOD PRESERVATION.

Personal Disinfection : Sachets and Lockets practically useless—Cleansing the Hands—Soloids—Gloves—Caustics—Snake-Bites—Burns and Scalds. **Disinfection of Cavities of the Body**: (*a*) By Washing out—(*b*) By Spray—(*c*) Gargles—(*d*) Injections of Gases or Vapours—(*e*) Inhalations. **Antiseptic Dressings** : Sulphocarbolate of Zinc—Salufer Cubes—Sozal—Gauzes and Wools—Antiseptic Paper—Rinsing Surgical Instruments. **Hypodermic Injections. Antiseptic Soaps**: Mouth Washes—Ointments. **Respirators**: "Sanitary Wool" Clothing. **Internal Disinfection** : Charcoal—Sodium sulphethylate—Chlorinated Soda—Oxygen—Sulphides. **Internal Antisepsis**: Phenol—Creosote—Essential Oils—Mineral Waters—Acids—Sulphuric Lemonade—The Vienna Mixture—Betol, &c.—Quinine—Benzosol—Phenosalyl—Vaccination. Preservation of Food: Causes of Change in Foods—(1) Oxidation—(2) Reduction—(3) Metallic Contamination—(4) Organisms—Methods of Exclusion of the Latter—Drying—Smoking—Necessity of Proper Cooking—Curing by Wood Vinegar—Danger of Poisoning by Stale Fish. **Infection by Milk**: Tyrotoxicon in Cheese, Milk, &c.—Infection of Food by Bacteria in Air—Precautions. **Preservation by Cold**: Does not Kill all Bacteria—Downward Draught—Methods of Freezing Meat—Large Refrigerators—Hydrocarbonic System. **Preservation by Chemicals** : Not Successful—Sulphites, &c. **Preservation by Heat**: Canning Processes—I. Chloride of Calcium Process—II. Aberdeen Process—III. Jones' Vacuum Process—IV. Salzer's Baltimore Process—V. Budenberg's Steriliser—VI. Hartmann's Method. **Milk**: A Common Vehicle for Contagion—Precautions—Heating under Pressure—Preservatives. **Condensed Milk** : The Anglo-Swiss (Borden) Process—Hooker's Cream Milk—Condensed Beer. **Butter** : Conditions affecting Rancidity. **Cheese**: Aseptic Wrappers—Pickling and Cleansing Grain. **Bread**: A Means of carrying Infection.

PERSONAL DISINFECTION.

The "last line of defence" includes the precautions taken by the private individual. These may be considered to include cleanliness of the home, cleanliness of the person, and purification of the clothing. The first and third have been discussed, and it has already been pointed out that individual immunity cannot be ensured by carrying about the person camphor, aromatic vinegar, eucalyptus, or other chemical substances, which in former times found favour as charms, since these agents cannot reach an effective proportion in the atmosphere. Many devices of little value have, however, been patented for personal protection in even recent years. Thus Woodthorpe and others * suggest an ingenious arrangement like a vesta-box, with a sliding perforated case, to be kept in the pocket, and a mixture of bran 4 ounces, camphor 1 ounce, eucalyptus oil 2 drachms, hydro-naphthol 1 drachm, carried in a linen sac, has been seriously recommended to ensure wearers against infection in houses.

In fever cases it is now generally customary to sterilise the hands by washing in a 1 per mille solution of mercuric chloride with a little salt and hydrochloric acid (p. 138), and rinsing them with plain water before washing with soap. In cases of very great danger the clothes are afterwards disinfected by steam. Notwithstanding the fact that many other antiseptics have been proposed for the hands, mercuric chloride seems still to be the best. A few ounces are quite sufficient, and should not be diluted beyond 1 in 1,000. The same solution should also be used by nurses and attendants when leaving the room; a convenient way of preparing the solution is to dissolve one "soloid" in a pint of water, taking care to stir well till all has dissolved. One of the soloids in a pint of water makes a 1 in 1,000 solution. They are characteristically coloured and shaped to avoid mistakes. Infectious matter is particularly liable to remain under the nails.

It is well known that any cut or abrasion of the skin when handling septic matter inevitably causes blood-poisoning, which, if not fatal, leaves dangerous after-effects; also that specific diseases can be inoculated in the same way. Waterproof gloves are manufactured for operations involving such risk, but as they very much deaden the delicacy of touch, they are seldom used. If a cut or wound has been accidentally produced, cauterising with nitrate of silver, nitric acid, phenol, permanganate, or osmic acid is frequently recommended, but the eschar left is often very painful and troublesome to heal, besides not being thoroughly safe against inoculation. Covering with lead or court plaster, or with collodion; painting with iodine or iodoform tincture; thoroughly drying the cut and painting with a solution of Stockholm tar or Burgundy pitch in alcohol, ether, or acetone, are among the other treatments suggested. None of these methods give absolute immunity, so that, in case of accidental puncture during a *post-mortem* or operation, or in handling contagious matter such as dead meat, skins, or evacuations, it is probably safest to wash immediately with mercuric chloride, dry, and at once cauterise, and thus combine the two precautionary measures. When, unfortunately, the abrasion has not been noticed at the time, this treatment should still be resorted to. Afterwards, hypodermic injections of an antiseptic have been recommended, and cinnamic acid, styrol, phenyl-propionic acid, β-naphthol, and betol are used for this purpose; phenol or any other reagent

* Patent No. 2,770, 1894.

which coagulates the blood is of course inapplicable. For ordinary bites and scratches similar treatment may be adopted; the part should be afterwards protected by antiseptic gauze or wadding, iodoform powder, or, failing these, by lead plaster, an ointment, or flour paste.

Snake-bites are considered to owe their virulence to an ill-defined poison of an albuminoid nature (a "leucomaine," *Selmi* and others), or to the crystalline cobric acid of Blyth. Filtration, which removes micro-organisms, does not affect the potency of snake-venom. Hypodermic injections of diluted ammonia, after sucking out the poison (it is almost inert internally), seems the best remedial treatment. Burns and scalds are liable to septic poisoning if the epidermis is broken, so that they also should be protected, but not cauterised. Wasp-stings and insect-bites have caused death. The best remedies are liquor plumbi subacetatis (p. 134) or Goulard's extract, and the old-fashioned hartshorn and oil.

Disinfection of Cavities of the Body.—Cavities of the body, such as the lungs, larynx, nasal passages, throat, urethra, bladder, and uterus, are peculiarly liable to the attacks of microbes, causing inflammatory and purulent conditions, and even absorption and specific diseases. Several modes of treatment are in use, and have been several times alluded to in the chemical section. They may be thus summarised:—

(*a*) *Washing out* by inflow and outflow tubes with lukewarm water, then with a weak solution of an antiseptic, which should not be one with a strongly poisonous action on the system. Phenol, resorcin, and mercuric chloride have been absorbed with dangerous, and even fatal, effects. Iodine is very irritant. Iodol has been recommended, likewise betol and phenyl-propionic acid.* Salicylic acid is dangerous, irritant, and not effective. A solution of silver nitrate in distilled water has been tried with great success: the objection to it is that if weak (1 in 1,000) it is almost wholly precipitated by the chloride of sodium in the fluids of the body, and if stronger (1 in 200) it has on some occasions caused sloughing. Sulphocarbolate of zinc, 1 in 1,000, has the advantage of being mildly astringent, and seems to be safe. A sulphocresylate would probably be still safer, and is a stronger antiseptic. Alumnol (p. 179) is a useful and powerful astringent. Glycerine is irritant to mucous membranes, but it is useful when it is necessary to keep surfaces moist. On boric solutions see p. 101. A number of the newer antiseptics are advocated for this special branch of antisepsis, but they await more extended and impartial surgical trials, as many of the earlier statements have not been verified by recent experiments.

(*b*) *Spraying.*—Any of the former may be used in the form of spray,

* Klein, in Stevenson and Murphy's *Hygiene*, p. 261.

the advantages being that stronger solutions may be used, that only the affected parts are treated, that the irritating and depressant action of large volumes of water are avoided, that a local refrigerant effect may with safety be produced, that much less of the medicament is required, and that the action can be watched, and the process repeated with facility and without shock. The various spray-producers nearly all act on the same principle; a current of air is blown by an india-rubber ball, with a second ball to render the blast steady, across the narrowed orifice of a vertical tube dipping into the liquid in the bottle. The strength and fineness of the spray are regulated by the relative size and position of the orifices, and the amount of liquid delivered is known by the graduations on the bottle. The use of chlorine water, with or without cocaine hydrochloride, has already been alluded to (p. 59), and boric sprays are frequently used for the throat. Solutions in ether were recommended by Philip Sterne, as far back as 1767,* as antiseptic spray. Sprays are much used in Vienna on the ground that they more easily penetrate parts covered with hair—*e.g.*, mercuric chloride, 1 to 2 per cent., for mucous membranes, and chrysarobin, 10 per cent., for mycosis of the skin.† In hooping-cough, 2 per cent. resorcinol in water, sprayed on the nose, pharynx, and larynx every two hours, is said to give speedy relief.

(*c*) *Gargles* are a form of washing out only applicable to the throat. Honey and borax, tannin, and alum have been used from time immemorial. This method is easily used by unskilled persons, but is inferior to that of spray, as there is no certainty that the parts affected will be reached. It is evident that no drug which will be poisonous if swallowed can be employed.

(*d*) *Injections of Gases or Vapours.*—It is a familiar fact that if an abdominal cavity be wounded, septic poisoning and peritonitis is almost certain to supervene, and that washing out may be dangerous, owing to the intense irritation, and may even cause the above disastrous result. In these cases spraying is also interdicted. Life has frequently been saved by gaseous injections, and sulphur dioxide seems to be the best remedy to employ. This is most readily obtained by blowing a current of air through a tube containing some fragments of sulphur, and allowing the gas produced to enter the cavity. The part of the tube containing the sulphur is heated by a spirit lamp, taking care that the end of the tube is kept cool. Blowing air through a saturated solution of sulphurous acid or through a mixture of a sulphite with acid is inferior to the above, as the quantity delivered is uncertain. Liquefied sulphurous acid from a Boakes' bottle cannot be used for this purpose, as the cold produced is intense and would

* *Advice to the Consumptive.* ‡ *Pharm. Journ.*, vol. xxi., p. 1040.

produce shock. Unfortunately sulphurous acid, by being absorbed into the system, is recorded to have produced fatal effects in one or two cases. Baxter experimented specially on its effect on the virus of peritonitis* with favourable results. Chlorine, bromine, and iodine vapours are irritant and dangerous. Many others, such as chloroform, ether, phenol, &c., are excluded by their narcotic action. Iodoform vapour has caused poisonous effects. Carbonic acid is very soothing, and rapidly subdues inflammation, but for this purpose the gas must be thoroughly washed. It is only a feeble antiseptic, but would be a better medium for other antiseptics, such as eucalyptol, than air.

(e) *Inhalations.*—Chloride of ammonium is beneficial in bronchitis and asthma. The simple breathing of the vapour of vinegar and hot water also gives relief. Koch proved that a number of essential oils when inhaled with steam are inhibitory to tubercle.†

Antiseptic Dressings usually include cotton-wool, wood-wool, or gauze, which act as germ excluders; they are kept moist with diluted soda chlorinata (p. 63), or with boric acid solution (p. 99); sometimes phenol 2½ per cent., or mercuric chloride 1 in 1,000, are used, but they are liable to produce ill effects on absorption. A large number of other preparations have been already described in the chemical section. Sulphocarbolate of zinc is one of the best. There is a great advantage in changing the agent every few days; even the most innocuous are liable to become irritating if continuously used. Diluted cresol and Sanitas fluid are useful in rotation with boric and with chlorinated lotions. Glycerine is objectionable. Salufer cubes (see *Silicofluoride*, p. 79) are portable and convenient. One cube dissolved in a quart of water is used for dressings, or with a pint of water for washing the hands. Sozal, aluminium sulphocarbolate, is a strong astringent and antiseptic lotion (p. 158). Diaphtherin (p. 193) in 1 per cent. solution has been much used in Germany. Tichborne recommends‡ zinc sulphite as non-poisonous and not irritating.

Gauzes and Wools are described under iodoform, boric, and salicylic acids, and zinc-mercuric cyanide (p. 142). Hydronaphthol gauze (p. 179) has recently been much praised. Salicylic gauze is irritating. Thymol or eucalyptus gauze would seem to be the best and safest. Benzoated gauze, 5 per cent. has also been recommended.

Mr. Duquaire, of Lyons, has invented an ingenious antiseptic paper. The material is asbestos with about 5 per cent. of ordinary paper pulp, worked into soft paper and soaked in a petroleum-benzene solution of beeswax. The solvent having been evaporated off in the open air, the

* *Appendix to the Report of Med. Off. of the Privy Council,* 1875.

† Marshall Ward, *Journ. Soc. Chem. Ind.*, 1893, p. 943.

‡ *Brit. Med. Journ.*, 1890, p. 1064.

tissue is ready for use. When required it is set on fire, and is so made aseptic, and may be employed at once for dressing wounds.*

Unfortunately many of the antiseptic wools and dressings met with commercially are of uncertain composition, and insufficient attention has hitherto been paid to the importance of storing these articles in such a way that the antiseptic present shall not be volatilised.

In France their sale, except by duly qualified pharmacists, is forbidden, but the question does not seem to have been discussed in England.

Surgical instruments must be rinsed in a disinfectant which does not corrode steel; the various cresol preparations are much used for this purpose. Those that turn turbid with water have the disadvantage that the instruments cannot be so well seen (see p. 163). A good preparation seems to be potassio-mercuric iodide, 1 in 4,000, or two of the soloids to a pint, for hands or instruments.

Antiseptic Hypodermic Injections.—Several of these have been much employed recently in France, particularly for phthisis; the basis is olive oil, and all the ingredients are carefully sterilised by heating to 120° C.

Picot uses guaiacol 5, iodoform 1, olive oil to 100; Morel-Lavallées' solution consists of eucalyptol 12, guaiacol 5, iodoform 4, olive oil to 100.

Also solutions in olive oil of creosote 1 in 15, and eucalyptol 2 to 4 in 10 have been suggested.†

A number of mercurial compounds are used specially in syphilitic affections. They have been already enumerated and described (p. 143).

Antiseptic Soaps.—The incorporation of a suitable antiseptic with soap has long been recommended by medical men as being a convenient method for ensuring a regular use of an antiseptic. Coal tar was one of the earliest materials used in this manner, and coal-tar soaps, containing, however, mainly the phenoloid derivatives of tar, are frequently employed. At the present time many other bodies are utilised. The Sanitas Company since 1888 have incorporated their "Sanitas fluid" with an ordinary soap, and advocate this preparation for a variety of uses. These soaps are prepared as follows:—Resin or crude turpentine is dissolved in alcohol, and sufficient potash added to saponify the resin, and to leave an excess to combine with some fatty acid which is subsequently added in alcoholic solution. Soap, essential oils, or any disinfectant can also be added at the same time, and the alcohol recovered for a second operation.

* *Chem. and Drug.*, 1890, p. 36.

† Vicario, *Amer. Druggist*, June 15, 1891.

The Jeyes' patent covered the use of gas tar from which the light oil has been distilled off. To the heavy oil an equal weight of caustic soda and twice its weight of cocoanut oil are added, and the mixture saponified in a jacketted pan. The addition of rosin, sulphate, and carbonate of soda is also provided for, if deemed desirable. Quibell's disinfectant soap and powder belong to this class; they are made from a liquid which seems to be a mixture of cresol and pine oil.* Calvert's carbolic soap and Wright's coal-tar soap have long been recognised as proprietary articles. The manganates have also been suggested for rendering soap antiseptic. The salts must be mixed with the cold dry soap. They cannot be recommended, as besides being poor disinfectants, they are liable to leave a brown stain on the hands.

Eucalyptus, thymol, and terebene soaps are very pleasant preparations, and are, of course, antiseptic, but only feebly disinfectant. Terebene and glycerine jelly decrease inflammation. Perhaps more satisfactory than any of the foregoing are those soaps which contain a salt of mercury, of which mercuric iodide is the best (p. 141). It is dissolved in potassium iodide, and added to the soap in the proportion of from 1 in 10,000 to 1 per cent., according to the purpose. Resorcin and salicylic acid soaps are used by Hebra in his clinic at Vienna, and are said to be powerfully bactericidal. Max Jolles has recently shown that ordinary soaps without any added antiseptic have marked disinfectant properties.

Mouth washes and Tooth powders.—These are too numerous to be discussed here. They are chiefly empirical mixtures which owe their reputation to custom or advertisement. Some people use only water with a little soap in it to clean the teeth, but it is of advantage to assist the friction with a powder, and also to use an antiseptic which will penetrate the crevices which cannot be reached by the brush. Wood-charcoal powder is excellent, but rather disagreeable. The best is said to be Areca nut; it should not be used constantly, as it is apt to scratch and wear away the enamel. Prepared chalk is the best foundation for tooth powders, as it neutralises any acid, and being softer than the enamel, it polishes but does not scratch. Powdered myrrh, Peruvian bark, quinine, and other ingredients are frequently added. Honey, borax, various scents, such as orris and rose, are among other substances which are commonly found in dentifrices. As a mouth wash, where there is decay and the breath is offensive, one of the best applications is chlorinated soda diluted to about 1 per cent., and used occasionally. It is not very pleasant, but it removes all odour. Saccharin, sodium bicarbonate, oil of peppermint, benzoic and boric acids, tannin, tincture of iodine, and tincture of myrrh are also occasionally met with.

* *Lancet*, 1889, vol. xi., p. 701.

Ointments.—With the exception of vaseline, which in itself is decidedly somewhat disinfectant, and to a certain extent the preparations of glycerine such as "glycerinum saponatum," described at p. 227, the bases of ointments are only antiseptic in the sense that they exclude air and moulds and bacteria from the surface covered. Otherwise their virtues are simply emollient, or depend on the drug, such as mercury or zinc, which is incorporated with them.

G. H. Fox* recommends sulpholeate of sodium as having a remarkable power of dissolving antiseptic drugs and of yielding them to the skin.

Respirators for asthma, &c., are made of thicknesses of silvered copper gauze. The air is warmed and filtered before entering the lungs. Almost all microbes are removed by the moist sides of the little tubes formed by the gauze, which has to be occasionally cleared from the dust. Several patents have had for object the introduction of a disinfectant into the respirator. Only one that is non-volatile would be permissible, as the constant inhalation of any medicated vapour would be injurious. Permanganate, charcoal, and various tissues have been tried, but without success, as they obstruct the breathing. Every arrangement for filtering air by the action of the lungs must obviously place an additional burden on the muscles of respiration, and the supply of air will almost certainly be lessened. Hence the use of respirators has become much less frequent. Tyndall is credited with suggesting that the human frame should be encased in cotton wool to keep out germs. Many of the patents are quite as impracticable. Wool clothing comes near to this ideal, permitting free egress to perspiration, while excluding dust and microbes. Its film of air keeps the body warm, like a respirator. Pasteur, in 1879, recommended cotton wool respirators for doctors and attendants in fever wards, in the same way that Alphonse Guerin in France, and Lister in England, protect wounds.

Internal Disinfection.—In the alimentary canal, and sometimes in other parts of the body, there are always present large numbers of micro-organisms, and it is probable that the process of digestion itself may be assisted by certain microbes. Even pathogenic bacilli may enter in limited numbers without producing disease. They are not destroyed by the gastric juice, but rarely survive in the struggle for existence with the far more numerous non-disease-producing organisms. They only produce dangerous results when, multiplying beyond control, they penetrate the blood and tissues, interfere with nutrition, set up irritation by their presence, or poison the system by their products of excretion. If they are present

* *Therapeutic Gazette*, 1891.

largely in food, water, or air, it is impossible to exclude them from the body, and equally impossible to kill them when they have entered, since, as has been insisted on before, any chemical agent of sufficient power to destroy the germs would also be noxious, or might even be fatal, to the higher animal. All disinfectants must necessarily be more or less poisonous.

The removal of bacteria may, however, be brought about by hastening their elimination by purgatives, or by entangling them and their products by inert substances like wood-charcoal, which is known to have proved most beneficial in indigestion and flatulency, states which are probably due to, or at least intensified by, organisms promoting abnormal fermentations. Charcoal biscuits are not so effectual as a large dose of fresh charcoal in water. Opinions differ as to whether bacteria are eliminated by the skin in profuse perspiration; there is no doubt that the latter frequently gives great relief in fevers, &c. Saline purgatives are specially indicated. One of the best for this special purpose is sodium sulphethylate, which has been much used in France, but rarely in England. The alcohol basis which it contains renders it slightly stimulant and antiseptic. It is distinctly worthy of an extended trial.

It has been hoped that oxidising agents like chlorinated soda, peroxide of hydrogen, potassium permanganate, and even potassium chlorate would be capable of attacking bacteria in the alimentary canal. But the last-mentioned passes right through the system into the urine without change, while the others not only disturb digestion, but are rapidly used up by the easily oxidisable organic matters present—*i.e.*, they act on the food before affecting the far more stable bacteria. Much was expected from hydrogen peroxide, but results have been disappointing. An oxygenated milk, also an effervescing water saturated with the gas under pressure, have also been introduced, under the idea that the free gases would destroy bacteria.

Sulphuretted hydrogen water and sulphites were formerly given with the object of destroying organisms. They are unpleasant, disturb digestion, and do not seem to bring about the desired effect.

Internal Antisepsis.—Although it is impossible to kill the bacteria within the body, it is quite feasible to hinder their growth and the development of spores by an inhibitory or antiseptic treatment, and so at the same time to lessen their irritant and poisonous action. If the contents of the stomach were undergoing fermentation by the action of yeast, &c., it would be quite possible to stop the process by means of phenol, creosote, or an essential oil, with a dose so small as not to injure the coats of the stomach. But the same dose would also stop or at least impede salivary, pancreatic, and gastric digestions.

Therefore these powerful agents, though occasionally given in capsules, are not in general favour. It has been suggested in a previous chapter that the use of condiments such as salt, vinegar, pepper, mustard, and spices is really an instinct founded on their antiseptic action, since many animals resemble man in this respect. The effect of mineral waters, too, depends in a large measure on the antiseptic action of carbonic acid, and not on the alkali, since soda water generally does not contain soda.

It has been already pointed out that acids are antagonistic to most bacteria (p. 69). Dilute sulphuric acid has been preferred in many diseases, especially cholera, on account of the additional advantage of its astringent action. Sulphuric lemonade, made by the addition of the acid, which should be perfectly pure, to sweetened and sterilised water in quantities sufficient to give a marked, but pleasant, acidulous flavour, may be employed freely, and according to all experience with much benefit. Dr. Waller Lewis, the late General Medical Officer of the Post Office, attributed excellent effects to the habitual and free supply of a pleasant-flavoured sulphuric orangeade among the *employés* of the Post Office during several cholera seasons. It is cheap and innocuous, and is very likely to do much good. Although ordinary lemonade contains citric acid, it is more costly, and is inferior to sulphuric for this special purpose.

The Vienna mixture for choleraic diarrhœa consists of 15 drops of aromatic sulphuric acid (sulphuric acid 1 in 12, with rectified spirit, cinnamon, and ginger) to 1 ounce of sweetened water; to this is often added, under medical advice, 5 or 10 drops of ether and 5 drops of laudanum. The mixture has been much used and highly thought of in Austria, Germany, and France, and by the English Local Government Board.

For intestinal antisepsis neither phenol nor creosote can be employed, being too poisonous and irritating. Betol, however (p. 179), has been successfully used, the β-naphthol produced by its decomposition being comparatively non-injurious. Resorcinol, thymol, and sodium benzoate are sometimes used as internal antiseptics, but they have mostly the same objection to their use as phenol. Sodium sulphocarbolate (p. 158), on the other hand, is safe and is much used.

Quinine and its source, cinchona bark, probably owe a great deal of their power in fevers to their antiseptic action. None of the substitutes for quinine are equal to it in general utility, and many of them, such as kairine, have proved very dangerous.

Several of the derivatives of guaiacol, such as benzosol, have been highly recommended, and are described under their respective heads.

Pheno-salyl (p. 200) is a good preparation for washing out the bladder and urethra.

Vaccination.—Vaccination and other preventive measures of inoculation are at present foreign to the scope of the present work, but may properly be regarded as precautionary measures relating to personal disinfection. Modern research seems to indicate that the toxines produced by the micro-organisms of infectious disease are the natural disinfectants for combating the disease, and there seems good ground for believing that progress on these lines will be rapid in the near future. The present absence of definite chemical knowledge as to the nature of these remedies for phthisis, hydrophobia, diphtheria, and similar diseases, renders the subject unsuitable for treatment here, although their investigation from a bacteriological point of view has yielded, without doubt, some of the most valuable and suggestive results obtained in recent years.

Natural immunity is produced either by dissolved alexines or from the resistance of the tissues, whilst acquired immunity is due to the presence of modified bacterial products. Roux has shown that the serum of animals vaccinated against cholera and pneumonia has no antitoxic properties, although it is germicidal on the microbe. With diphtheria and tetanus the antitoxin is properly so called, as it is destructive to the toxines secreted by the micro-organisms.*

PRESERVATION OF FOOD.

Among the principal food preservatives are boracic acid (p. 99), glycerine (p. 226), salicylic acid (p. 198), bisulphites (p. 96), carbonic acid (p. 104), creosote (p. 161), acetic acid (p. 225), and formaldehyde (p. 220). The changes which food substances may undergo before consumption may be classified under the following heads:—

Causes of Change in Food.—1. *By Oxidation.*—This is comparatively rare and slow in the absence of microbes. Dilute alcohol is transformed into acetic acid by air when in contact with platinum black, but the process is quicker under the action of the vinegar fungus, *Mycoderma aceti.* As far as is known, simple oxidation never renders substances injurious.

2. *By Reduction.*—The only reducing agent that could naturally occur in this connection would be sulphuretted hydrogen, which would involve putrefaction in the substance or in the neighbourhood, and would therefore presuppose the presence of bacteria. It has been suggested that the peculiar taste of certain canned foods depends on the reduction of the fluids by the metal, on the ground that its degree

* Buchner, *Amer. Journ. Med. Sci.*, Jan., 1895; Roux, *Med. Week*, Sept. 14, 1894; Pagano, *Brit. Med. Journ.*, Dec. 1, 1894.

is out of proportion with the traces of metal dissolved, and that it is caused with such extreme rapidity, as, for example, when an apple or fish is cut with a steel knife. In this latter case the taste is often imaginary, as blindfold experiments with apples and fish show that the majority of persons are unable to detect which was cut with clean steel and which with silver. Of course if the metal is allowed time to become acted upon, a ferruginous taste is imparted. Zinc gives a different flavour. Magnesium gives none. Hence the cause would seem to be the metal, not reduction. There is no evidence that a slight reduction would be at all injurious. Sulphites and formaldehyde, if used for preserving, would cause some reduction in unstable constituents of the food.

3. *By Metallic Contamination.*—Vegetable substances coming in contact with iron are blackened and their flavour spoilt. This has led to the use of copper vessels for preparing jams and syrups; even pickles were formerly made in copper vessels. The employment of this metal for vinegar or very acid juices is most reprehensible, as even if the surface is clean, an unknown and often considerable amount of metal finds its way into the food. Mainly through Dr. Hassal and Messrs. Crosse & Blackwell, apparatus of wood, stoneware, and even silver and platinum have displaced copper in making pickles. Enamelled iron should be used for making jams. The presence of copper in preserved peas has been defended on the ground that (*a*) it improved the colour; (*b*) being antiseptic, it increased the keeping properties; (*c*) it was not poisonous in small quantities, but acted as a beneficial tonic. The best authorities regard it as irritant; it is probably cumulative, and it should certainly be prohibited. Lead may be present from the solder, and Hehner has drawn attention to the fact that almost all canned provisions contain tin in solution. Superior goods are put up with oiled paper linings, so as not to come in contact with the metal. The irritant effects of some tinned goods have been attributed to chloride of zinc, which had entered in the soldering; this, and also the dropping in of particles of solder containing lead, have been since prevented by a guard-plate underneath the hole, or by the use of resin for soldering instead of zinc chloride. W. Reuss* has noticed the presence of lead in preserves contained in tinned-iron canisters. The latter were constructed by bending some sheet-metal together, thereby avoiding contamination with lead by means of solder, and hermetically sealed by india-rubber bands. He subsequently traced the lead to these bands, which owed their colour to red lead. On examining red india-rubber bands of French, German, and English manufacture, he found them to contain as much as 60 per cent.

* *Chem. Zeitung*, 1891, pp. 1522 and 1583.

of red lead. Many of the india-rubber bands used for sealing pickles, jams, meats, and preserves owe their red colour to sulphide of antimony, and are free from lead, but antimony has not been found in the food itself. In New York, glass vessels have been tried to overcome these difficulties; but, owing to the expense, breakage, and unsightly appearance of some forms of soups and meats, have not met with much success. For brawn and potted meats earthenware is used. Its weight and fragility are the only disadvantages.

Attempts have been made to coat the inside of the tin with varnish, paraffin, &c., but have not been successful.

If the inside of the tin be much discoloured, or if tinned fruits show a strongly marked crystalline appearance on the interior surface they are unsafe to be eaten. Any discoloration of the contents, or any peculiar odour or taste, should also be distrusted.

4. *By Organisms.*—Yeast, moulds, and bacteria of all kinds can be carried in the dust of the air, on to the surface of any exposed food. There they develop their mycelium, which ramifies throughout the substance and accomplishes fermentative and putrefactive changes. It would be supposed, therefore, that exclusion of air and dust would suffice to preserve changeable bodies. With this object receptacles exhausted by an air pump and afterwards hermetically sealed have been patented. Pasteur and Tyndall's experiments, which proved that air purified from germs by filtration through cotton-wool caused no alteration in urine, beef tea, milk, or sugar solutions, showed also that these must be previously collected so as to exclude the microbe, or must be sterilised by sufficient heat. It is impossible, however, to preserve most alimentary substances in the raw state without the addition of spices or chemicals, because the air contained in them, and the few germs which it is impossible to keep out, are sufficient to bring about their decomposition. However, eggs can be preserved for months by keeping them in a pan of lime water, or by dipping them in a cream of slaked lime and water; in each case the shell is rendered impervious by a coating of carbonate of lime, and the albuminous inner lining of the shell is coagulated and rendered aseptic, as can be proved by breaking and examining. Smearing with fat or varnishing gives a bad flavour. Paraffin wax easily peels off, and is expensive. Fruit has been kept from decay by a coating of melted wax, when gathered fresh and not quite ripe. Jams are usually covered with parchment paper sealed down by white of egg. This membrane does not necessarily exclude air, but its tiny holes must be small enough to exclude bacteria and spores of mould. Generally a disc of tissue paper is laid on the jam, when hot, as an additional precaution. It will be found sometimes that mould

has grown on the top of this, but has not penetrated to the preserve.

Coating with glue, gelatine, or melted fat has been tried for meat without success. Meat is preserved to a certain extent by membranes such as sausage skins.

L. Smith, of Chicago,* proposes to store the goods in air-tight vessels from which the air can be exhausted, while by a three-way tap carbonic acid is admitted in its place. This gas is antiseptic, has no effect on the foods or containing vessels, and does not alter the flavour.

Drying alone is the subject of a large number of patents, differing only in mechanical details. Expression of water and desiccation leave the fibre and dried juices incapable of pütrefaction, but the flavour and digestibility are much impaired. Charqui, South American dried beef, and pemmican are well known. Dried vegetables are manufactured by several firms. Soup-tablets and desiccated soup are generally made with vegetables and meat extract, with very little fibre; many of them are wholesome and palatable, and keep well in closed tins.

Smoking is accomplished properly by hanging up in peat or wood smoke. The surface becomes dried, and also impregnated with acetic acid, wood spirit, and creosote. Although the two former eventually volatilise from the food, the surface retains a good deal of the creosote, and undergoes no change except that the fat in time may become rusty or rancid. A great part of this rankness may be removed by putting about half a dozen lumps of freshly-burnt, or re-heated, charcoal in the water in which the meat is boiled. The charcoal removes the odour, but does not thereby render the article wholesome, hence the change must not have gone too far. Smoking has only a surface preservative action, and does not reach the interior, so that the ova of trichina, tapeworm, &c., remain undestroyed. In countries like Germany, where smoked sausages are consumed raw, or nearly so, the ravages of these parasites are frequently severe. In England, where thorough cooking is the rule, such epidemics are very rare. Still it must be remembered that neither drying, smoking, nor salting secures safety against the ova of parasites. To save time, hams, haddocks, &c., are often cured by dipping in pyroligneous acid, or crude wood-vinegar, with or without brine, or even by being merely brushed over with this solution. Kippers and haddocks are often prepared under most unsanitary conditions, and as the treatment is often far from complete, may be a source of danger. Very slight evidences of decomposition in fish are sufficient to indicate the possibility of an extremely poisonous product in the body of the animal,

* Patent No. 2,444, A, 1891.

so that fish must never be trusted in the same way as high game and mutton sometimes are. The faintest trace of decomposition in fish forbids its use as an article of food.

B. Piffard* prepares an antiseptic liquid by burning wood in a suitable furnace and conducting the smoke into a tube or chimney through which steam is propelled from a boiler; the vapours are then condensed in a suitable apparatus. The woods employed vary according to the nature of the food and the flavour it is required to impart. The patentee uses oak for pork, peat for fish, birch for tongues, and so on. The length of time during which the food is immersed in the liquor varies according to the nature of the article and the strength of the antiseptic. When the liquor is of a dark straw colour, the time is from three to six days for pork, a few hours for fish, and one minute for imported preserved meat, which is thereby much improved in flavour and keeping properties.

It must not be forgotten that as, in the first instance, micro-organisms settle on the surface of foods, such food may often present a normal appearance, and consequently be passed by inspectors and others as suitable for consumption.

Milk has been shown to be a frequent source of danger, and many epidemics have been traced to its pollution, either through the water supply of the cows, carelessness in the dairy, or in the conditions obtaining between the time when it is supplied by the farmer and when it reaches the house of the consumer. Vaughan has further shown that in addition to the danger of milk containing pathogenic organisms, under certain conditions tyrotoxicon, a ptomaine produced by a non-pathogenic form, is produced which gives rise to summer and infantile cholera. As the poison is destroyed by boiling, its absence may be assured by this precaution. Vaughan has also demonstrated its presence in cheese, ice creams, and stale fish.

Cold.—It has already been shown that most micro-organisms are not killed by cold. Nevertheless, various methods of refrigeration are largely employed for preservative purposes. In Russia and Canada carcases are buried in frozen earth from November to May. Fish and poultry are constantly brought to town packed in ice. Ships fitted with refrigerating apparatus bring meat from Australia and America. One of the earlier forms of cooling plant is the downward draught method of Kent, in which the cooled air being denser descends from the ice-chambers and passes round the meat. It has been found in practice that it is not absolutely necessary that the meat should be perfectly frozen, a low temperature approaching freezing point is all that is required for temporary preservation. In Gamgee's process the

* Patent No. 21,305, 1891.

rapid evaporation of sulphurous acid, aided by pumps, produces intense cold, circulating by glycerine and water through pipes. Liquid ammonia is also used in a similar way.

At the Victoria Docks there are twenty-one refrigerating chambers, holding at times 200,000 carcases of sheep. At Smithfield Market the refrigerating space is equal to 250,000 cubic feet, in addition to the cold rooms in the basement of the building. The walls and roof are insulated by an inch of hair-felt between two thicknesses of deal boards joined very closely and with an air-space separating them from the building. The floor is rendered a non-conductor of heat by two layers of deal separated by a layer of finely-divided charcoal. Refrigerating machinery on the hydrocarbonic system is erected in the basement. In this system carbonic acid gas, produced by the combustion of coal or otherwise, is forced by a pressure of several atmospheres into cooled water. On removing the pressure by means of reversible air pumps the gas escapes rapidly, thereby abstracting heat from a reservoir of brine (which stands a low temperature without freezing); the brine circulates by pipes throughout the building, and also cools the inlets of fresh air. The gas is forced again into another cooled condenser, and when the excess has been transferred, the apparatus is reversed, and the gas escapes back again, cooling another reservoir of brine, in the second vessel. By a couple, or a series, of these twin vessels, and a system of valves for the brine tubes, the cold is kept constant, using the same carbonic acid and the same brine. The apparatus is safer in case of leakage or accident than those using sulphurous acid and ammonia, and does not involve such high pressures as when liquefied carbonic acid is employed. A leak is discovered by the hissing sound, or by a light being extinguished when applied. It is obvious that in case of emergency the solution of carbonic acid could be used like the ordinary fire *extincteur.* Arrangements are provided by which the temperature of the various sections of the building may be regulated to requirements, and special precautions have been taken for the ventilation of the building, and for changing the air very rapidly if need be, so that in the event of a carcase going bad from any cause, the risk of its tainting the rest may at once be obviated.

Preservation by Chemicals has not hitherto been successful. Either the food has acquired a peculiar flavour, or has lost a great deal of its nutriment and digestibility with its juices, as in ordinary salting. Sugar-curing aims chiefly at excluding air, as the antiseptic properties of sugar are very feeble, but where it is employed for preserving jams and candies, it is the heat that is the real agent, since a solution of sugar boils at a much higher temperature than water. Protection from air is also an effect here, since the viscosity opposes resistance to the penetration of germs. Saltpetre, ammonium acetate, acid sulphate of potash, ammonium chloride, lactic, tartaric and citric acids, &c., have appeared in several patents, but have not been successful. When using these preservatives it is to be noted that (1) if the food be directed to be merely dipped, or to have the antiseptic rubbed on, so that it can be cut, washed, or rubbed off before cooking, the surface only is kept sterile; (2) if it were possible to permeate the whole mass with the antiseptic, the result would be the presence of a quantity of the chemical that would certainly be unpalatable and injurious to health if frequently consumed.

Gamgee invented a chemical process to be used before the death of the animal. Having noticed that carbonic oxide when it combined with the blood rendered it almost imputrescible, he caused the animal to inhale this gas for two minutes. They were thereby rendered insensible. After slaughtering, they were hung up in chambers filled with the gas (produced by passing carbon dioxide from burning coke through layers of red-hot charcoal), and containing boxes of charcoal saturated with sulphur dioxide. After twenty-four to forty-eight hours' exposure the treated meat kept for many months. The process appears to have been unsuccessful on the commercial scale, owing to the expense. Injection of various fluids into the veins has been also a failure.

It is said that in the salt mines of Cheshire the atmosphere containing salt dust preserves the miners against cold, rheumatism, neuralgia, and infectious diseases, without being injurious to the lungs, and that raw meat will keep for a very long time.* This effect may, however, be due to the comparative absence of bacteria in still air, as the salt mines are not artificially ventilated. In France the use of boric acid, borax, and bisulphate of soda for the preservation of food has been adversely reported upon by M. Nocard, and the Seine Council of Hygiene have prohibited their use in consequence.

Preservation by Heat.—The conditions under which heat alone, or heat with steam, will sterilise have already been discussed (p. 29). Articles of food always contain moisture, so that the conditions present here are heat and steam. While the exterior of a joint reaches the boiling point, the interior does not attain that temperature, so that the germs or ova that may be present are not raised to a sterilising temperature. In most canned meats it is probable that the whole of the food is raised to the temperature of the water, and, when of good quality, they are probably as wholesome, nourishing, and digestible as meat that has been cooked in the ordinary way.

* Manley, *Brit. Manuf. Industries*, 1878, p. 10.

M. Appert, of Paris, in 1810, first introduced the process of heating provisions in vessels which could be hermetically closed, so that the steam should drive out the air and a vacuum be produced. This is clearly seen by the fact that the ends of tins which are in proper condition are concave, that they often collapse, and that there is an inrush of air when they are opened. Unless these signs are observed, the tin is bad and must not be eaten. All tins are examined in the warehouse, and such as are blown, *i.e.*, convex at the ends, owing to gases from decomposition inside, are rejected. Collapsed or crushed tins (which are sometimes offered cheap) are also dangerous, as in the sharp bending of the tin holes are apt to be formed. There are three principal processes for canning foods:—

1. *The Chloride of Calcium Process.*—The tins after being filled have the lids soldered on, leaving a pin-hole for escape of steam. They are immersed to two-thirds of their depth in a bath of calcium chloride solution, which boils at a higher temperature than water, heated from 260° to 270° F. for one to three hours, and the hole closed by a drop of solder.

2. *The Aberdeen Process.*—The tins are placed in a bath as before, but they are entirely closed. During the heating they are raised at times by a frame, opened to let out air and vapour, so that the tin does not burst, closed again and the heating continued. This is repeated two or three times, according to the size and substance. The pressure within is judged by the forcing out of the ends. Superheated steam is used by some firms instead of salt baths; it is rather more difficult to manage, but leaves the tins clean. This process, which is known by the tins having two or three blow-holes, presents the advantage that more of the natural moisture and flavour are retained. It has superseded the former process in Scotland, Australia, South America, and New Zealand.

3. *Jones's Vacuum Process.*—The tins are packed quite full, and soldered up except a small hole, with a little quill tube, in the top. The bath contains ninety-six 2-lb. tins. Along the centre of the bath runs a tube with twelve taps, each of which carries eight stuffing boxes connected with the tubes. By a fan or pumps a vacuum is created, and the bath is heated gradually to 212° F. The fluid in the tins, under the diminished pressure, boils at about 100° F., so that the steam and air are carried off at a low temperature. After a time the exhaust taps are turned off. The tins then contain no air, and are full of steam. The cooking is continued for two hours at 250° F., letting off the steam occasionally as the pressure increases.

4. *Salzer's Baltimore Process.*—Meat is subjected to dry steam and compressed in moulds, then wrapped in paper or other material, coated

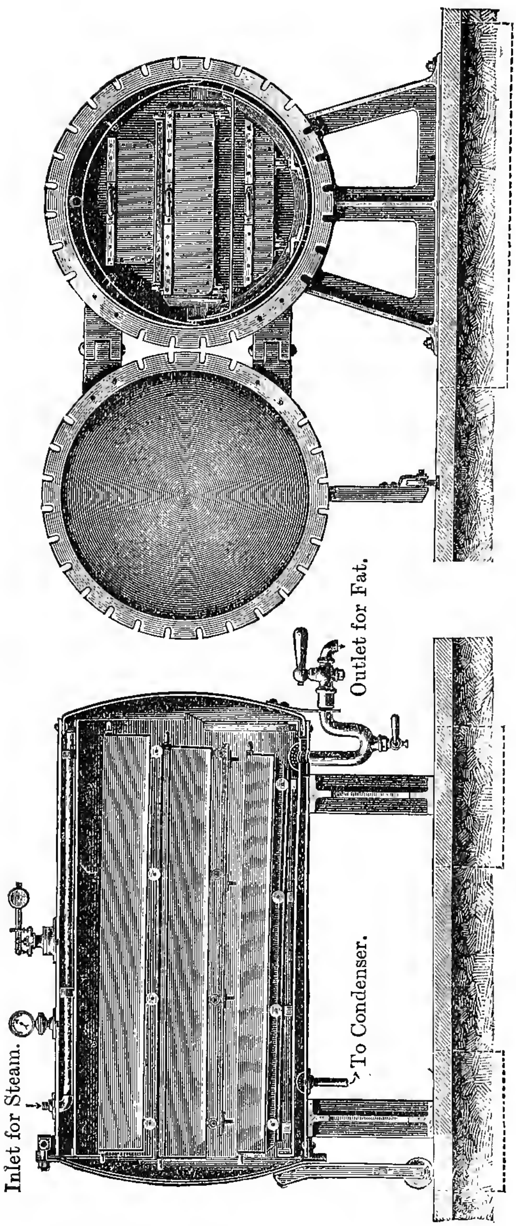


Fig. 24.—Longitudinal section.

Fig. 25.—Transverse section.

Budenberg's flesh steriliser.

with plaster of Paris, embedded in a heated fat such as suet or lard, in a can or in metallic foil, with certain precautions.*

5. In Germany, and to a certain extent in Italy and France, the dangerous and objectionable custom is prevalent of eating meat in the uncooked state, simply smoked or pickled. Raw hams and bacon only smoke-dried, Gotha sausages, and even chopped raw steak with bread crumbs and onions are commonly consumed. This practice necessitates that the meat in the markets should be rigidly inspected, and hundreds of carcases are seized and destroyed. With the idea of saving this confiscated diseased meat for food, W. Budenberg, of Dortmund, has invented a flesh steriliser, in which the disease germs are killed by steam under pressure.

It consists of a large iron cylinder, one end of which opens on hinges and closes hermetically against packing. Steam at a pressure of half an atmosphere (112° C.) is injected at the top, circulates round the movable iron shelves on which the pieces of meat are placed, and escapes to a condenser through a tube at the bottom, or can be led into a fireplace to burn any unpleasant vapours from the meat. The temperature can now be raised to 127° C. by letting in steam of 2½ atmospheres; after two or three hours' heating all germs of disease are destroyed. The fat and liquor are drawn off separately below. The fat can be used, the liquor is thrown away. At a higher temperature the meat is much disintegrated and dried, but is still digestible and fit for the food of animals, dog biscuits, &c. The temperature of the interior of the largest lumps of flesh, as registered by a maximum thermometer, remains steady at some degrees over 100° C. The loss of weight is from 40 to 50 per cent.

In some cases, where the apparatus is only used as a meat-steamer to save large quantities of meat from being lost by putrefaction in summer, it can be worked throughout at half an atmosphere of steam pressure. At this lower temperature the meat is as juicy and savoury as in ordinary cooking. The interior of the pieces reaches a temperature of 100° to 120° C., so that it can be sold for eating without hesitation. The inventor states that the sterilisation at the higher temperature was found by experiment to be perfect.

6. *G. Hartmann's process* † dispenses with the use of antiseptics, and consists of three steps—preliminary sterilisation, germinating period, and final sterilisation. The first step consists in subjecting the preserves to a temperature of 100° to 120° for a short time; the second in keeping them for some days at a temperature of 20° to 30°, when any germs which have not been destroyed in the primary

* Patent No. 11,988, 1892.

† Patent No. 14,601, 1892.

sterilising process develop. They are then completely destroyed by a final sterilisation process.

7. *Process for Preserving Organic Substances by Formaldehyde.*—The remarkable antiseptic properties of formaldehyde are said to render it a suitable substance to employ. Meat and similar substances are immersed for a few seconds in an aqueous solution of formaldehyde, liquids are mixed with $\frac{1}{25000}$ part of it. Solid substances may also be exposed to the formaldehyde vapour. Considering the minute quantity employed, there seems not the slightest objection to its use; moreover, meat, vegetables, and similar articles of food, when treated with it, do not lose anything of their appearance or freshness, or suffer in any other respects.

Milk.—Bacterium lactis, the organism which turns milk sour, is not the only one which finds a favourable place of growth in milk. Infection of different kinds apparently can be carried by it, and several epidemics have been traced to this cause. Hence the strong recommendations that milk should in all cases be boiled, and that dairies should be kept scrupulously clean, and well-ventilated. All cases of infectious diseases occurring on the farm must, under heavy penalties, be instantly reported, and the supply of milk discontinued until the case has been removed and the buildings properly disinfected. Milk cans should be washed out as soon as possible after use, and finally scalded with boiling water, and turned upside down, in a place free from dust, to drain and dry; then they should be covered till wanted. Removing any stale smell by charcoal is not a safe proceeding, as the odour is a sign that the cleaning has not been thorough; in such a case the can should be thoroughly steamed, and then washed. Water from ponds or contaminated wells should never be used for washing vessels that are intended for milk, as this has originated many cases of typhoid, scarlet fever, and other zymotic diseases. Strongly smelling disinfectants cannot be employed for dairies, since milk is so particuarly absorbent of odours. Probably peroxide of hydrogen would be the best agent for this purpose, if it were cheaper. Formaldehyde is now largely used in this country and Australia. It is to be regretted that jets of steam are not more extensively used for cleaning milk vessels; it would be easy to fit up an apparatus for this treatment at railway stations, where the cans could be systematically cleansed before going to the farms.

Milk can be kept for an indefinite time by heating it under pressure to 120° C., closing it whilst hot with corks or stoppers, and storing it in a cool place. If exposed in a warm situation after this, the casein is apt to undergo some molecular change, by which it clots into granules, or even sets almost solid, but no putrefaction ensues. It does not usually pay to preserve milk without concentration, on account of the bulk. The usual methods for milk-preservation may be divided into two groups—(1) those based on the addition of a foreign ingredient; (2) sterilisation by heat.

1. Boric and salicylic acids, borax, formaldehyde, cane and milk sugars, glucose, sodium carbonate, potassium nitrate, and glycerine have been added. Some of these preservatives are obviously likely to be prejudicial to the health of young children, and should not be used.*

2. Bethell in 1848 patented a process for preserving milk, which consisted in boiling it to expel all the air, and then saturating with carbonic acid; by this means, milk can be kept fresh for weeks.

Duclaux kept milk for five years in a vessel from which he had previously exhausted the air and heated the contents to 120° C.

Sterilised milk is now supplied, in many of the larger towns, in bottles which are hermetically sealed. Such sterilised milk is valuable for voyages and for invalids.

In *Gronwald's patent sterilising apparatus for fluids* † the fluid is sterilised in the vessel used for storage; it can be closed without admitting air, and allows the vessel to be filled to any desired height without any risk of the fluid being deteriorated, or the bottle bursting through an increase of temperature.

Condensed Milk.—The process was invented by De Leinac in 1852, and modified later by Borden of New York, who introduced vacuum pans for concentrating the milk without burning. In 1866 the Anglo-Swiss Company started Borden's process on a large scale. The milk is brought in every morning by farmers, who are kept under very careful supervision as to cleanliness of surroundings, and absence of disease. It is tested, mixed, and heated in a bath, pure white sugar is added, generally beetroot, then run into the vacuum pans (closed copper vessels from which the air and steam are exhausted), and evaporated rapidly at a low heat for two or three hours, till it is of the consistence of honey.

It has been kept in this way for upwards of twenty years. Great cleanliness is of course necessary in the process. The tins must be sterilised by scrubbing, then a jet of steam, and finally pure cold water. If there be any imperfection in the process, or if the tin be not properly sealed, the milk becomes solid and cheesy. If too highly concentrated, the milk-sugar crystallises, and the preparation becomes gritty.

Condensed milk is perfectly wholesome, but the balance of its food-value is disturbed by the enormous proportion of sugar, about 50 per cent. For this reason it is unsuitable for infants. The directions on

* See the article on *Boric acid*, p. 99.

† Patent No. 1,910, 1890.

the tin as to dilutions are frequently misleading—1 in 5 or 6 for adults, and 1 in 12 for infants—as the concentration is only 1 to 3 or 3½.

A condensed milk containing no added sugar and sterilised in tins has recently been introduced. By diluting with twice its volume of boiled water a fluid of the composition of ordinary milk is obtained.

Butter.—The production of sterilised butter has not been entirely successful, owing to the fact that the proper sterilisation of the cream is prevented by the necessary changing of the receptacles during the manufacture. The cream is in consequence brought in contact with numerous surfaces, and is necessarily subjected for a considerable time to the action of the air. E. E. Ritsert* points out that notwithstanding the occurrence of most diverse micro-organisms in rancid fats, both aerobic and anaerobic germs die when added to the fresh undecomposed fat, from which it is inferred that the change is not initiated by them. He also found that under the influence of sunlight, which killed the germs, the rancidity was produced more rapidly. Experiments were therefore made with sterilised lard—(1) protected from access of air, but exposed to sunlight, to diffused daylight, and kept in the dark; (2) with access of air, exposed to the sunlight, and kept in the dark; (3) in atmospheres of moist and dry oxygen, carbonic acid, nitrogen, and hydrogen. As a general result it may be stated that the result favourable to the production of rancidity proved to be the action of light during contact with air, the change being induced the more rapidly the more intense the light. Thus it was found that sterilised lard, either moist or dry, when kept from contact with air in sealed tubes, remained free from rancidity for two months, even though exposed to sunlight and warmth. Oxygen, both dry and moist, was absorbed freely in the light, the fat becoming strongly rancid in one month; but none was absorbed in the dark, the fat remaining quite fresh. Nitrogen and hydrogen were not absorbed in any case, and the fat remained unchanged. Carbonic acid was absorbed in the light, and to a less extent in the dark, but the lard only acquired a tallow-like taste, and no odour.

G. Muller† has invented an apparatus by which the whole process of butter-making is conducted in the same vessel with the most complete precautions. The cream is first sterilised by high-pressure steam at about 103° C. Any air which may enter on cooling is sterilised by a cotton-wool filter. The churning is then proceeded with in the same vessel, the butter-milk being run out at the bottom, sterilised air entering at the top. Sterilised water is then added to wash the butter, salt and colouring matter (sterilised) is added if desired, and finally

* *Pharm. Zeitung*, Sept. 13, 1890, p. 579.

† Patent No. 8,264, 1892.

the butter is churned dry to remove excess of water. The product is free from microbes, and will keep for a considerable time.

Butter that has once been churned cannot be melted without losing its character as butter. If sterilised butter from Muller's process above could be delivered by a screw pug mill into sterilised tins, so as to fill them as nearly as possible, and then soldered up, avoiding exposure, the ideal conditions would be fulfilled, and the butter ought to keep for an almost unlimited time. It would be free from germs, and would be secured from access of either light or oxygen.

Lactacidine, p. 202, is recommended for butter preservation, to be removed by washing before use. Since butter entangles about 10 per cent. of water, containing part of the butter-milk which in practice cannot be thoroughly removed, and can only be partially preserved by salt, no external application—neither this, nor boric, nor even salicylic acid—can be depended on.

Cheese, as is well known, soon undergoes putrefactive changes, without apparently rendering it unwholesome. Antiseptic, or, better, aseptic, wrappers of close canvas, soaked in boric acid and boroglyceride (p. 101) are here of value, and unobjectionable, as the rind is not eaten. They may prevent the access of the organism producing "tyrotoxicon" (p. 266), which is the cause of poisonous cheese.

Wheat and other kinds of grain are subject to the attacks of numerous fungi, such as ergot, mildew, &c., which render the flour prepared from them unwholesome. The common remedy is to pickle with sulphate of copper before sowing. Although the quantity of copper which passes into the food is infinitesimal, it would be better if a less poisonous disinfectant could be found. Chloride and acetate of aluminium have been well spoken of; they must be used very dilute, say 1 in 500, or germination is checked.

Bread acquires from the air germs of all kinds, and under certain conditions becomes poisonous. Hence the use of a covered bread-pan, kept scrupulously clean and free from stale crusts, &c., should be insisted on. In the early part of 1894 Dr. Waldo drew attention to the unsanitary state of London bakehouses. Filth, communication with drains, privies in direct proximity, and personal contamination from the work-people were discovered in a number of cases. Places where the food of the people is prepared should be above ground, in strong daylight (the fatal effects of light on bacteria have been before mentioned), well-ventilated, and clean. Much more supervision should be exercised. It is almost useless to combat bacteria when they are allowed to multiply in the daily food. The London County Council has issued regulations on the subject, and legislation from Parliament is awaited. Dr. Waldo and Mr. Welsh have also shown that organisms and their spores are not destroyed by the ordinary process of baking. By plate cultivation they succeeded in obtaining thirteen different species of micro-organisms from the centre of recently baked loaves from bakeries in different parts of London. The results show the necessity of having proper regulations for bakehouses, as sewage pollution of such places would mean that bread might be sent out to customers charged with specific organisms. Microbes withstand a long exposure to a much higher temperature than that to which the centre of the loaf is exposed, without being destroyed, and there is no reason to believe that even the greater number of the bacteria in the loaf are killed. They also found that tinned and small loaves were often sterile, and conclude that the number of bacteria in loaves seemed to bear a direct relation to the dirtiness of the bakehouses. It is also important that the flour, which undergoes in unsuitable warehouses a rapid change, should be kept dry and sterile. Dr. Brown has suggested that the use of flour has been the cause of many cases of outbreaks of diseases, especially sporadic outbreaks of intestinal complaints. In Bristol the number of such cases in the district has directly diminished *pari passu* with the recent activity of sanitary interference with the dirty bakehouses of the town.

CHAPTER XIV.

LEGAL STATUTES AND REGULATIONS.

Duties of a Medical Officer of Health, and of Sanitary Inspectors. PUBLIC HEALTH ACT, 1875: Clauses relating to Infection—Hospitals for Infectious Diseases—Prevention of Epidemics—Mortuaries—Port Sanitary Authorities. GENERAL ORDER OF LOCAL GOVERNMENT BOARD ON CHOLERA, 1883: Regulations as to Detention. DAIRIES, COWSHEDS, AND MILK SHOPS ORDER OF 1885: Regulation of Bakehouses—Housing of the Working Classes Act, 1890—Public Health (Water) Act, 1878—Vaccination Acts—Burial Regulations—Merchant Shipping Acts—Canal Boats Acts—Infectious Diseases (Notification) Act, 1889—Infectious Disease (Prevention) Act, 1890. Public Health Amendment Act, 1890. Public Health (London) Act, 1891: Rules for Hospitals for Infectious Diseases, Local Government Board. CIRCULAR OF THE MEDICAL OFFICER OF HEALTH: Local Government Board Remarks on the Clauses. Suggestions of the Society of Medical Officers of Health. Model Bye-Laws of the Local Government Board: As to Cleaning, &c.—As to Nuisances of Animals—As to Buildings. Metropolitan Asylums Board. SYSTEMS IN OTHER COUNTRIES: Brussels: Waggon Sluices—Rules as to Meat. Paris. Germany. Berlin. Leipzig: The Suvern Mixture. Vienna. Complete Regulations in Denmark. Report of American Public Health Association. Quarantine: English System. Italy.

AN outline may be here given of the Sanitary Regulations that apply to our subject.

Duties of a Medical Officer of Health (revised order of Local Government Board, 1891)—Rule 6.—On receiving information of the outbreak of any contagious, infectious, or epidemic disease of a dangerous character within the district, he shall visit without delay the spot where the outbreak occurred, and inquire into the causes and circumstances of such outbreak, and in case he is not satisfied that all due precautions are being taken, he shall advise the persons competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and take such measure for the prevention of disease as he is legally authorised to take under any statute in force in the district, or by any resolution of the sanitary authority.

7. Subject to the instructions of the sanitary authority, he shall direct or superintend the work of the inspector of nuisances, in the way, and to the extent, that the sanitary authorities shall approve.

15. He shall give immediate information to us of any outbreak of dangerous epidemic disease within the district, and shall transmit to us a copy of each annual report and of any special report.

Sanitary Inspectors—Rule 9.—He shall give immediate notice to the Medical Officer of Health of the occurrence within the district of any contagious, infectious, or epidemic disease.

10. He shall, subject to the directions of the sanitary authority, attend to the instructions of the Medical Officer of Health with respect to any measure which can be lawfully taken by an Inspector of Nuisances under the Public Health Act, 1875, or under any statute or statutes for preventing the spread of any contagious, infectious, or epidemic disease of a dangerous character.

Public Health Act, 1875.—Earth-closets may be substituted for water-closets if the local authority approves, and the local authority may themselves undertake or contract with any person to supply dry earth or other deodorising substance to houses within their district for use in earth-closets (section 37).

The keeper of a common lodging-house, in the first week of the months of April and October in each year, is required to limewash its walls and ceilings (section 82), and to give immediate notice to the Medical Officer of Health of any case of fever or infectious disease occurring in the house (section 84), and to give any officer of the local authority free access to every part of the house at all times when required (section 85).

Similar regulations may be applied to houses let in lodgings.

The following are the provisions against *infection*:—

Where the Medical Officer of Health or any other legally qualified medical practitioner certifies that the cleansing and disinfection of any house or part thereof, or of any articles therein, would tend to prevent or check infectious disease, it is the duty of the local authority to give notice to the owner or occupier of the house in question requiring him to do the necessary work within a specified time. The person on whom the notice is served is liable on default to a penalty of 1s. to 10s. for every day during which he continues to make default, and the Local Authority is required to execute the necessary work, and recover the expenses incurred from the responsible party.

If from poverty or other reason the person responsible is unable to carry out the requirements of the local authority, the latter may, with his consent, carry out the necessary work at their own expense (section 120).

Any local authority may direct the destruction of any bedding, clothing, &c., which have been exposed to infection from any dangerous infectious disease, and may give compensation for the same (section 121).

The local authority may provide a proper place with all necessary apparatus and attendance for the disinfection of bedding, &c., and may there disinfect any articles free of charge (section 122).

They may also provide and maintain a carriage suitable for the conveyance of infectious patients, and pay the cost of conveyance of such patients to a hospital or elsewhere (section 123).

Any person suffering from a dangerous infectious disorder who is without proper lodging or accommodation, or lodged in a room occupied by more than one family, or is on board any ship or vessel, or who is lodged in any common lodging-house, may, on the certificate of a legally qualified medical practitioner, be removed by order of any justice to any suitable hospital or place provided within a certain convenient distance. Any person wilfully disobeying or obstructing the execution of this order is liable to a penalty not exceeding £10 (section 124).

Regulations may also be made by any local authority for removing to a hospital persons brought within their district by any ship or boat, who are infected by a dangerous infectious disorder (section 125). Any person who—

1. While suffering from any dangerous infectious disorder, wilfully exposes himself without proper precautions in any street, public place, shop, inn, or public conveyance, or enters any public conveyance without previously notifying it to the owner, conductor, or driver, that he is so suffering; or,

2. Being in charge of any person so suffering, so exposes such sufferer; or,

3. Gives, lends, sells, transmits, or exposes, without previous dis-

infection, any bedding, clothing, rags, or other things which have been exposed to infection—

Is liable to a penalty not exceeding £5, and must also pay the amount of any loss or expense incurred in disinfecting the public conveyance which has been entered.

Every owner or driver of a public conveyance must immediately provide for its disinfection after it has been used, to his knowledge, by an infectious person, or is liable to a penalty not exceeding £5 (section 127).

Any person knowingly letting for hire any house or part thereof, in which has been any person suffering from infectious disease, without proper disinfection to the satisfaction of a qualified medical practitioner, is liable to a penalty not exceeding £20 (section 128).

Any person who, when letting a house or part thereof for hire, knowingly makes a false answer as to the occurrence of a case of infectious disease within six weeks previously, is liable to a penalty not exceeding £20, or to imprisonment not exceeding one month (section 129).

The Local Government Board may make or modify regulations for the treatment of persons affected with cholera or any other epidemic disease, and for the prevention of their spread, whether on water or land, and may prescribe by what authorities it may be enforced. Publication of such regulations in the *London Gazette* shall be regarded as conclusive evidence of such regulations (section 130).

Hospitals for Infectious Diseases.—Any local authority may build hospitals or temporary places for the reception of the sick belonging to their district, or may contract with any person for the reception of the sick. Two or more authorities may combine in providing a common hospital (section 131).

The expenses incurred in maintaining a patient, who is not a pauper, in such a hospital, may be recovered from the patient at any time within six months of his discharge (section 132).

Any local authority may, with the sanction of the Local Government Board, provide, or contract with any person to provide a temporary supply of medicine, of course including disinfectants or antiseptics, and medical assistance for the poorer inhabitants of their district (section 133).

Prevention of Epidemic Diseases.—Whenever any part of England appears to be threatened, or is affected by any formidable infectious disease, the Local Government Board may make and modify regulations for—

1. The speedy interment of the dead.
2. House-to-house visitation.

3. The provision of medical aid and accommodation, the promotion of cleansing, ventilating, and disinfection, and guarding against the spread of disease—

And may declare these regulations to be in force in any district, and to apply to any waters within English jurisdictions (section 134).

The local authority within whose district the above regulations are in force shall see to their execution, and appoint the necessary officers for this purpose (section 136).

The local authority and their officers shall have power of entry on all premises or vessels for the purpose of executing such regulations (section 137).

The Local Government Board may, if they think fit, require two or more local authorities, to act together for the purposes of these provisions relating to the prevention of epidemic diseases (section 139).

A penalty not exceeding £5 is incurred by any person who wilfully violates any of the regulations issued by the Local Government Board, or wilfully obstructs the carrying out of these regulations (section 140).

Mortuaries.—Where the body of any one who has died of any infectious disease is retained in a room in which persons live or sleep, or where any dead body is in such a state as to endanger the inmates of the house or room in which it is retained, any justice may, on the strength of a certificate signed by a legally qualified medical practitioner, order the body to be removed, at the cost of the local authority, to any mortuary provided by them, and order its burial within a specified time. If the friends or relations of the deceased do not undertake the burial of the body within the time specified, it is the duty of the relieving officer to bury the body, but the expense may be recovered from the person legally liable to pay the expense of the burial (section 142).

Port Sanitary Authorities.—The Local Government Board appoints the Sanitary Authorities of Ports from the neighbouring local authorities (section 287). The port sanitary authority may delegate its powers to any riparian authority within or bordering on their district. The Lord Mayor and Common Council of the City of London form the port sanitary authority of the Port of London (section 291).

The General Order of Local Government Board for Preventing the Spread of Cholera, July 12, 1883, contains the following regulations:—

1. Every ship is deemed infected with cholera in which there is, or has been during the voyage, or during the stay of the ship in a port in the course of the voyage, any case of cholera.

Regulations as to Detention.—2. If any officer of customs, on the arrival of a ship, ascertain, or has reason to suspect, that the ship is infected with cholera, he shall detain the ship and order it to be moored or anchored in such a position as he may direct.

3. No person must leave the ship while thus detained.

4. The officer thus detaining any ship must give immediate notice to the sanitary officer of the place where the ship is detained.

5. Such detention shall cease as soon as the ship has been duly visited and examined by the Medical Officer of Health, or if the ship is found to be infected with cholera, as soon as it has been moored and anchored in pursuance of Article 10 of this order. The examination must be commenced within twelve hours of the giving of the notice as aforesaid, otherwise the ship shall be released from detention.

10. The master of any ship so certified to be infected with cholera, shall moor his vessel at the place fixed for that purpose under Article 6, and she shall remain there until the requirements of this order have been duly fulfilled.

17. All articles soiled with cholera discharges must be destroyed, and all clothing and bedding shall be destroyed or disinfected.

18. The ship must be disinfected and every article therein, according to the directions of the Medical Officer of Health.

Dairies, Cowsheds, and Milk Shops Order of 1885.—All dairies and cowsheds, whether new or not, can only be occupied as long as the lighting, ventilation, including air space, and the cleansing, drainage, and water supply are such as are necessary or proper—

(*a*) For the health and good condition of the cattle therein; and

(*b*) For the cleanliness of all milk vessels used therein; and

(*c*) For the protection of the milk against infection or contamination.

It is unlawful for any person following the trade of a cowkeeper or dairyman, or purveyor of milk, or being the occupier of a milk store or milk shop—

(*a*) To allow any person suffering from a dangerous or infectious disorder, or having recently been in contact with such a person, to milk cows or handle milk vessels, or in any other way to help in connection with the preparation or sale of milk; or (*b*) still less himself to offend in a similar way.

No water-closet, privy, urinal, &c., is allowed to communicate with any dairy or milk store, and the milk store must not be used as a sleeping apartment, nor for any other purpose incompatible with the cleanliness of the milk. Pigs are not allowed to be kept in a cowshed. Local authorities may make regulations for prescribing precautions to be taken against infection or contamination. The milk of a diseased cow shall (*a*) not be mixed with other milk, nor (*b*) sold or used for human food, and shall not (*c*) be used for the food of swine or other animals until it has been boiled.

Regulation of Bakehouses (Factory and Workshops Acts of 1878 and 1883).—Where a bakehouse is situated in a town containing over 5,000 persons at the last census, all the inside walls and ceilings of its rooms, and all the passages and staircases shall be painted with oil and varnished with three coats, to be renewed once at least in every seven years, and washed with hot water and soap once at least in every six months (section 38, Act of 1878).

1. No water-closet, privy, or ashpit shall communicate directly with the bakehouse.

2. Any cistern for supplying water to the bakehouse shall be separate and distinct from the cistern supplying water to the water-closet.

3. No drain or pipe for carrying off sewage matter shall have an opening within the bakehouse (section 15, Act of 1883).

The occupier of any bakehouse whatever is liable to a penalty if the inspector of a local authority satisfies the court of summary jurisdiction that the bakehouse is, on sanitary grounds, unfit for a bakehouse (section 16, Act of 1883).

The medical officer of health, for the purposes of these sections, has all the powers of an inspector under the Factory and Workshop Act, 1878.

The Housing of the Working Classes Act, 1890, contains a number of regulations as to unhealthy areas. The medical officer of health is required, on complaint from ratepayers, to report on the condition of any area complained of as being unhealthy (section 5). Part II. relates to closing orders, demolition, re-housing, and re-building.

Public Health (Water) Act, 1878.—It is the duty of every rural sanitary authority, from time to time, to ascertain the condition of the water supply within their district, and to take all the necessary steps for this purpose (section 7).

The Vaccination Acts, 1867, 1871, 1874, prescribe measures to be taken for the vaccination or re-vaccination of unprotected persons.

Burial Regulations.—Burials within any place of worship built since 1848 are not allowed. No new burial ground can be opened within any city or town, and burials within any existing one may be prohibited by order of the Queen in Council.

Merchant Shipping Acts, 1854 to 1876; Passengers Act, 1855.—These contain orders as to the disposition of berths and air space allowed per person carried.

The ventilation must be sufficient, no nuisances allowed, the drinking water of good quality and sufficient in amount. On long voyages each person must drink a daily allowance of lime juice, against scurvy. Every passenger vessel on a voyage of eighty days for a sailing vessel, or forty-five days for a steamer, when the number of passengers exceeds fifty, or of one day when the passengers exceed three hundred, must carry a medical man. In the absence of a doctor, instructions are given for the captain's guidance in cases of sickness. Captains are required to destroy the clothing and bedding of cholera patients before the ship enters an English port. Every passenger vessel must have at least two properly arranged water-closets, and sufficient space allotted for a hospital.

Canal Boats Acts, 1877 and 1884.—Rules as to air space, cleanliness, and infectious diseases.

The Infectious Diseases (Notification) Act, 1889.—Both the householder and the medical practitioner are responsible for the notification of each case of infectious disease to the medical officer of health for the district. This applies to any building, ship, boat (English or foreign), any tent, van, shed, or similar structure, whether belonging to Her Majesty or not. Penalty, forty shillings. The infectious diseases specified are:—Smallpox, cholera, diphtheria, membranous croup, erysipelas, scarlatina, scarlet fever, typhus, typhoid, enteric, relapsing, continued, or puerperal fever, and also any infectious disease to which the Act has been applied by the local authority.

The Infectious Diseases (Prevention) Act, 1890.—Increased control over milk supply is given in section 4, which enacts that if the medical officer of health is in possession of evidence that any person in the district is suffering from infectious disease attributable to milk supplied to a dairy within or without the district, or that the consumption of milk from such dairy is likely to cause infectious disease to any person residing in the district, such officer shall, after receiving the authority of a Justice for this purpose, have power to inspect the dairy in question, and, if accompanied by a veterinary surgeon, to inspect the animals in it. If on such inspection the medical officer of health is of opinion that infectious disease is caused from consumption of the milk supplied therefrom, he shall report thereon to the local authority, who shall give notice to the dairyman to appear before them, and to show cause why an order should not be made requiring him to discontinue supplying the milk. If in the opinion of the local authority he fails to show such cause, the order may be made, and shall hold good until they are satisfied that the cause of infection has been removed.

Secs. 5 and 6 give increased powers of disinfection to the officers of the local authority. It is generally admitted that domestic disinfection is of a most unsatisfactory character; by section 6, power is given to remove bedding, &c., for the purpose of disinfection by the local authority at the cost of the latter.

It is forbidden to retain the body of any person who has died of an infectious disease elsewhere than in a public mortuary, or in a room not used as a dwelling place, sleeping-place, or work-room, longer than forty-eight hours (sec. 8).

By order of a Justice of the Peace, any person suffering from infectious disease, and then in a hospital for infectious disease, may, although unwilling, be detained there until free from infection, if it can be shown that he is without proper means of isolation and lodging elsewhere (sec. 12).

The throwing of infectious rubbish into ashpits, &c., is forbidden (sec. 13).

The local authority is required to provide free temporary shelter with the necessary attendance to the members of any family who have been compelled to leave their houses to enable them to be disinfected by the local authority (sec. 15).

The bodies of persons dying of infectious diseases in hospitals are only allowed to be removed for the purpose of being forthwith buried (sec. 9).

The Public Health Amendment Act, 1890, does not apply to the metropolis. It forbids the discharge of injurious matter into the sewers (sec. 16), gives power to regulate public conveniences, and those in lodging houses, factories, or workshops. Rooms over privies, middens, or ashpits, are not allowed to be used as dwelling or sleeping rooms (sec. 24). It is not lawful to erect a new building on any ground filled up with offensive matter, unless the latter is removed by excavation, or has become innocuous.

Urban authorities may make bye-laws for prescribing the times for removal through the streets of offensive or noxious matters, and for providing that the vessels or carts be properly constructed and covered (sec. 26). The section of the Public Health Act relating to unsound meat is made to apply to articles which have been already sold (sec. 528).

The Public Health (London) Act, 1891, consolidates and amends all previous sanitary enactments. Section 15 says—Any person damaging or destroying any drain, water-closet, or water-supply apparatus, is liable to a fine of £5 (sec. 15).

It is compulsory on the sanitary authorities and County Council to make bye-laws for the cleansing of streets and prevention of nuisances from rubbish, offal, &c., and as to paving of open spaces about houses; and on the County Council to make bye-laws for the removal of filth, &c., in properly covered vessels, and as to the filling up of cesspools, &c.

The petty sessional court may prohibit the using of any place for the keeping of any animal, if it is proved to the satisfaction of the court that the place is unfit for this purpose (sec. 18). (This section applies to fowl-houses, pigeon-houses, rabbit-hutches, &c., and the keeping of cats and dogs.)

By section 22 the removal of house refuse and street refuse is placed under the same category as offensive trades under private control, and the sanitary authority are liable to be proceeded against for any infringement of the bye-laws made by the County Council in this behalf. The regulation of dairies and cowsheds is placed under the control of the County Council (secs. 23 to 28). It is made the duty of the sanitary authority not only to keep the streets swept and cleaned, but also to secure the regular periodic removal of house refuse. If after forty-eight hours written notice, when the house refuse has not been removed from any premises at the proper period, the sanitary authority fail without reasonable cause to comply with this notice, they are liable to a fine not exceeding £20 (secs. 29, 30).

Sec. 48 constitutes a dwelling-house without a proper supply of water unfit for habitation; and by section 49 makes any Water Company liable to a fine of £10 if within twenty-four hours after cutting off the water supply to any house for non-payment of water-rates they do not give notice to the sanitary authority. Every sanitary authority is required to make bye-laws for the cleansing of receptacles for storage of water for drinking or domestic purposes.

Secs. 55 to 57, on the notification of infectious diseases, make it compulsory on Medical Officers of Health to send a copy of the certificate to any school attended by any child who is an inmate of the infected house.

Secs. 58 to 81 make compulsory the provision of disinfecting apparatus and carriages for carrying infected materials, free of charge, by the Sanitary Authority.

Every Sanitary Authority is required to provide and fit up a public mortuary (sec. 88).

Memorandum on Hospital Accommodation—Local Government Board.—When two contagious diseases break out at the same time, they should each be separately isolated. In towns, and for several villages of smaller size, there should be provided at least two special wards with four beds in each, in order that the sick may be isolated from the commencement. Proposed plans and sections accompany the Memorandum.

In rural districts without a hospital, a trustworthy married couple without children may be charged with the isolation and care of cases of infectious disease. In the event of a more serious epidemic several lodgings may be hired, or the sick may be isolated in temporarily erected tents or barracks. Fever hospitals in urban districts ought to have one bed for every 1,000 inhabitants. In a manufacturing town with a very dense population, the proportion ought to be even greater. Permanent fever hospitals are built on the system of separate pavilions. Illustrations and details are given in the Memorandum, which cites as examples St. Thomas's Hospital, the Herbert Hospital, and the Royal Infirmary at Edinburgh. The laundries and mortuaries should be in separate buildings.

In wards for infectious diseases there should be openings for admission of fresh air between each bed, a little above the floor, so that pure air bathes the patient's bed. They should be furnished with a grooved fastening, so that the admission of air can be graduated. The openings for the extraction of foul air should be near the ceiling, and as remote as possible from those admitting fresh air. They should, unless entering into the chimney breast, be carried vertically to the roof, and be provided with an aspirating cowl. 2,500 cubic feet of fresh air should be supplied for each patient per hour. The openings should be easily cleansed and freed from dust, and protected by an outside grating. Every hospital should possess a disinfecting apparatus.

Memorandum on Ambulances.—In the construction, special regard should be had to the fact that after each use, it has to be cleaned and disinfected to the satisfaction of a Medical Officer.

Rules for Hospitals for Infectious Diseases (Local Government Board).—Among these are :—

(3) No person is admitted without the permission of the Medical Officer.

(4) No patient is permitted to leave until discharged by him.

(5) The patient's clothes must be disinfected before being given up to him at his discharge.

(6) Officers and servants are not allowed to leave without authority of the Medical Officer, and they must first change their clothes.

Circular of the Medical Officer (Local Government Board).—After insisting on the proper ordering of houses, drains, &c., the circular contains :—

"Sec. 4. In the removal of filth during epidemic disease, it is commonly necessary to employ chemical agents for reducing and removing the offence or harm which may be involved in the disturbance of the filth. In the removal of privy contents these agents are more particularly wanted if the disease be cholera or enteric fever. The chemical agent should be used liberally over all exposed surfaces from which filth has been removed. Unpaved earth close to dwellings, if it be sodden with slops or filth, ought to be treated in the same way."

"Sec. 5. Sources of water supply should be well examined. Water from sources which can in any way be tainted by animal or vegetable refuse, especially those in which there may be any leakage or filtration from sewers, drains, cesspools, or foul ditches, ought no longer to be drunk, above all where the disease is cholera, diarrhœa, or enteric fever. If unfortunately such is the only water to be got for the time, it must be boiled, and then not drunk later than twenty-four hours after boiling. Filtering of the ordinary kind cannot by itself be trusted to purify the water (see p. 15). It cannot be too distinctly understood that dangerous qualities of water are not obviated by the addition of wine or spirits."

Sec. 6 (after remarks about dairies). . . . "Even apart from any apprehension of milk being concerned in a particular outbreak of disease, it is desirable that English people should adopt the custom, which is always followed in some Continental countries, of boiling all milk at once upon its reception into a house."

Secs. 7 and 8 deal with washing, lime-whiting, overcrowding, and ventilation.

Sec. 9 enjoins cleanliness, rapid removal or destruction of refuse, and avoidance of delay in disinfecting.

Sec. 10 gives directions as to discharges from the sick (see p. 233). "In enteric fever and cholera the evacuations should be looked upon as capable of communicating an infectious quantity to any night-soil with which they are mixed in privies, drains, or cesspools, and after such disinfection of them as is practicable they should be disposed of without delay and under the safest conditions the local circumstances permit." (It is quite impossible for this to be done by private effort; the evacuations can only be securely sterilised by heat, and this would involve either a steam apparatus or a dust-destructor. The local authorities must arrange to remove the evacuations daily in sealed iron receptacles, which must be heated for several hours in steam ovens, or steam passed through them, the gases being led into a fire and burnt. A small quantity, about 1 in 500, of phenol, or a cresol preparation (see p. 170) should be added; it has been proved that disinfectants, when hot, act with much more energy than when cold; or mercuric chloride may be used. The residue is then safe.)

"Sec. 17. Provision by the public authority for disinfection by heat of bulky articles, and of those which cannot without injury be exposed to chemical agencies, ought always to be in readiness." (Such provision could be associated with the arrangements for the sterilisation of excreta described above. Many of the existing apparatus are not large enough.) "Without such provision no complete disinfection can be effected. Partial and nominal disinfection, besides being wasteful, may be mischievous, as giving rise to false security."

Sec. 18. This rule commends a system of domestic disinfection to sanitary authorities "who have already provided adequate public means for the disinfection and for the disposal of infected matters and things." Soiled linen is treated with mercuric chloride solution.

"In places provided with proper systems of excrement disposal, excrements of cholera and enteric fever, after having been treated in detail with the same disinfecting solution (acidified mercuric chloride in ample quantity), may be safely put into the ordinary closet; but special care as to the flushing of drains and sewers, and special frequency in the removal and exchange of excrement receptacles, must be insisted upon. Where the closet is one that communicates with the cesspool or privy pit, the best arrangement for the disposal of infected stools that under these improper local circumstances may be found practicable will have to be adopted." This rule ought to be reconsidered. Koch has proved that mercuric chloride may easily be insufficient even in larger amount than is here recommended (p. 137). The throwing of cholera excreta, even "disinfected" as here described, into closets, to pass thence into rivers and streams, might spread the disease through an entire neighbourhood. Nothing short of the sterilisation by heat, as detailed above, is at all certain.

"A substance generally available in the removal of filth from privies and ashpits, and for application to foul earth and the like, is sulphate of iron (green copperas), either in a strong solution made by stirring crystals of the salt with five or ten times their bulk of hot water, or in the form of powder, to which form the crystals may easily be brought by desiccation. This agent should be used in quantity sufficient to destroy all odour, and in the removal of filth accumulations it should be well mixed with successive layers of the matter to be removed. The dry form of application is to be preferred where masses of wet or solid filth have to be dealt with." (But Dr. Thorne himself says: "It cannot confidently be stated that either the iron salt or any available substance will effect a true disinfection of such masses of filth as are here in question. The removal of dangerous filth is here the object to be attained." It is strongly to be hoped that a protest will be made against the recommendation of a plan admittedly inefficient, since removal without exposure, and the subsequent action of heat, are the only courses effectual. Even for temporary removal of stench, there are better remedies than sulphate of iron; for instance, a cresol powder, or liquids of the Sanitas type, or saprol, or other pyridine-containing disinfectant.)

"For the disinfection of the air of rooms . . . sulphurous acid . . . is ordered, and wall paper should be stripped." . . .

Suggestions of the Society of Medical Officers of Health.—Most of these have been previously noticed. The following are the chief points :—

" 1. Hang up a sheet outside the door of the sick room, and keep it wet with a quarter of a pint of carbolic acid, No. 4, or a pound of chloride of lime, with a gallon of water. The floor should be sprinkled . . . and the cloths hung up."

" 2. Everything that passes from the sick person should be received into ½ pint of green copperas, 1 lb. to the gallon. A like quantity to be added before emptying."

" 3. Every sink, closet, or privy should have a quantity of one of the above-named disinfectants poured into it daily, and the greatest care should be taken to prevent the contamination of well or drinking water by any discharges from the sick person."

" 4. All cups, glasses, spoons, &c., used by the sick person should be first washed in the above-named solution of carbolic acid, and afterwards in hot water, before being used by any other person." (It would be better to insist that the utensils used by the sick person should not be used by any one else. At the end of the illness, they are better destroyed, but if they must be used, they should be boiled for an hour or two with water and washing soda, and then wiped dry. No carbolic acid is necessary.)

" 5. All the bed and body linen . . . before being taken from the room, should be first put into a solution of carbolic acid . . ."

6. Prescribes linen garments for nurses, and washing the hands with carbolic soap.

7. Visitors should not be allowed, as their clothing is apt to carry away infection.

" 8. The scales and dusty powder which peel from the skin in scarlet fever, and the crust in small-pox, being highly infectious, their escape may be prevented by smearing the body of the sick person all over every day with camphorated oil. This and the after use of warm baths and carbolic soap are most essential. The sick person must not be allowed to mix with the rest of the family until the peeling has entirely ceased and the skin is perfectly smooth ; clothes used during the time of illness, or in any way exposed to infection, must not be worn again until they have been properly disinfected " (p. 283).

9. Directions for final disinfection of the room by burning sulphur, and bedding, &c., by heat. The amount prescribed is not sufficient (see p. 94).

10. Children from an infected house not to attend school until they obtain a certificate from the medical attendant.

11. In case of death the body should not be removed from the room except to a mortuary; a pound or two of carbolic powder should

be put into the coffin, which should be fastened down and buried without delay. (Cremation is here to be advocated).

Model Bye-Laws of Local Government Board as to Cleansing, &c.—The following pertain to our subject (the wording is slightly condensed) :—

Sec. 1. The occupier of any premises abutting on a street shall clean the adjoining pavements at least once a day, except on Sundays.

Sec. 2. He shall remove house refuse from his premises at least once a week.

Sec. 3. He shall at least once in three months cleanse earth-closets provided with a fixed receptacle and supply dry earth;

Sec. 4. Those with a movable receptacle, at least once every week;

Secs. 5 and 6. Privies of either kind, at least once a week ;

Secs. 7 and 8. Ashpits, whether mixed with fæcal matter or not; and

Sec. 9. Cesspools.

Model Bye-Laws as to Nuisances and Animals.—Sec. 3. Salt and snow must be effectually removed.

Sec. 4. Ashes, &c., must not be deposited on paths or roads, must be swept up, and must be removed in a covered receptacle, instead of in open pails.

Sec. 4*a*. Privies, cesspools, &c., must be emptied within special hours (p. 240).

Secs. 5 to 8. Ashes, &c., must be removed in covered carts, to special depôts, 100 yards distant from houses, every twenty-four hours.

Sec. 9. When filth is deposited for agricultural purposes, the distance from the nearest inhabited premises must be at least 100 yards, and the filth must be forthwith ploughed in or covered with mould (ordinary earth does not sterilise it, see p. 238).

Sec. 10. Pigs must not be kept, nor swine dung deposited, within 100 yards of a house, nor so as to pollute a water supply.

Sec. 11. Cattle and their dung must not endanger any water used for drinking, domestic, or dairy purposes.

Sec. 12. Regulations as to manure from stables, &c.

As to Buildings.—Secs. 55 to 59. Rooms and public buildings must have proper ventilation according to specified details.

Sec. 60. Drains and water pipes must be disconnected from the sewer by ventilated traps.

Sec. 62. Regulates the material, diameter, setting, jointing, and course of drain pipes; and

Secs. 63, 64, and 65. The traps, gratings and ventilating shafts which should be carried to the top of the house.

Sec. 66. No inlets to drains are allowed within houses. The soil pipe must be at least 4 inches in diameter and be fixed outside the building and continued upwards without bends or angles to a height above the top windows. All waste and overflow pipes must be taken through an external wall of the house, and discharge in the open air.

Secs. 68 and 69. Water-closets within houses shall have at least one of their sides to an outer wall, must be ventilated, have a special cistern and sufficient flush, must not have a "container," or "D-trap."

Secs. 70, 71, and 72 relate to earth-closets.

Secs. 73 to 79. Privies must be 6 feet from a house, 40 to 50 feet from any source of drinking water (not sufficient—*Newsholme*), easily accessible, ventilated, the floor non-absorbent, raised above the ground level, and sloping towards the door (to prevent stagnant water). The receptacles must not be exposed to rainfall or drainage.

Secs. 80 to 85. Ashpits must be 6 feet from a house, 30 to 40 feet from any well, &c., roofed, cemented, and easily cleaned.

Secs. 86 to 89. Cesspools must be 50 feet from a house, 60 to 80 feet from any well, &c., easily emptied without passing through the house, properly cemented, unconnected with a sewer, covered, and adequately ventilated (cesspools should be forbidden where there are sewers).

The model bye-laws as to lodging-houses resemble those of the Public Health Act, 1875, with many additions and improvements. Those as to slaughter-houses are in considerable detail.

Metropolitan Asylum's Board.—The disinfection of ambulance carriages and steamers is done by washing with carbolic acid.

The hospital linen is soaked in carbolic solution, and then boiled and washed (it requires not less than 1 in 20 carbolic to disinfect linen; the solutions usually employed are not as strong as this—*e.g.*, the one recommended by the Society of Medical Officers of Health (p. 153) is only ¼ pint to a gallon, or 1 in 32. This means that carbolic disinfection as commonly carried out is imperfect. In the new hospitals clothing is disinfected by steam).

Legislation as to Vagrants.—On July 19, 1894, a conference of Medical Officers of Health and others was held at the hall of the London County Council to consider whether means could be adopted to prevent the spread of infectious diseases by vagrants. The matter is still under discussion.

SYSTEMS IN OTHER COUNTRIES.

In some respects the sanitary administration of Brussels is superior to ours, and compulsory notification has been enforced since 1824.

Slaughtering is only allowed in the town *abattoirs*. The meat is inspected and stamped, and the name and address of the owner, and destination of the meat, are recorded, with the date and hour; this arrangement has secured almost perfect protection against diseased meat, and also that it should be fresh. Even "offal" must be dressed at the *abattoir* and stamped. During transport the stamp and certificate must be shown when demanded. The control of other foods is also much more satisfactory than ours.

The *Waggon Sluices* used to clean deposits from the sewers travel along rails throughout their length. The deposits being continually removed, cannot decompose and produce fœtid gases, and the air of the sewer is comparatively pure.

The corpses of persons having died of an infectious disease are wrapped in linen clothes soaked in carbolic acid. The body is then at once conveyed to the observation chamber of the mortuary outside the town, and is interred as soon as certain signs of death have appeared. Special clothes are worn by the undertaker's men, and these are returned after use to the station for steam disinfection.

Germany has necessarily instituted compulsory inspection of pork (see p. 271), and authorised inspectors are appointed for this purpose. If infested with trichinosis, the fat only can be used, after being cooked for three hours; the rest of the meat is buried. Tuberculosis is also keenly looked after.

The rules as to corpses and burials are very explicit (see p. 280). Corpses must not be exposed in the churches. Midwives are forbidden to wash or lay out corpses.

In *Berlin* only water-closets and movable tubs are allowed. Steam disinfection is carried out at the Reichemberger Strasse station. Mercuric chloride is not used as in Paris, but the walls of rooms are rubbed with bread and then washed with $2\frac{1}{2}$ to 5 per cent. carbolic acid. Various chemical methods of disinfection of excreta are used in *Leipzig*. "The Suvern Mixture" is made by soaking 42·5 grammes of quicklime with 102 of water, and adding thereto 8·5 kilos. of coal-tar and 8·5 of magnesium chloride in an equal quantity of water; it is diluted with water when used. Half a kilo. is used for each person per day. It is mixed with the excreta when removed; the mixture then flows into settling reservoirs, the liquids run off into the sewers, and the solid deposit is cleared out about once a year. Palmberg states that both the solid and liquid matters are rendered inoffensive. The theory is that the carbonic acid developed by the fermentation of the organic matters combines with the lime to cause a deposit of carbonate of lime which encrusts or petrifies the microbes; the spores as they develop are destroyed in the same way. The ammonia generated by putrefaction is fixed by the magnesium chloride, the sulphuretted hydrogen by the lime. "The deposit consists of carbonate of lime mixed with organic matters; it is greyish in colour, inodorous, and aseptic."* It is useless for manure. The process of Friedrich and Glass is also much used. The composition of the disinfecting powder is not given.

In *Vienna*, 5 per cent. carbolic acid (the least effective strength), sulphurous acid fumigation, and steam are the legal disinfectants.

In *Denmark* very elaborate regulations are in force, and the following summary may therefore be useful as a model for further legislation in this country. The rules were proposed by the Royal Board of Health for disinfection, and were carried out in pursuance with the Act of April 20, 1888, on measures against the spread of infectious diseases, and are now established in Denmark in virtue of the authority vested in the Minister of Justice by the said Act. It rests with the Boards of Health to supervise the proper carrying out of public disinfection; the Boards must also see that the necessary staff and appliances are at hand, and that the former are properly instructed in their duties. It is the duty of the medical man sending in the requisition for disinfection to state what rooms or things are to be disinfected.

Disinfectants.—(1) Boiling in water for at least twenty minutes. (2) Steam under or without pressure in "disinfecting ovens"; those most generally used are Reck's and Geneste & Herscher's (see pp. 45, 47). (3) Carbolic acid in 5 per cent. solution, "strong carbolic water," or in 2 per cent. solution, "weak carbolic water," according to the purpose for which it is used. (4) Chloride of lime is used partly as a powder mixed with twice the quantity of clean dry sand, for covering excreta, dung-heaps, and such like; partly in strong solution, viz., 4 parts to 100 parts. To be thoroughly efficient, chloride of lime must meet the requirements of the *Danish Pharmacopœia*, and contain 20 per cent. of available chlorine, and must be kept in the dark in corked glass receptacles, which is also the case with the solutions. The solutions are prepared best in the following manner:—The chloride of lime is made with a little (clean) water to a smooth paste, after which the rest of the water is gradually stirred in for thirty minutes. An insoluble residue will remain, which may be removed by filtration, but this is not necessary when the solution is only to be used for disinfecting the patients' excreta, &c. The solutions are most efficient when freshly made. (5) Mercuric chloride (corrosive sublimate) in a solution of 1 part to 1,000 parts of boiled water should, on account of its poisonous nature, be only used under the supervision of the sanitary authorities or of medical men; on this account also no vessels should be used in the preparation of the solution from which either man or beast drink or eat, nor such in which drink or food is kept. Further, the solution of mercuric chloride must not be thrown away in places where such

* *Palmberg*, p. 409.

may give rise to poisoning; should the solution be used in the disinfection of any utensil, it must, when the disinfection is finished, be carefully removed from the object disinfected by repeated rinsing or washing with clean water that has been boiled. A solution of soda should be employed for the same purpose in rooms which have been disinfected with mercuric chloride (see below). As mercuric chloride is decomposed by metals, metallic vessels must not be used in the preparation of the solution, neither must any articles made of metal be disinfected with this agent.

To prevent mistakes the solution of mercuric chloride may be coloured with any dye which does not injure the objects to be disinfected (especially woollens, or silks which easily take dyes), for instance the aniline dye, which is at present manufactured in Germany and known as *Wasserblau*, which can be obtained from C. A. Kahlbaum, Berlin. A little acetic acid is recommended to be added to preserve the colour. (6) Aëration may be employed to second any of the other agents, or when it is impossible to disinfect in any other way, in which case it must be continued for three or four weeks. (7) All worthless articles (straw, hay, or seaweed mattress stuffing, old clothes, cloths which have been used for wiping away infectious discharges, &c.) should be burnt as soon as possible, the necessary precautions being taken to prevent the spread of the disease.

Special Rules for Disinfection.—1. The *discharges* of patients (dejections, vomited matter, sputa, urine) must be immediately mixed with the strong solution of chloride of lime, or with strong carbolic water. It is advisable to pour a little of these disinfectants into the vessel before it receives the discharge. The total quantity of the agent employed must be at least equal to that of the discharge. The mixture should be immediately poured into a tight, well-covered vessel, specially used for that purpose, and placed in an isolated place; in this vessel the mixture is to remain until the disinfectant has acted—viz., one hour when a solution of chloride of lime is used; four hours when carbolic water is used. This vessel should be emptied daily, preferably into a pit, dug especially for that purpose; if this is not possible, into a privy, the contents of the pit or privy to be immediately covered with a layer of the mixture of chloride of lime and sand, should circumstances necessitate the immediate emptying of the mixture into the pit or privy.

It should be carefully stirred with a stick, and the stick left in it. If the mixture is emptied into a tub, this must be changed daily.

2. *Privies.*—Excreta contained in privy pits or tubs should be covered with a thick layer of a mixture of 1 part of chloride of lime and 2 parts of sand. Privy tubs should be frequently emptied, and after-

wards disinfected with a 4 per cent. solution of chloride of lime and 5 per cent. carbolic water; the seat and floor of the privy should be washed with one of these disinfectants at least twice daily. The pan and pipe in water-closets, as also urinals, should be cleansed at least twice daily with one of these disinfectants.

3. *Clothing.*—Dirty clothes, bed-clothes, pocket handkerchiefs, towels, cloths, and such like, should not be shaken or brushed previous to disinfecting. In Denmark the rules in force are as follows:—

Everything which can be washed without injury should immediately be put into boiling water for thirty minutes, or into 2 per cent. carbolic water, or the solution of mercuric chloride, for at least four hours; after being wrung out, the articles should be placed in a vessel full of water, in which they remain until they can be washed. If the articles cannot be placed in the above-mentioned disinfectants in the sick room itself, they must only be taken from it wrapped up in a sheet or sack saturated with 2 per cent. carbolic water. Clothes should not be sent to the wash from infected places, unless they have been subjected to the treatment above mentioned, and should not be washed until they have been boiled for thirty minutes in soap and water. Hay and straw mattresses should be opened after being moistened in such a way that their opening causes no dust; the hay or straw should be removed or burnt, the covers treated in the manner above mentioned. Persons employed in washing the articles above mentioned should, on the completion of their work, disinfect themselves according to the rules given below for the persons engaged in disinfection. Everything which cannot stand boiling water or washing should be taken in the manner above described to the disinfecting oven, to be disinfected with steam. If this is impossible, the articles should be brushed with a brush dipped in strong carbolic water; after which they should be aired for three or four weeks in a dry place protected from rain—places where there is a draught being preferred. Spots of blood or matter must be removed by soaking in a cold disinfecting fluid, previous to disinfection, either with boiling water or steam. Leather, morocco, or indiarubber articles (boots and shoes, boxes, bags, &c.), which would be injured by steam, should be carefully washed over several times with 5 per cent. carbolic water.

4. Upholstered furniture, carpets, curtains, and such like, when circumstances permit, should be disinfected with steam; they should not be beaten or brushed previous to disinfection, and should be taken to the place for disinfection wrapped in sheets or sacks saturated with 2 per cent. carbolic water. When it is not possible to employ steam, the articles must be brushed with a brush dipped in 5 per cent. carbolic water (if they can stand it), after which they should be aired

for three or four weeks in a dry place, protected from rain; a draughty place being preferred. Polished or carved furniture, pictures, and articles which cannot stand strong carbolic water, should be wiped with soft cloths dipped in 2 per cent. weak carbolic water and wrung out; they should then be immediately dried with a clean, dry cloth. Any parts of the above-mentioned articles which are not polished or stained, should be washed twice with 5 per cent. carbolic water; they must be first washed with hot soap and water, should they be very dirty. The cloths washed in the cleaning should be washed or burnt immediately. All articles which can be placed in a fluid without injury, should be boiled or put into a strong or weak carbolic water for four hours, according to their nature. Articles of no value should be burnt.

5. *Rooms, Carriages, &c.*—The sweeping or dusting of such is not permissible. Whitewashed or oil-painted walls, floors, ceilings, windows, doors, wainscotting, and other woodwork, should be disinfected with 5 per cent. carbolic water or solution of mercuric chloride; the latter only under supervision (see above). With these disinfectants the surfaces should be wiped with cloths or, (when they can stand it) should be scrubbed with a scrubbing brush, or sprinkled by means of a syringe or spray apparatus constructed for that purpose. Plaster walls may also be disinfected by giving them a coating of a mixture of 1 part chloride of lime and 2 parts water. Such surfaces as cannot stand washing or scrubbing, for instance wall papers, covers, or fixed cushions, should be sprinkled with the disinfectant fluids above mentioned (which do not injure many wall papers) or carefully rubbed with pieces of soft bread, the crumbs being swept up and burnt. Surfaces disinfected with the solution of mercuric chloride should be washed over or sprinkled with a solution of soda (1 part to 100 boiled water), at least thirty minutes after disinfection. Care should be taken that all parts of the surfaces to be disinfected are thoroughly exposed to the disinfectants, and that these latter penetrate into all cracks and holes, which, if necessary, should be scraped free from all dirt and dust, this being wiped away with cloths dipped in a disinfectant fluid, the cloths to be afterwards burnt. Special care should be taken in cleansing such parts of the floors or walls as have been soiled by the patient's discharges; wall paper thus soiled, after having been moistened with one of the above-mentioned solutions should be taken off or burnt. Disinfection being completed, the room, carriage, &c., should be left for twelve hours; after which time the surfaces disinfected should be thoroughly washed with warm water and soap. Finally, they should be exposed to a thorough draught,

if possible for at least a week. In ships, special care should be taken as to the disinfection of the bilge. Ships in harbour are disinfected according to special rules, under the supervision of the authorities in question. In ships at sea, the bilge water should be pumped out, and the bilge thereafter rinsed out with salt water at least twice.

6. Persons who have been in contact with patients suffering with infectious diseases, should first wash their hands, arms, and face in weak carbolic water or a weak solution of chloride of lime, then in warm soap and water. Their clothes and hair should be brushed with brushes dipped in weak carbolic water. Persons devoting themselves to the nursing of patients, or constantly staying in the sick room, should, when their task is completed, thoroughly disinfect themselves before visiting healthy persons or dwellings. This disinfection should consist of thorough washing of the whole body, and brushing of the hair with weak carbolic water, or weak solution of chloride of lime; after which a warm bath should be taken, if possible; finally, clothes free from infection should be put on. Clothes worn while nursing should be left in the infected place. Nurses should carefully wash their hands, first with carbolic water, or the weak solution of chloride of lime, and afterwards in warm soap and water, every time they have reason to believe that infectious germs have stuck to them. Nail brushes should be used for brushing the nails. Convalescents should be washed all over the body (hair included) with weak carbolic water, or the weak solution of chloride of lime, after which they should take a warm bath, and put on a suit of clothes free from infection, before they mix with healthy persons. The clothes worn during illness should be disinfected according to the regulations laid down above. Persons employed in disinfecting rooms, furniture, &c., should wear a linen suit consisting of a blouse, trousers, and cap with a brim in front and behind, which suit should be disinfected after having been used. The persons who have been engaged in disinfecting should cleanse their hands, arms, and faces as above prescribed.

7. Drinking water, milk, beer, provisions, &c., which have been exposed to infection, should be rendered harmless in the most effective manner possible. In no case should they be consumed unless they have been thoroughly boiled a short time before. Any scraps left should be boiled before being eaten.

The *Report of the Committee on Disinfection of the American Public Health Association*, Baltimore, 1885, recommends:—

For spore-bearing bacteria (*e.g.*, anthrax)—

1. Combustion wherever possible. 2. Steam under pressure at 110° C. for ten minutes (not long enough). 3. Boiling for an hour.

4. Chloride of lime, 4 per cent. solution (almost inert unless acidified, see p. 64). 5. Mercuric chloride, 1 in 500.

For non-spore-bearing bacteria (*e.g.*, cholera)—

1. Fire. 2. Boiling half an hour. 3. Dry heat at 110° for two hours. 4. Chloride of lime, 1 to 4 per cent. 5. Soda chlorinata (p. 63), 5 to 20 per cent. (also almost inert unless an acid is added). 6. Mercuric chloride, 1 in 1,000 to 1 in 4,000. 7. Phenol, 2 to 5 per cent. 8. Sulphur dioxide for twelve hours, until there is 4 per cent. in the air, preferably moist (see p. 92). 9. Cupric sulphate, 2 to 5 per cent. 10. Zinc chloride, 4 to 10 per cent.

Quarantine.—The arguments for and against quarantine, as compared with our system of port sanitary inspection, cannot be discussed at length here. Quarantine has been described as an elaborate system of leakiness, and our English method seems to be as effective, without its hardships. In a commercial country, rigid quarantine regulations would be fatal to all interchange of commodities, whilst, if partial measures are adopted, there is danger to be feared from laxity on the part of the local authorities, who may rely on these partial measures as being complete. With infectious diseases like cholera, in which the period of incubation is about fifteen days, it is possible for a person to arrive in this country from the Continent and pass the port inspection before any symptoms of the disease are manifest. It is therefore important that the local authorities throughout the country should have adequate provision for dealing with such sporadic cases, and medical officers of health receive special instructions from the Local Government Board when there is any likelihood of such cases reaching this country.

In August, 1894, special regulations of this character were issued, and diarrhœa was scheduled as an infectious disease which might be reportable to the local sanitary authority. Special beds at such times are arranged for by the Metropolitan Asylums Board and other authorities, and instant removal of suspected cases to the various hospitals is enforced.

At the international conference held in Paris in 1894, the following precautions were agreed upon :—The convention regulates the pilgrim ships from India and Oceania, and the sanitary and police rules under which they shall be ; it provides for the watching and care of pilgrims in the Red Sea, and for the protection and sanitary rules of the places of traffic in the Persian Gulf. The carrying out of the regulations are to be entrusted to a commission, sitting in Constantinople, to which very great powers are committed. The internal sanitation of Mecca itself is left for the present to the management of the Sultan, to whom strong representations have been made.*

* *Brit. Med. Journ.*, April 28, 1894.

Prof. De Chaumont, of Netley Hospital, held that quarantine regulations were absolutely useless, interrupted business, and delayed travellers, without doing any real good.*

The French quarantine legislation is very prolix, although confined to three maladies—plague, yellow fever, and cholera. Among the precepts is frontier quarantine. For the regulation of maritime quarantine, which apparently is the only form possible at the present day, the coast is divided into eleven districts, each with a medical officer and proper staff. Each port has an office with agents and subordinates. The control is in the hands of district sanitary councils, who, with the prefects, prepare reports for the Minister of the Interior.

Italy is the country in which quarantine is most rigid, being in the highway to the Levant and India, although cholera almost always travels in one well-marked course—through Russia and Germany to Hamburg, and thence to England and France. The chief difference between the English system and strict quarantine is that ours is only rigidly enforced in times of special danger. It has therefore a chance of being loyally carried out, whereas quarantine is a continual vexatious obstruction and is frequently evaded.

CHAPTER XV.

METHODS OF ANALYSIS.

A. Bacteriological Methods: Errors to which these methods are exposed—Conditions to be observed—Determination of the Antiseptic Value—I. Of Antiseptics in Solution—Wynter Blyth's Method for Sewage Antiseptics—Precautions necessary in these Tests—II. Of the Vapours of Volatile Liquids—Chamberland and Klein's Methods—III. of Gaseous Antiseptics. **Determination of the Germicidal Value**: Relative Value of the Culture and Inoculation Tests—Examination of Disinfectants in Solution—Dilution Methods of Sternberg and Wynter Blyth—Thread Methods—Examination of Gases and Vapours—Fischer and Proskauer's Apparatus. B. Chemical Methods: Necessity of Analysis—Requirements. **Chloride of Lime**: Preparation of Standard Solutions and Titration. **Sulphurous Acid and Sulphites. Peroxide of Hydrogen. Boric Acid. Metals. Permanganate. Phenol**: Estimation of Water—Of Phenol by Bromine—Of Cresol—Examination of Tar Oils—Carbolic Powders—Hager's Glycerine Test—Carbolic Soaps—**Salicylic Acid** and other Preservatives in Foods—Tests for Thymol, Naphthol, &c.—Medicated Wools.

In order to ascertain the antiseptic or disinfectant value of a given substance it is necessary to ascertain its effect upon known organisms

* *Sanitary Congress*, Glasgow, 1883.

under known conditions. In dealing with commercial products it is always desirable to ascertain their chemical composition and the relative amount of the active ingredients present. A full analysis is in many cases of value, since there is abundant evidence for the belief that when an active substance is mixed with others the germicidal value of the mixture is modified. It is impossible to explain the extraordinary results which have been obtained when two or more chemical substances have been used together in any other way. The probable cause of this phenomenon is the selective affinity which different micro-organisms exhibit towards different chemical compounds, so that, in addition to the cumulative effect of the several constituents present, there is a further toxic effect produced by their simultaneous action.

A. BACTERIOLOGICAL METHODS.

The principles which underlie the methods employed in the bacteriological investigation of the value of antiseptics and disinfectants are of extreme simplicity. The conditions under which the determinations of efficiency are made have, however, a very great influence in modifying the results obtained, and unfortunately sufficient care has not, in the past, been taken to specify the conditions of experiment with exactness, nor has it been recognised that the relative values given for the efficiency of antiseptics and germicides are only to be accepted for the given experimental conditions. While the experimental methods employed have had general resemblance, they have varied infinitely in details, so that the results obtained by different observers are very rarely strictly comparable. The danger of neglecting the conditions is especially evident when attempts are made to apply certain experimental results to the actual practice of disinfection.

The earliest investigations were chiefly directed to ascertain the antiseptic value of various agents by observing their preservative action on putrescible animal and vegetable infusions. To the infusions, sterilised by boiling, various proportions of the antiseptic were added, and the dose necessary to prevent putrefaction, or the period during which putrefaction was averted, was noted. The infusions were exposed to the air and compared with similar infusions untreated with the antiseptic. The materials used as tests were very various such as beef-broth, milk, urine, infusions of hay and turnip, or pastes made of bread, potato, &c. The occurrence of smell and turbidity indicated the failure of the antiseptic to prevent decomposition. The converse experiment, which was a crude attempt to determine the germicidal value of the disinfectant, was also employed. A fluid in which putrefaction was already well established was treated with the antiseptic in known proportions for a known time, and drops of the putrescent fluid were then used to infect fresh sterile, but putrescible, media. If these materials decomposed it was evidence that the antiseptic had failed to sterilise the original fluid. The errors to which these methods are exposed are—

1. An unknown mixture of micro-organisms is experimented with. It has been abundantly shown that an antiseptic has very varying effects on varying microbes. 2. The presence or absence of spores in the inoculating mixture is unknown. 3. When the inoculation is left to aërial contamination the time of infection is not known. 4. The infecting mixture may not be identical in the experimental and control media. 5. Odour and turbidity cannot always be relied upon to indicate the first occurrence of microbic growth. 6. In conducting experiments in which the already putrescent fluid is used to inoculate fresh media it is impossible, since it is not known what varieties of organisms are present in the inoculating fluid, to be sure whether the secondary growths are caused by the inoculation or are the result of accidental contamination. Koch in his classical researches on the value of antiseptics pointed out these objections, and insisted that the experiments should be made with pure cultures of microbes, whose condition as to spore formation was accurately known and which could be used to artificially inoculate the test fluids with a known organism. Many pitfalls have since been discovered, but accurate experimental work dates from these researches.

The bacteriological examination of antiseptics and disinfectants is directed to ascertain —

1. What retarding or inhibitory influence the agent exercises on the growth of a specific micro-organism—*i.e.*, what is its *antiseptic* power. 2. What effect it has in diminishing the virulence of pathogenic germs. 3. In what dose and in what time it will cause the death of the microbe; what is its *germicidal* value. Modifications of virulence under the action of antiseptics, though most important, have only been determined for a small number of micro-organisms. For practical purposes the desirable end is to cause the death of the infective agent, not simply to modify it. The experimental methods vary according to the physical condition of the disinfectant, whether it is employed as a solution or as a gas. Though solid antiseptics are employed it is only after solution that they are effective. The relative efficiency of antiseptics and disinfectants is expressed in terms of the dose and the time of action required to produce a given effect.

DETERMINATION OF THE ANTISEPTIC VALUE.

I. Examination of Soluble Antiseptics in Solution.—(*a*) A series of flasks or test-tubes containing suitable culture fluids is prepared. To certain of these flasks known quantities of the antiseptic to be tested are added, while others are left as control flasks. After sterilisation the flasks are inoculated with the test organism and placed under suitable and similar conditions of temperature, aëration, &c. If the maximum antiseptic power is to be measured, then the conditions under which the flasks are placed must be those most favourable to the growth of the organism. As the only variable factor in the two series of flasks is the presence or absence of the antiseptic, any retardation or inhibition of growth must be due to this variant. The occurrence of growth is determined by changes in the appearance of the media and by microscopic examination. (*b*) Wynter Blyth * suggested a method, intended chiefly to gauge the value of an antiseptic for sewage purification, in which the proportion of microbes remaining alive after a given time of action of the antiseptic is estimated by culture and enumeration of colonies. Sewage or sewage-contaminated water is treated with a known proportion of the antiseptic, and at varying periods known volumes of the mixture are withdrawn and inoculated into definite volumes of liquefied gelatine medium. After thorough mixing plate cultures are made in Petri capsules. The capsules are placed under suitable conditions, and the number of colonies which develop are counted. If parallel experiments are made with two or more antiseptics the relative efficiency is in inverse proportion to the number of colonies found in the cultures. In this method it is assumed that the number of organisms inoculated is approximately equal. The plan has the usual disadvantages attaching to the gelatine plate method.

Precautions.—If the antiseptic is volatile the culture fluids must be first sterilised by heat, and then the antiseptic added by means of a sterilised pipette. It must not be assumed that because growth does not appear so readily in the flasks containing the antiseptic as in the control, that therefore the proportion of antiseptic is sufficient to arrest growth. The flasks should be kept for not less than two weeks (*Sternberg*), as after long periods of retardation the restraining power often breaks down and copious growth takes place. The principal factors which cause variations in the efficiency of the antiseptics are—

(1) *Change in the Microbes experimented with.*—Certain microbes have a peculiar tolerance towards certain antiseptics—*e.g.*, *B. typhosus* and iodine trichloride. Others are much affected by the acidity or

* *Proc. Roy. Soc.*, 1886.

alkalinity of the medium, and the change in reaction due to the added antiseptic may be the cause of variation.

(2) *Change in the Medium.*—A diminution in the nutritive value of the medium will apparently increase the antiseptic power. The chief effect of change of medium is, however, due to changes which occur in the chemical reactions between the antiseptic and the constituents of the medium. All antiseptics which form precipitates with albumens have their efficiency diminished when an albuminous fluid is employed —*e.g.*, $HgCl_2$, $AgNO_3$, &c.; and, similarly, any substance which by precipitation diminishes the available amount of soluble antiseptic present—*e.g.*, NaCl with $AgNO_3$, or H_2S with $HgCl_2$—will greatly diminish the apparent activity of the agent.

(3) *Change of Temperature.*—This factor acts in two opposite directions. An increase in temperature up to the *optimum* temperature of growth of the microbe is favourable to the micro-organism, but the rise of temperature also increases the activity of the antiseptic. Which factor will prove most active can only be determined experimentally.

II. **Examination of the Vapours of Volatile Fluids.**—The principle of the methods employed is similar to that described for solutions.

(*a*) *Chamberland's Method.**—A U-tube similar to those used for anærobic cultures is employed. Into one limb the volatile fluid is aspirated, into the other the inoculated culture medium. The tubes are then sealed. The space above the fluid becomes saturated with the antiseptic vapour. The occurrence of growth is determined as before.

(*b*) *Klein's Method.*†—Short and wide tubes are prepared containing sterile agar medium with the usual sloping surface. The volatile antiseptic is placed on the side of the tube opposite the agar, and the excess runs to the bottom of the tube. The agar is then inoculated in its upper part, well away from the fluid and the tubes, tightly plugged and, if necessary, capped with an india-rubber cover, and kept at a suitable temperature. The efficiency of the antiseptic is evidenced by the absence of growth.

III. **Examination of Gaseous Antiseptics.**—The methods will be described when dealing with the germicidal value of disinfectants.

DETERMINATION OF THE GERMICIDAL VALUE.

Principle of the Methods.—The disinfectant is allowed to act for a known time in a known strength on a pure culture of a micro-organism. The disinfectant is then removed, and the death or continued vitality

* *Ann. Inst. Pasteur*, vol. i., p. 163.

† *Brit. Med. Journ.*, 1894, vol. i., p. 375.

of the organism determined by (1) the capacity to produce fresh cultures, or (2) the power to produce a pathogenic effect when inoculated into susceptible animals. The objects to be attained are:—(1) The perfect exposure of the organisms to the action of the disinfectant. In order to ensure this condition the organisms should be in suspension or exposed in a very thin layer, and care should also be taken that the microbes are not coated with any layer, such as oil, which would mechanically prevent the action of the disinfectant. (2) The perfect removal of the disinfectant from the organisms whose vitality is to be tested. The various modifications in the experimental methods are chiefly directed to this end. Seppert has shown the great difficulty that there is in freeing the organisms from adherent material, and also the enormous influence that infinitesimal doses of disinfectant may have in retarding or hindering growth. This is especially marked with regard to the germination of spores. Seppert experimented with anthrax spores and mercuric chloride, and demonstrated the different results obtained according as the mercuric chloride was simply washed away or removed by precipitation with ammonium sulphide. He also showed that the amount of mercuric chloride required to prevent the development of spores which had been exposed to the action of the disinfectant was very much less (only 1 : 2,000,000) than the proportion required to produce the same effect on spores which had not been so exposed, and that the longer the exposure the less was the amount required.

Relative Value of the Culture and Inoculation Tests in the Determination of the Vitality of the Disinfected Organisms.—Opinions differ very considerably on this point. There can be little doubt that for the determination of the continued vitality of the organism the culture test is the more delicate, and for this reason, as well as for the considerations of economy and convenience, it is the one usually employed. For determining alterations in the virulence of the microbes, the inoculation test is the only one available. The great objection to the animal inoculation test is the fact that exposure to the disinfectant so modifies the virulence of the organisms that they no longer produce their pathogenic effect, though they retain their vitality. There is no certainty that these non-virulent organisms may not give rise on germination to virulent growths, and therefore, for practical purposes, the death rather than the alteration of the organisms is to be desired. An animal which has been used for an inoculation test cannot be employed a second time even if it has apparently not suffered any ill effects, as a condition of insusceptibility, a vaccination, may have been produced by the first inoculation.

Examination of Disinfectants in Solution.—*Dilution Methods.*—There are several methods, varying in detail, in which, after exposure of the organisms to the action of the disinfectant, a small portion of the culture is removed and inoculated into a relatively large volume of a nutrient medium. The dilution thus brought about is trusted to reduce the amount of the disinfectant carried over below the amount which would cause inhibition of the growth. If thought advisable, a second inoculation, with consequent further dilution, may be made from a primarily infected culture. It is obviously important that fluid media should be used for the culture test, or otherwise the removal of the disinfectant is not secured.

(*a*) *Sternberg's Method.*—A known volume (5 c.c.) of the standardised disinfectant is added to an equal volume of a fluid (*bouillon*) culture of the micro-organism. After exposure for a given time a small portion of the mixed culture is withdrawn and inoculated into a suitable culture medium. The results are calculated as produced by a disinfectant of one half the strength of the solution added to the culture. Either the time of exposure or the strength of the solution can be made the variable factor.

(*b*) *The Drop Method* (*Wynter Blyth*).—Sterilised distilled water is infected with the test organism, and measured volumes of the infected water are added to known volumes of the disinfectant. After a given time a drop of the mixture is added to 10 to 20 grammes of liquefied gelatine medium, and the growth watched. *Bouillon* is a more suitable medium, as many pathogenic germs grow slowly at temperatures at which gelatine remains solid and retains its distinctive advantages. *Bouillon* has also been shown in Miquel's experiments to give greater opportunity for the growth of organisms whose vitality has been reduced than the solid media. If it is desired to use micro-organisms from cultures in solid media, the growth is scraped off with a wire and suspended in sterile distilled water. Such suspensions, filtered to remove flocculi, are employed advantageously, because the disturbing effects of varying media and the presence of precipitates are avoided.

The Thread Method.—This is often known as *Koch's method*, as it was employed by him in examining the action of antiseptics on the spores of *Bacillus anthracis*. Sterilised silk threads were soaked in cultures containing anthrax spores (or, better, suspensions of spores in sterile water) and dried. The threads were allowed to hang in the disinfectant for the desired time and afterwards withdrawn, washed in sterile water, and inoculated either into animals or fresh nutrient media. Koch employed solid media for his inoculations. This method has been much used, and possesses the advantage that the disinfectant can be got rid of by washing. If fluid media are employed for the test cultures it possesses also the advantages of the dilution methods.

When employed for non-spore-bearing organisms the intermediate drying should be omitted, as that itself will diminish the vitality of many organisms in the vegetative form. Suspensions in sterile water are preferable to fluid cultures in which to soak the threads, as the (often albuminoid) medium forms a coating when dry which protects the organisms. In all cases control experiments must be made in which threads are treated, just as are the test threads, except that sterile water is substituted for the disinfectant. Instead of threads platinum wires have been employed, and Blyth has suggested the use of small plugs of sterilised cotton wool attached to capillary glass rods by means of sealing wax. There must be some difficulty in securing efficient sterilisation of these mops.

Examination of Gases and Vapours.—The method of Chamberland described above is equally convenient for the determination of the germicidal action of the vapour of essences, volatile oils, &c. Instead of an inoculated medium a suspension of a given microbe is aspirated into one limb of the tube, and after exposure for the desired time a drop of the culture is withdrawn for inoculation. It must be remembered that unless the gas or vapour is soluble in water only the surface is exposed to the action of the disinfectant. When it is not required that the proportion of a gaseous disinfectant present should be known, or when the effect of a saturated atmosphere is to be tested, the micro-organisms, either on threads, or in very thin layers on sterile cover glasses, or on sterile filter paper which has been dipped into cultures or water suspensions and allowed to dry, may be exposed under a bell jar to the action of vapour evolved from a capsule of the volatile disinfectant also placed under the jar. Test-tubes with bulbous ends, such as are used for potato cultures, may also be conveniently employed, the disinfectant being placed in the bulb. The threads, cover glasses, &c., are used to inoculate culture media either directly or after washing.

*Fischer and Proskauer's Method.**—These two observers made a series of very complete investigations on the action of several gaseous disinfectants, including sulphurous acid and the halogens. Their apparatus consisted of a 20-litre very wide-mouthed jar, through whose stopper tubes for the delivery and exit of gas were passed. Both tubes were provided with taps, and the exit tube was furnished with a series of absorption bulbs. A thermometer also passed through the stopper. The centre of the stopper was itself perforated and fitted with a large india-rubber cork, through which passed a glass rod, carrying a series of glass shelves on which the objects to be disinfected could be placed. Such an apparatus permits of the ex-

* *Mitt. aus dem K. Gesund.*, Bd. II., 1884.

posure of test objects to the action of the disinfecting gas under the most diverse conditions, and also allows the amount of the gas present in the apparatus to be determined.

Most of the conditions which affect the determinations of antiseptic and germicidal values have been already considered, but there is one factor which is not under experimental control, and which imparts an element of uncertainty into the results. This factor is the variation in vitality and resistance of different specimens of the same micro-organism. In any culture there is a rather wide range of variability in the individual organisms, and this range of variability is increased if the cultures are not of the same age and grown under the same conditions on the same medium. The age and nature of the culture should always be specified, and this element of variability eliminated so far as possible by multiplying the experiments. It is obvious that the methods detailed above must be varied as the problems to be solved differ; but the principles to be kept in view, and which have been insisted upon, are constant; while the errors to be avoided are also very similar in every investigation.

B. CHEMICAL METHODS.

As already pointed out, a full chemical analysis of a given disinfectant is desirable, owing to the influence of foreign substances upon its germicidal value. In many cases in which the active ingredient is volatile, it is necessary to test from time to time the chemical strength of the material, as there have been several instances in which neglect of this precaution has allowed the use of a disinfectant which has been found to be of no value in preventing the spread of the infection through deficiencies in its activity having arisen either by storing or the culpability of the vendor. The methods of analysis obviously depend on the kind of substance to be employed, and may frequently involve much labour and skill. It is extremely important, however, that all disinfectants should be purchased on analysis, and that samples should be taken from bulk after the order has been executed, in order that the medical officer may be assured that the material is equal in strength to that which has been prescribed. It would exceed the scope of this chapter if all the methods which might be of service were described at length. A selection has therefore been made of some of the quantitative tests which may be of use in identifying an unknown disinfectant.

For any exact analysis, a laboratory, and such special skill, knowledge, and training as no engineer or medical man can possess, is indispensable; hence such questions should be referred to a competent chemist. But there is always an advantage in being able to quickly and roughly determine factors like the strength of chloride of lime, &c. It has already been pointed out that disinfection in ignorance is almost worse than no disinfection at all.

In the following sketch for the simplest processes for testing the most important disinfectants, a knowledge of elementary quantitative analysis is assumed. Further details will be found in the various manuals on analysis. The following is a typical example of methods of procedure :—

Chloride of Lime.—As already explained (p. 63), the available chlorine is that existing as hypochlorite, $Ca(ClO)_2$; this easily breaks up into chloride, $CaCl_2$, and free oxygen, O_2. The usual way of estimating it is by standard solutions of iodine and arsenious acid, using starch as an indicator. The latter is not permanently blued until all the arsenious acid has been oxidised to arsenic acid.

All volumetric solutions are usually made decinormal—*i.e.*, one-tenth equivalent in grammes of the active agent in one litre; then 1 c.c. is equivalent to 1 c.c. of another.

Iodine Solution.—Dissolve 12·65 grammes of iodine, mixed with about 20 grammes of potassium iodide, in a litre of water.

Arsenious Solution.—4·942 grammes of pure arsenious oxide and 20 grammes of sodium bicarbonate are dissolved in a litre of water.

Take 10 grammes of chloride of lime, triturate it in a mortar with successive small quantities of water, and transfer the whole gradually through a funnel into a stoppered litre flask. For each determination take out 10 c.c. of the well-shaken turbid fluid (to decant the clear solution gives a lower result—*Fresenius*), equal to a decigramme of the powder. Add from a burette the arsenious solution in slight excess—*i.e.*, until a drop ceases to produce a blue spot on ozone paper (KI and starch). Then add fresh starch paste, and run in iodine solution from another burette until there is a slight permanent blue colour. The number of cubic centimetres of iodine solution required gives the number of c.c. of arsenious solution that have been added in excess; subtract this from the total added, and the number of c.c. of the standard arsenious solution which are equivalent to a decigramme of the chloride of lime is obtained.

Each c.c. of the decinormal arsenious acid is equal to $\frac{1}{10000}$ of an equivalent of available chlorine, or ·00354 gramme.

The iodine solution should have its strength determined by the arsenious acid before each series of experiments. It keeps fairly well in the dark.

The same method can be used for the examination of chlorinated soda and potash, Hermite liquid (p. 67), bromine and iodine water, tincture of iodine, chlorine water, and indeed most oxidants.

Sulphites and Sulphurous Acid.—The solution must be very dilute containing not more than 0·05 per cent. of SO_2 (*Bunsen*), then iodine converts sulphurous acid into sulphuric. If sulphite powders are examined the method is exactly as with chloride of lime, omitting the arsenious solution, but adding starch paste and running in iodine solution until the permanent blue tint is obtained. 1 c.c. of iodine = ·0032 gramme of SO_2.

The same process answers for most reducing agents, such as sulphuretted hydrogen, &c., but not for ferrous sulphate, which should be determined by standard permanganate.

To test for the presence of sulphites in food, two portions should be strongly acidified by dilute pure sulphuric acid, and over each a piece of paper moistened with lead acetate should be suspended. To one should be added some pure granulated zinc, so as to obtain a slow evolution of hydrogen. If much frothing occurs, water must be added. The two are left for half an hour in a warm place. If the lead paper be blackened only over the one containing the zinc, it proves the presence of sulphite; if both papers be blackened, the blackening is due to other sulphur compounds, and the test is worthless.

Peroxide of Hydrogen is marked in commerce "10 or 20 volumes," meaning the number of times its volume of oxygen that is given off when it is treated with peroxide of manganese. An easy way of ascertaining this is as follows:—

A flask with cork and delivery tube is arranged to deliver the gas into a graduated measuring tube holding 200 c.c. filled with water and inverted in a basin or pneumatic trough. 10 c.c. of the hydrogen peroxide solution are measured into the flask. About a gramme of finely-powdered manganese dioxide is wrapped in a piece of paper, slipped into the flask, and the cork at once replaced. On shaking, the available oxygen is evolved. By warming the flask the last of the oxygen is removed, and is then measured. It can, of course, be calculated into weight. A rough idea of the quantity may also be obtained by adding to the diluted solution in a test-tube a few drops of potassium dichromate, then dilute sulphuric acid and ether. The intensity of the purple colouration of the ether layer is compared with that produced by a sample of known strength. This cannot be recommended except as a qualitative test.

Boric Acid.—A quantitative determination is tedious, but its presence in milk, &c., may be ascertained as follows:—Evaporate a large measured quantity (say 250 c.c.), rendered alkaline by lime water to dryness, and burn to ash. Warm the ash for some time with a little water containing a drop of ammonium chloride, and filter. Acidulate the filtrate just faintly with hydrochloric acid, and spread it on a sheet of turmeric paper specially made as follows:—Digest turmeric root with rectified spirit, filter, float a sheet of writing paper on the extract, then drain and dry it so that it has a uniform clear yellow coating. The spot is carefully dried over a water-bath; if boric acid be present there will be a rose-red colouration, turned dark dull blue by weak soda solution.

A few metals can be determined by volumetric processes, but as a rule, methods of precipitation and weighing are adopted. It will be rarely necessary or feasible to undertake these, as solutions of known strength can easily be made by dissolving the calculated quantities of the salts bought on a guarantee or on the analysis of a chemist.

Permanganate (Condy's Fluid).—A known volume of a decinormal solution of oxalic acid is placed in a beaker or porcelain dish, rendered strongly acid with dilute sulphuric acid, and the permanganate solution, properly diluted, run in from a burette until a permanent pink tinge is produced. The reaction is—

$$5H_2C_2O_4 + K_2Mn_2O_8 + H_2SO_4 = K_2SO_4 + 2MnSO_4 + 10CO_2 + 8H_2O.$$

Therefore 5 equivalents of oxalic acid require for oxidation 1 equivalent of permanganate, equal to 5 atoms of available oxygen.

Phenol.—Water is estimated by shaking the sample in a graduated tube with half its volume of a saturated solution of common salt. The diminution of volume of the phenol indicates the amount of water present. "Calvert's No. 1" contains none, crude acids often contain 10 to 17 per cent. Anhydrous cresol shaken up with three volumes of brine gives an increase of volume of about 5 per cent. If the cresol contains water, its volume either does not alter, or decreases slightly.

To Determine the Phenol.—Shake up bromine with water at 20° C.* To determine the phenol-equivalent of the bromine water, a sample of Calvert's No. 1 acid (crystals) is boiled for a short time to remove traces of moisture, 0·25 gramme weighed into a well-stoppered flask and dissolved in 100 c.c. of water, the bromine water run in from a stoppered burette, with constant shaking, until there is a good excess, as shown by the colour. After half an hour's standing, if the excess has disappeared, more bromine must be added, and the mixture again shaken and allowed to stand; the total amount added must be carefully noted, excess of potassium iodide is added, and the amount of liberated iodine ascertained by standard thiosulphate and starch in the well-known manner. This free iodine corresponds to the bromine in excess; deduct this from the total bromine added, and the amount of bromine water necessary to precipitate 0·25 gramme of pure phenol is

* Such a solution keeps better than water saturated with bromine in the cold, and may be preserved in well-stoppered bottles in the dark.

obtained. It is then easy to calculate the phenol-equivalent of each cubic centimetre of the bromine solution.

$$C_6H_5.OH + 3Br_2 = C_6H_2Br_3.OH + 3HBr.$$

The operation repeated with the sample under examination gives the phenol strength.

Samples containing cresol and higher phenols would require proportionately less bromine, so the result would be lower than the truth, if the bromine equivalent is calculated to phenol. Another process consists in determining the solidifying point of a mixture by cooling it in a narrow tube and adding a minute crystal of pure phenol to aid the solidification. The melting point is then compared with ready-made mixtures of known composition (or with a table).

It is possible to collect the tribromo-precipitate on a filter paper. Tribromophenol is crystalline, tribromocresol and the others are liquid; hence the latter soaks into the paper, and the two can be separately weighed. The liquid portion should be calculated as cresol and higher homologues.

Fractional distillation of the phenoloids gives doubtful results as their boiling points are too near one another.

Tar Preparations.—The ingredients of these may be divided into four groups :—

1. *Neutral* bodies not combining with acids or alkalies, divided into—

(*a*) *Light oils*, containing benzene and the homologues.

(*b*) *Heavy oils*, containing naphthalene, anthracene, &c.

The antiseptic value of these is slight. They are classed as neutral tar oils.

2. *Basic* bodies, combining with acids—*e.g.*, aniline, pyridine, &c. As their antiseptic value is high they may with advantage be present in disinfectant fluids. The commercial importance of aniline has led to this group being extracted in making phenol and cresol preparations. Hence there has been a reaction in favour of crude coal-tar preparations, instead of the purely phenol compounds that were formerly almost exclusively in vogue, although the neutral bodies in the former are undoubtedly of little value.

3. *Phenols*, soluble in alkalies, but not really acid bodies (p. 149). The valuation of these preparations is based on the proportions of these constituents.

A. 10 c.c. of the oil are taken in a graduated tube, 20 c.c. of 10 per cent. caustic soda added, and the whole well shaken, and allowed to stand. The phenoloids dissolve, while the neutral (and basic) substances collect as an oily layer; below, if they are heavy oils; at the top, if they are light oils. If they will not separate distinctly, which often happens, add 10 c.c. of petroleum ether and shake, measure the amount of the mixture and subtract the ether. The result is only approximate, but for ordinary purposes this method is considered sufficient, the volume obtained being returned as the neutral tar oils present.

B. For a more exact examination a larger quantity must be taken, 50 or 100 grammes of the original liquid, treated with soda as above, and the two liquids separately examined, after measuring their quantity.

(*a*) The portion insoluble in soda is evaporated below 100° C. to remove the ether; naphthalene and anthracene may crystallise out on standing, and may be identified by their melting and boiling points. The liquid which will not crystallise is washed in a graduated tube with 20 per cent. sulphuric acid to remove the bases as sulphates. Notice again the diminution of volume (result only approximate). The acid solution is distilled with aqueous potash; the bases (aniline, pyridine, &c.) come over and can be tested. If the quantity allows, dry them by fused calcium chloride, determine their boiling and melting points, their chemical reactions, and the nature of their platinum double salts. The portion insoluble in all reagents can be tested by its physical properties.

(*b*) The fraction soluble in soda, containing the phenoloids, is fractionally precipitated by successive small quantities of dilute sulphuric acid, whereby the carbolic acid is concentrated in the first fraction; then the melting points of the several fractions are taken, as above described.

Carbolic Powders.—In the case of powders made with lime, or others in which the phenol exists in combination, neither direct distillation, nor extraction with ether, give a correct result unless the powder is first acidified. Allen mixes 50 grammes in a large mortar with 5 c.c. of water, and drops in gradually with constant stirring, so as to keep down the heat, 50 per cent. sulphuric acid. The addition, which takes some hours, is continued till a fragment of the powder shows an acid reaction when moistened with water. If the mixture be pasty, it must be triturated with sand to make a granular powder. After standing covered for two hours, it is transferred to a large Soxhlet tube and extracted with ether or benzene. On distilling off the solvent below 110° C., the crude tar products are left, and can be further tested.

To distinguish between preparations made from wood-tar and from coal-tar is comparatively easy; in mixtures the identification of the source (shale oil, blast furnace oil, &c.) becomes more difficult.

1. Coal-tar acids coagulate collodion, B.P., wood creosote does not.

2. A neutral aqueous solution of ferric chloride gives with phenol a deep violet colour, with wood-creosote a yellowish or greenish-brown tint.

3. *Hager's Test.*—Thirteen volumes glycerine are diluted with 1 volume water. One volume of the sample to be tested is well shaken in a stoppered burette with 3 of the diluted glycerine, and allowed to stand. If the creosote be pure, the volume will remain unchanged. If reduced, the glycerine layer is drawn off and the remaining creosote again shaken with 3 volumes of the dilute glycerine, and the volume again observed. The undissolved portion includes the wood-creosote, but may also contain products from shale or blast-furnace oil; the chief distinction lies in the odour. The soluble portion may be diluted with water, the coal-tar acids extracted with chloroform, and the latter separated and distilled off. So separated, the phenoloids from blast-furnace and shale oils give with ferric chloride a violet-blue colour changing to brown, instead of a permanent deep violet, as with ordinary phenol.

Sulphuretted hydrogen should be tested for with dilute sulphuric acid and lead paper. Powders containing it emit an offensive odour, and are usually excluded by the terms of the contract. Sulphites and hypochlorites can be determined as at p. 308. With lime bases, the determination of sulphurous acid is difficult. As sulphurous acid powders oxidise on keeping, it is important to ascertain not only the "available" sulphurous acid, but also the quantity oxidised to sulphuric acid.

It is impossible to give a general process for the detection or estimation of the multitude of organic bodies that have been introduced for sanitary purposes. It may be mentioned that in the above division of the tar preparations into acid, basic, and neutral bodies, the following substances will appear in the places indicated:—

(*a*) *With the neutral oils:* Benzene, naphthalene, anthracene, vaseline, paraffins, pyrrol, essential oils, thymol, camphors, alcohol, ether, and neutral bodies generally.

(*b*) *With the bases:* Aniline, pyridine, quinoline, ammonia, compound ammonias, and volatile alkaloids such as trimethylamine, nicotine, &c.

(*c*) *With the acids:* Phenol, cresol, &c., resorcin, benzoic, and other aromatic acids, fatty and resin acids (distinguished by non-volatility and other physical characters; resin soap gives a brown colour and is not coagulated by strong soda solution, thus differing from a fatty soap).

The specific gravity of crude carbolic acid should be between 1·05 to 1·065; if it is less it is most likely adulterated with light tar-oil, in which case the specific gravity is often between 1·04 and 1·045.

Carbolic Acid in Soaps.—Five grammes of the soap are dissolved in warm water, and 20 or 30 c.c. of 10 per cent. caustic soda added. After cooling, the solution is shaken with ether to remove any hydrocarbons (terebene, camphor, &c.). The alkaline liquid is next mixed with saturated brine, which precipitates the soap and leaves the phenols in solution. It is then filtered, the soap again shaken up with brine and the washings added to the filtrate, and the liquid made up to 1 litre. 100 c.c. of the solution (= 0·5 gramme of the soap) are placed in a separator, acidulated with dilute sulphuric acid, and titrated with bromine water as at p. 310.

Salicylic Acid and other Preservatives in Foods.—The articles are cut up if necessary, and extracted, first with two portions of cold, then with about three of boiling water, separating any fat by passing through a wet filter, or in some cases by allowing the whole to cool and removing the layer of fat. The volume of the aqueous liquid should not be unduly large. Milk must be coagulated by a little acetic acid and gentle warming, then filtered and the whey examined. Solutions containing gummy or viscous matters, or colouring matters soluble in ether, can be precipitated by neutral acetate of lead filtered, the filtrate freed from lead by sulphuretted hydrogen, and the latter expelled by warming. The prepared filtrates should then be neutralised by soda, evaporated to a convenient bulk, acidified with hydrochloric acid, and extracted with ether in a separator. The ethereal solution, besides salicylic acid, will contain any phenol, cresol, benzoic and other aromatic acids, thymol, essential oils, ethers, glycerine, perhaps bitter principles, resins, glucosides, alkaloids, and sugars in traces, lactic and vegetable acids. If acetate of lead has been used, the resins and bitters will have been removed. Distil off the ether, evaporate the residue at a gentle heat, dissolve in a measured volume of water, and divide into several portions. Notice the odour, taste, and appearance, and apply special tests. If glycerine be sought for, neutralise with soda, again extract with ether, distil off the ether and evaporate; the nearly pure glycerine can be weighed and afterwards tested.

In an aliquot part the salicylic acid can be determined by adding neutral ferric chloride cautiously (iron alum is more convenient), and imitating the colour in another tube by a standard solution of salicylic acid.

If phenol or resorcin be present, the comparison must be effected in alcoholic solution (absolute), with alcoholic ferric chloride. Thus even 1 part of salicylic acid with 800 of phenol may be estimated.* In testing for resorcin H. Bodde† adds a few drops of sodium hypochlorite

* A. Fajans, *Chem. Zeitung*, 1893, vol. v., p. 69.

† *Nederl. Tydschr. v. Pharm.*, May, 1889.

(p. 63) to a watery or alcoholic solution of resorcin; a violet colour, rapidly changing to yellow, is produced. On warming or adding excess, the liquid becomes dark brown. One part of resorcin in 10,000 of water will still show this reaction. Carbolic, salicylic, benzoic, and other allied acids do not give it, but may turn the liquid slightly yellow on warming. Pyrocatechol (p. 172) turns green, hydroquinone yellow and red. Another test is to first add liquor ammoniæ and then a few drops of the hypochlorite, when the liquid will give a reddish-violet colour, turning green on boiling. The colour is not taken up by benzene. The reaction is not shared by salicylic nor benzoic acid, nor by antifebrin (p. 185), but phenol gives a greenish-blue, partly soluble in benzene. The colours are changed to red by dilute sulphuric acid.

Messenger and Vortmann have found that strongly alkaline solutions of phenol, thymol, β-naphthol, and salicylic acid admit of estimation by means of a decinormal thiosulphate solution, using starch as an indicator in the ordinary way. Each molecule of phenol consumes 6 atoms of iodine, therefore the iodine consumed multiplied by $\frac{93{\cdot}78 \text{ (1 mol. phenol)}}{759{\cdot}24 \text{ (6 atoms iodine)}}$ or 0·1235, gives the quantity of phenol. The process is as follows:—2 grammes of the phenol are dissolved in water with about 3 grammes of caustic soda, and the solution diluted to 250 or 500 c.c. 5 or 10 are measured into a flask, warmed to 60° C., and iodine solution added till the liquid is strongly yellow. On agitation a bright red precipitate will fall. After cooling, the liquid is acidulated with dilute normal thiosulphate to ascertain the excess of iodine.

Thymol gives a brownish-red precipitate, and requires no heat. It requires 4 atoms of iodine, hence the multiplier is 0·2957. From 0·1 to 0·3 gramme is taken.

β-Naphthol gives a dirty-green precipitate; the factor is 0·3784. The solution must be heated to 60° C.

Salicylic Acid.—At 60° C. the bright red precipitate should not be formed until the iodine is in excess, and should be increased by acidulation. If too little alkali be present, a yellowish-white precipitate is formed; in this case more soda must be added. The multiplier is 0·1813.*

In a mixture of two of these bodies, if the sum of their weights is known, as well as the iodine equivalent of the mixture, the amounts of the two constituents can be calculated.

Formalin can be recognised in foods by distilling and proving the presence of a volatile aldehyde in the distillate by means of a magenta solution bleached by sulphurous acid.

* *Berichte*, 1890, p. 2753.

Medicated Wools.—Mr. Hoseason, in a recent paper on medicated cotton wool dressings,* drew attention to the immense variation in the strength of these preparations as found in commerce. The method of analysis consists in shaking weighed quantities (10 grammes) of the wools with water (1 litre), and determining the amount of the effective constituent in the following way:—

1. *Phenol,* by the volumetric bromine process (p. 311).

2. *Boric Acid,* by evaporating one-fortieth (25 c.c.) of the solution to dryness with 5 c.c. of a strong solution of sodium carbonate, the latter being previously standardised. The loss of carbonic acid was estimated by weight in a modification of the usual CO_2 apparatus. The boric acid was thus determined by difference.

3. *Mercuric Chloride.*—Scherer's method with hydrochloric acid and decinormal thiosulphate is inapplicable if the quantity of mercury is small. A colorimetric method based on the depth of the brown colour with sulphuretted hydrogen may be used. Some results obtained with commercial antiseptic wool dressings are as follow:—

Carbolic, in five samples: 1·06, 1·07, 0·69, 0·25, 5·08 per cent.

Boric, in five specimens: 36, 21·6, 27·1, 15·8, 14·4 per cent.

Corrosive Sublimate, in two: none, and 1 in 8,000 to 9,000.

* *Chem. and Drug.*, Feb. 18, 1893.

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