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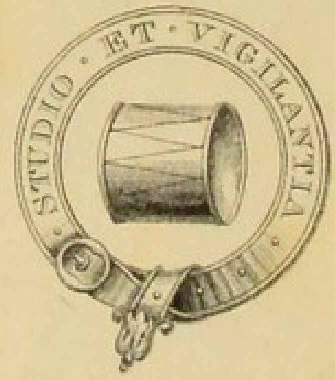
NATURE'S HYGIENE

AND

SANITARY CHEMISTRY

C. T. KINGZETT

FIFTH EDITION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NATURE'S HYGIENE.

NATURE'S HYGIENE

AND

SANITARY CHEMISTRY:

CONTAINING ALSO A SPECIAL ACCOUNT OF

THE CHEMICAL AND HYGIENIC CHARACTERS OF
EUCALYPTUS, PINE AND CAMPHOR FORESTS,
AND SOME INDUSTRIES CONNECTED
THEREWITH.

BY

C. T. KINGZETT, F.I.C., F.C.S.,

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ANIMAL CHEMISTRY; OR, THE RELATIONS OF CHEMISTRY TO PHYSIOLOGY AND PATHOLOGY (LONGMANS AND CO.), ETC.

FIFTH EDITION.

LONDON:
BAILLIÈRE, TINDALL AND COX,
8, HENRIETTA STREET, COVENT GARDEN.
1907.

PREFACE TO THE FIFTH EDITION.

THIRTEEN years have passed away since the preceding edition of this book was published, and although I have endeavoured to make clearer than before the exact relations of micro-organisms to infectious and contagious disease (so far as they have been determined), I have not attempted to summarize the vast amount of bacteriological work that has been done since 1894, because that work has not substantially advanced our previous knowledge of these relations.

This work does not profess to be one on bacteriology, but is concerned with Nature's Hygiene and Sanitary Chemistry, and I have dealt with bacteriological studies only so far as they have any material connections with these subjects. What progress has been made, has only strengthened the accuracy of the views which I first of all expressed with respect to germs in relation to disease. It is certain that there cannot be any great advancement in our knowledge of disease and its propagation until by means of exact quantitative studies, chemical expression can be given to the life-history of micro-organisms and the cells of the human tissues.

I have added some pages concerning the more newly-discovered chemical elements, the constitution of matter, and certain steps that have been taken in relation to the attempted standardization of disinfectants by means of mere germicidal tests.

It is a matter for deep regret, in my view, that we have not yet seen the appointment of chemical officers of health to take the place of public analysts, and to deal with a number of matters concerning which they would as a body be far more competent than medical men as public health officials, such as (in addition to the analyses of foods, drinks, and drugs) the character of gas and water supplies, the treatment and disposal of sewage and refuse, chemical disinfection, purity of the air, dust-laying, the preparation of road surfaces, and so forth.

In conclusion, I have to express my sincere appreciation of the kind services rendered by my friend Mr. R. C. Woodcock, F.I.C., F.C.S., in connection with the revision of the proof-sheets of this new edition of ' Nature's Hygiene.'

C. T. KINGZETT.

1, HORNTON STREET, KENSINGTON,
July, 1907.

PREFACE TO THE FOURTH EDITION.

THE third edition of this work has been out of print for some time, and I have at last yielded to the pressure of friends to bring out a new one, which will, I hope, be found to give a comprehensive, if brief, description of the various important subjects with which it deals.

The work has been carefully revised, and I have added a chapter on some new developments of bacteriological science (in relation to the subjects of Phagocytosis and Immunity), and also a chapter on Alimentation and Foods. My assistant, Mr. D. Homfray, B.Sc., has rendered me considerable help in the preparation of the last-mentioned chapter and in revising some of the other sheets.

The results of my further investigation of the chemistry of the aerial oxidation of Turpentines and other Essential Oils are also embodied.

It will be seen that the book has gradually grown from a series of scientific essays into a systematic treatise on Hygiene.

I take this further opportunity of emphasizing the importance of allocating to skilled chemists some of the duties which are at present entrusted to medical officers of health and engineers. The organization of the Institute of Chemistry has done much towards qualifying the present-day chemists to effectively deal with many matters concerning public health, and the possession of the Fellowship of that Institute may be accepted by the public, as sufficient guarantee of the ability of its holders to satisfactorily discharge such duties as I have referred to in the prefaces to previous editions of this work.

It is satisfactory to me to note that, in the interval which has elapsed since the third edition of 'Nature's Hygiene' was published, bacteriological research has made still more apparent the fact that micro-organisms are connected with the production of disease (as I have always contended) only by reason of the chemical products to which they give rise under certain specific conditions. Much of the bacteriological work at present in vogue is practically worthless, and I am convinced that no further material advancement of knowledge can take place in this direction until the chemistry of the subject has been explored in a thorough manner, and conducted side by side with properly-designed physiological experiments.

C. T. KINGZETT.

ELMSTEAD KNOLL, CHISLEHURST, KENT,
March, 1894.

PREFACE TO THE THIRD EDITION.

In preparing this further edition of 'Nature's Hygiene,' I have carefully revised the whole work, with the view of bringing it into thorough accord with existing information of the subjects which are dealt with therein, and I have added an account of my own recent investigations concerning the comparative action of a number of antiseptics, the precise chemical history of various fermentative and digestive processes, the chemistry of Camphor Oil and Russian Turpentine, and some other subjects.

The account of Camphor Forests and the collection of Camphor Oil and its uses, is a new feature of the work, and in addition to enlarging most of the chapters, so that they deal more comprehensively with all aspects of Nature's Hygiene, I have throughout the book endeavoured, as opportunity offered, to clearly indicate the precise relations, as cause and effect, which are now known to exist between micro-organic life and so-called infectious or contagious diseases. In this connection, it is gratifying to be able to record the fact that by the investigations of later years it has been well established that micro-organisms do not produce disease in any direct manner or by their mere mechanical presence in or upon the body, but that the real poisons are of the nature of chemical (toxic) products which result from changes in the media in which the microbes develop and upon which they grow and multiply. This view I have for many years past persistently and consistently advocated, although it received little credence until quite lately.

In conclusion, I renew the expression of my opinion, that chemical officers are urgently needed to act side by side with medical officers of health and engineers, to effectively deal with the many important matters affecting public health and the rating of the community at large, which were referred to in the preface to the second edition of this book. While the development of chemical science in recent years has been most marked, sanitary authorities have not sufficiently availed themselves of its services, but have relied much too confidently upon mere engineering skill. The disposal of the London sewage as at present effected will serve to exemplify my meaning, and may be taken by way of illustrating the disastrous results that may ensue from such an unfortunate reliance. The water-carriage system of sewage has grown in London from a blessing into an unmitigated and terribly costly evil.

C. T. KINGZETT.

March, 1888.

PREFACE TO THE SECOND EDITION.

DURING the four years that have elapsed since the first edition of this work was issued, so much attention has been paid to sanitary matters, that I have found it necessary to rewrite the greater part of it, and to add several new chapters dealing with Water Supply, Sewage, Infectious Diseases, and the Treatment of the Sick. At the same time I have given even more attention than in the first edition, to the process of oxidation as carried on in nature, and I think the book will be found to contain an accurate account of present knowledge concerning the relations of micro-organisms to disease. All matter relating to the chemistry and hygiene of the eucalyptus and the pine has been retained ; but it has been found desirable to divide the work into two parts, one dealing in particular with this subject (which has been my special study), and the other with the general principles of natural hygiene.

I take this opportunity of expressing my opinion that great public benefit would result from the appointment of chemical officers to act in conjunction with medical officers of health. It is notorious that medical men and engineers are not qualified, by their special education and training, to deal with many questions which are of the greatest importance to public health and wealth, and I entertain a strong conviction that by the appointment of efficient chemists as officers to act under Sanitary Authorities and Local Boards, a saving would be effected to ratepayers generally. Chemical officers, if appointed in accordance with my suggestion, should do the work at present conducted by public analysts, and to them should be referred all matters in connection with water supply, gas supply, and the disposal and utilization of sewage and refuse. In order to obtain the services of efficient chemists, it would, of course, be essential to offer adequate remuneration for the duties that would be imposed upon them. I beg to commend this suggestion to the earnest attention of my readers, and to Members of Parliament in particular.

In conclusion, I hope this new edition of my book will prove useful to many.

C. T. KINGZETT.

December, 1884.

PREFACE TO THE FIRST EDITION.

Of the many scientific subjects which, during recent years, have strongly arrested the attention of the public, few have excited more interest than that which has been manifested, from time to time, regarding the reputed sanitary properties of the eucalyptus-tree.

But while this interest extended even to several European and other Governments, and although the hygienic value of the eucalyptus is based upon an abundant and increasing amount of evidence, yet no satisfactory explanation of this influence has ever been presented to the public.

During some years I have spent much time in the study of what are known to chemists as processes of slow oxidation, and have communicated the results of my researches to various scientific societies. These investigations, conducted, so to say, in the laboratory of nature, furnished a full and sufficient explanation of the sanitary properties of the eucalyptus-tree, and they also proved that the pine-tree exhibits characters of the same important order.

In bringing this work, therefore, before the public, I am really endeavouring to place before them a scientific research in a popular manner. In so doing, however, I have not merely described my own experiments, but have also given particulars of those of all others who have worked upon the subject, and have incorporated the results in a number of chapters, which deal with a variety of questions more or less intimately concerned with Nature's Hygiene.

Each chapter will be found to form a complete essay in itself, and thus the book combines the features of a continuous study of some processes of nature's chemistry and hygiene, and of a series of articles on scientific subjects.

Wherever an educated public is to be found, there must also exist a demand for popular scientific literature, and it is towards feeding such a demand that I have ventured to contribute this work, trusting it may not be received altogether without favour.

C. T. KINGZETT.

March 31, 1880.

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NATURE'S HYGIENE

PART I.

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CHAPTER I.

INTRODUCTORY — ARGON — HELIUM — RADIUM — CONSTITUTION OF MATTER — INDESTRUCTIBILITY OF ENERGY AND MATTER — ELECTRONS — ETHER — CHEMICAL ELEMENTS — ATOMIC WEIGHTS — CHEMICAL COMPOUNDS — LAW OF COMBINING PROPORTIONS — SYNTHESIS AND DECOMPOSITION — VALENCY — SYMBOLS — FORMULÆ — REACTIONS AND EQUATIONS — LAW OF GASEOUS VOLUMES — TEMPERATURE.

THE natural processes which are connected with the study of hygiene are, to a very large extent, chemical in essence, and as, consequently, there will be frequent references in the following pages to chemical principles and chemical changes, it is desirable that readers should be prepared in the onset to understand such matters as they arise.

By the science of chemistry it has been ascertained that the globe—comprising all substances that are found in it and upon it, whether entering into the composition of minerals, vegetables, or animals—is built up of a number of more or less ultimate principles (commonly termed 'elements'), and of compounds resulting from their chemical combination. The word 'element' is here employed to represent a substance which until lately was supposed to be incapable of undergoing change of nature, and which could not therefore be resolved into two or more distinct bodies. Whether there are really ultimate and absolutely distinct elements is not yet known, but this view is becoming apparently much more doubtful. It may be that means will yet be found by which chemists will be enabled to decompose them into more simple principles, and it may also be that they are really identical in essence—that they are, in fact, composed of primordial matter (*protyle*), and only differ in properties according to the various conditions under which they are revealed to us as so-called elements.

In early times it was thought that there were four elements—the earth, air, fire, and water; and the belief that air was an elementary substance prevailed until rather more than 200 years ago. During the next 100 years our chemical knowledge made great strides, and, thanks to the work of some few chemists —notably, Boyle, Black, and Cavendish—it was conclusively proved that air was not an elementary substance, but approximately a mixture of 80 parts of nitrogen and 20 parts of oxygen, with small quantities of carbon dioxide and aqueous vapour. Then for another 100 years no further important discoveries were made in this direction, and it was generally accepted that the composition of the air had been definitely settled beyond dispute; consequently, the announcement in 1895 by Ramsay and Rayleigh that they had discovered a new and hitherto unknown gas, which they named argon, in the air, was received by all scientists with extreme surprise, and by many with undisguised scepticism.

For some years previous to 1895 Lord Rayleigh had been carrying on a series of extremely careful experiments with the object of determining the density of nitrogen, and he found that chemically prepared nitrogen from various sources was about ½ per cent. lighter than the nitrogen which is obtained from the air by removing the oxygen, carbon dioxide, and water. Being unable to account for this in any way, he consulted with Professor Ramsay, and the two set to work to clear up the mystery. One possible explanation, of course, was that atmospheric nitrogen contained some other constituent.

Argon.

In order to see if this was so, nitrogen obtained from the air was absorbed by passing it repeatedly over red-hot magnesium, the last traces being removed by adding a little oxygen, and passing electric sparks through the mixture in the presence of caustic soda. The residual gas thus obtained was found to differ from nitrogen; its density, for example, was 19·96, whereas that of nitrogen is 14. Further, when examined spectroscopically by Professor Crookes, it was found to give two distinct spectra, differing from those of nitrogen.

The amount of argon present in the air is rather less than 1 part in 100 parts of air. Argon is an extremely inert body, much more so even than nitrogen, and so far all attempts to get it to combine with other elements have failed. Its solubility in water is about the same as that of oxygen, and about two and a half times as great as that of nitrogen.

Argon boils at 187° below, and solidifies at 189° below, zero (0° C.). When a tube of the rarefied gas is excited by means of an electric current, it gives out first a purple, then a beautiful blue, light. By the fractional distillation of liquid argon, Ramsay has shown that it contains traces of other gases, having distinct spectra, to which he has given the names neon, xenon, and krypton.

About forty years ago Professors Frankland and Lockyer made a large number of photographic and spectroscopic examinations of the sun's corona during an eclipse. When the photographs came to be examined a brilliant line was discovered in the yellow part of the spectrum, which failed to correspond with the lines of any known element, and Lockyer suggested calling this unknown gas in the sun's atmosphere helium.

In 1895 Professor Ramsay, whilst experimenting on a gas given off by a mineral called cleveite (found in America and Sweden), ascertained that its spectra gave this same brilliant yellow line, thus showing it to be probably identical with the gas helium discovered in the atmosphere of the sun thirty years previously.

Helium has since been found in a large number of minerals, more especially those containing salts of uranium. It appears to exist in these minerals in a state of occlusion, and not of combination; in fact, so far all attempts to get helium to combine with other elements have failed. Traces of helium have also been found in the air, whilst in the gases escaping from certain springs it is present in quite appreciable quantities. The gas from the springs at Bath, for instance, contains, it is said, as much as 8 per cent. of helium after removing the hydrogen. The vapour density of helium is 1·98. It has been liquefied by Dewar, who determined its boiling-point to be about 240° below 0° C. Helium is very sparingly soluble in water, and quite insoluble in alcohol and benzene. When the rarefied gas is excited by means of an electric current, it gives a most beautiful spectra.

Radium.

The discovery of radium by Mme. Curie and her late lamented husband was apparently suggested to them by M. Becquerel's study of the luminous effects exhibited by the chemical compound known as potassium and uranium sulphate, a salt which, when exposed to sunlight, becomes for a moment self-luminous. These so-called 'Becquerel rays' in turn followed upon Röntgen's discovery of the X rays, which they resemble in many respects: 'Thus, they cause damp dust-free air to deposit fog, make air conduct electricity, will pass through such substances as paper, glass, paraffin, quartz, sulphur, Iceland spar, and thin layers of metal, even more freely than Röntgen rays; and they cannot be reflected, refracted, nor polarized, like the waves of which ordinary light is composed. It was found, further, that they are not homogeneous, but consist of several different radiations, which can be filtered off from each other, as it were, and can then be distinguished by their separate characteristics. Bodies which emit these remarkable emanations are said to be radio-active.'*

Mme. Curie and M. Curie and their colleague M. Bémont, in following up Becquerel's investigation of radio-active metals and other materials, were led to the discovery, not only of radium, but also polonium and actinium, although neither of the last two supposed new elements have yet been isolated in the form of salts. Radium is known to yield salts, including a bromide, a chloride, and a nitrate, and a combining proportion has been assigned to it by Mme. Curie of 112·5.

Radium itself has not been isolated, but its spectrum in the ultra-violet has been studied by Crookes, and affords a means of identifying it. Heretofore it has in the main been prepared from pitch-blende (the radio-activity of some specimens of which exceeds that of the uranium present in them), after the uranium has been extracted from it, and a ton of this material, after adequate treatment, is said to yield about 10 or more kilogrammes of a mixture of sulphates of barium, lead, iron, and calcium, with a trace of radium. By the removal of the other bases, the radium is ultimately obtained in the form of a chloride. By successive

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* See paper by W. A. Shenstone, F.R.S., *Knowledge and Scientific News* for May and June, 1904, vol. i., pp. 78, 79, 107-109.

processes of purification it is said that products are obtained enormously greater in radio-activity than uranium, the highly-refined and purified product being said to be a million times as active as the standard substance.

Radium salts in general resemble those of barium; they are, however, visible in the dark and continuously evolve heat. It is reported that a gramme atom of radium gives out in a year as much heat as a gramme of hydrogen when burnt in the oxyhydrogen flame. Its powers are destroyed to a great extent when strongly heated, but these are automatically recovered after a few weeks upon cooling.

The radiations of radium are said to be very destructive; for example, a piece of cambric placed above a box containing a little radium salt was found by Lord Blytheswood to be pierced with holes after two or three days, and very unpleasant effects have followed when specimens of the radium salts have been kept too long near the human body.

It is comparatively rare, although its known sources of supply are becoming gradually more numerous. The study of its properties has thrown considerable light on the ultimate constitution of matter, and it is in a large measure due to the investigations made with it that chemists have lately come more generally to the view that atoms are capable of dissociation into so-called corpuscles or emanations of a much simpler constitution. The transformation of radium into its emanation, and the connection between this change and the radio-active phenomena which accompany it, have been investigated by Professor Rutherford, who suggested upon certain grounds that probably helium would be found among the products of its disintegration. This suggestion led Sir W. Ramsay and Mr. Soddy to seek it, and they found that the spontaneous breaking up or dissociation of radium is attended by its apparent transformation into helium, and they have to some extent determined the volume of the emanation produced in a given time from a known weight of radium in the form of bromide, as well as the quantity of helium resulting from the spontaneous change of the emanation. The helium thus produced was found to yield a spectrum agreeing with the solar spectrum of that substance—that is to say, it gives the same characteristic yellow lines.

It may also be usefully noted here that Sir William Crookes some few years since, when working with the rare earth called *ytria*, succeeded by a long series of fractional precipitations in obtaining products which yield different phosphorescent spectra.[*] This seems to indicate that the material with which he started, although elemental in the ordinary sense of that word as hitherto used by chemists, may yet be made to yield a number of different substances which it is difficult to separate from each other.

It was in 1872 that I first directed chemical attention to the constitution of matter, at the same time pointing out that others before me had been impressed with somewhat similar, but not precisely identical, views. Prout had at an earlier date suggested that the

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[*] See *Chemical News*, vol. lv., pp. 83 and 95.

numbers which represent the combining proportions of the several elements are multiples by whole numbers of the combining proportion of hydrogen—the lightest known elementary substance.

Miller had ventured a little further, and suggested that 'it is not altogether impossible that the various bodies at present regarded as elementary may in reality be compounds of a single primordial substance condensed in different degrees in the various so-called elements.'

In my own contributions* to the subject I discussed the matter from a more advanced and different platform —viz., that of evolution or genesis rather than one of mere density or condensation, thus regarding all the sixty-five elements then known as 'the same matter actually, but each under different forces, the forces engaged so operating as to give to each different properties.' In my several communications on this subject I sketched some of the considerations leading to the conclusion that 'from one primordial matter have been developed or evolved all those integrant parts the study of which constitutes the science of chemistry.'

My readers who may care to examine the subject in greater detail can refer to the publications to which reference is made in the footnotes, but it is not convenient to discuss it in further detail in this place. I have only referred to it to this limited extent in order that, so far as I am entitled to any credit for viewing it in an aspect which has obtained much more credence

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* See *Chemical News*, vol. xxiv., p. 131; vol. xxvi., pp. 138 and 202; vol. xxviii., p. 288.

of late years, it may not be altogether overlooked or placed to the account of others.

In his address to the British Association for the Advancement of Science in 1898, Sir William Crookes said: 'As the host of the celestial asteroids, unimportant individually, become of high interest when once the idea is grasped that they may be parts of the original nebulæ, so do these insignificant and rare elements rise to a supreme importance when we regard them in the light of component parts of a dominant element.'

In this phrase expression is given to precisely the same hypothesis that I had advocated in 1872, and which was then and at some later time the subject of discussion in the *Chemical News*. To that hypothesis I have adhered ever since, and I am now more profoundly convinced of its accuracy than I was originally.

Of late some other modified interpretations of this matter have received attention, and if correct, they would dispose of the conceptions of matter and force as distinct things; but I adhere to the view taken by Dubois Raymond—viz., that, although separately they do not exist and cannot be dissociated—'no force without matter; no matter without force'—yet they are distinct in essence, matter, that is to say, as recognized by us being the expression given to it by the forces which control it.

In delivering the Faraday Lecture before the Chemical Society in April, 1904, Professor Wilhelm Ostwald represented that the only difference between elements and compounds consists in the supposed impossibility of proving the former to be compounds ; and in connection with the transmutation of radium into helium, he pointed out that enormous amounts of energy are required for the transmutation of one element into another, whilst enormous amounts of energy will also be liberated if, as in this instance, an unstable element is changed into a stable one.

The view of the constitution of matter to which I have given expression involves the conception that matter and force are alike indestructible, and until quite recently physicists were prepared to grant that matter and energy were alike uncreatable and indestructible.

Although not directly bearing upon the subject under discussion, it is interesting to call attention to the fact pointed out by Sir Oliver Lodge, when delivering his presidential address to the members of the Birmingham and Midland Institute in October, 1904—that although matter possesses energy and is propelled by force, neither matter nor energy possesses the power of automatic guidance or control. 'Inorganic matter is impelled solely by pressure, is not influenced by the future, nor does it follow a preconceived course or seek a predetermined end'; and, in his view, it is more reasonable to say that just as we are conscious of power of guidance in ourselves, so guidance and intelligent control may well be an element running through the universe and incorporated even in material things.

At the British Association meeting in 1905 Professor G. H. Darwin chose as the subject of his address that of 'Atomic Evolution.' Professor Darwin is the second son of the late Charles Robert Darwin, author of the 'Origin of Species,' and in dealing with the subject of atomic evolution he approached it from a mathematical standpoint rather than from the naturalist's point of view. Adopting the view that the atom previously supposed to be indivisible really consists of a large number of component parts, he arrives at the conclusion that there is good reason to believe that in radium and in other elements possessing very complex atoms we do actually observe the break-up and spontaneous rearrangement which constitute a transmutation of elements. Professor Darwin alleges that 'by various convergent lines of experiment it has been proved that the simplest of all atoms—namely, that of hydrogen—consists of about 800 separate parts, while the number of parts in the atom of denser metals must be counted by tens of thousands. These separate parts of the atom have been called corpuscles or electrons, and may be described as particles of negative electricity. It is paradoxical, yet true, that the physicist knows more about these ultra-atomic corpuscles, and can more easily count them, than is the case with the atoms of which they form the parts.'

As a chemist, and devoid of the requisite mathematical knowledge, I am unable to follow Professor Darwin in describing these so-called electrons as 'particles of negative electricity.' Whatever they may be, however, it appears to me that they must consist of matter under the influence of force, and to describe them as he has done seems to me to be confusing matter with force. I think this is an error and a conclusion to be avoided, just as the mathematical conception of ether may also be regarded as having proved to be a falsity. Writing as a chemist, I find it impossible to conceive, alike, the existence of matter as identical with that of energy and the existence of an absolute vacuum. The so-called ether of mathematicians—if it exists at all—can only consist of highly attenuated matter, such as is realized in the more or less exhausted vessels used by Professor Crookes in his investigations on the subject of radiometry.

Taking the definition as given in Webster's Dictionary, the so-called ether of Nature is 'an hypothetical medium of great elasticity and extreme tenuity, supposed to pervade all space, the interior of solid bodies not excepted, and to be the medium of transmission of light and heat.'

I see no grounds whatever for the assumption of the existence of any such substance, and think, indeed, it is contrary to all scientific understanding and conception.

If there were such a thing, it would have to be regarded as a universally distributed elemental form of matter, but there is no evidence of its existence.

Take, for instance, a glass vessel and exhaust it of air as far as is practicable by means of a Sprengel pump or otherwise, and what remains but a highly attenuated atmosphere of the same air? An absolute vacuum is unattainable and inconceivable. Enormous attenuation can be obtained, but that is all; and, for all we know to the contrary, directly the state of greatest attenuation is obtained, particles of air from without may gradually find their way through the walls of the glass vessel itself, for no substance is absolutely impervious; or, for that matter, particles of matter may fly off from the substance of the glass vessel itself, and so help to fill the attenuated atmosphere still forming the contents of the so-called exhausted vessel. It seems to me that the radiometric effects studied by Crookes would not be possible in an absolutely vacuous apparatus; nor could Röntgen rays or the emanations of radium be transferred across an absolute devoid space. The effects we witness are only possible by reason of the attenuated particles of matter that are still left in such tubes and bulbs, and which conduct or carry them, just as a beam of sunlight is carried by the air and becomes visible by reason of the motes that are suspended in it.

In other words, I do not believe that energy or force can be conducted without matter, or transferred through space without the material assistance of particles contained therein.

Returning now to more purely chemical considerations, the elemental state, as hitherto represented by chemists, may be approximately illustrated by figures. Just as numbers are composed of units, so are chemical compounds composed of contributory parts or so-called elements; and in the same sense that a numerical unit cannot be divided, so also the chemical units or elements were supposed to be indivisible. From metallic lead nothing but metallic lead can be extracted; from gold nothing but gold can be obtained, and so on.

There are three well-defined general *states* of matter, not different in essence, but dependent upon pressure and temperature. To illustrate this fact we may refer to the metal called mercury (quicksilver), which at the ordinary temperature of the atmosphere is a fluid. If heated, it assumes the state of vapour, and it may be distilled just in the same way that water is subjected to that process in order to purify it; on the other hand, it can be frozen into a hard solid.

A chemical compound results from the combination of two or more chemical elements or proximate principles, but it must not be supposed to be a mere mechanical mixture of them. A quantity of sulphur may be admixed with lead shots, but the admixture is not a chemical combination; in proof of this, there is the fact that the shots may be mechanically removed one by one from the sulphur, thus dividing the lead wholly from the sulphur. Again, a separation of the latter sort is in no sense related to the process which is known in chemistry as decomposition. If, on the other hand, the mixed lead and sulphur be placed in a crucible and strongly heated by fire, real chemical combination occurs; the lead and the sulphur individually disappear as such, and the product is a substance which is called sulphide of lead, the properties of which are not those of a mere mixture of the lead with the sulphur, but are peculiar to the combination. The formation of rust on articles made of iron, which takes place on their exposure to the air, affords a more familiar example of chemical combination.

Again, if metallic mercury be gently heated in a suitable vessel while exposed to the air, it absorbs oxygen therefrom and becomes coated with a yellow substance, which we know to be an oxide of mercury; but by no mere mechanical admixture can oxygen and mercury be made to assume this form. The use of heat, light, electricity, or some other agency, is generally requisite to bring about chemical change.

If the yellow oxide of mercury, produced as above described, be exposed to a greater heat than that employed in its production, it is then decomposed, yielding once more oxygen gas and metallic mercury as its products.

The number of well-known so-called elements at present known to chemists is about seventy, exclusive of certain new ones said to have been discovered a few years since in rare Scandinavian minerals by Krüss and Nilson, and the following is a list of the more important elements, together with their chemical symbols (that is, representative letters) and atomic weights, so far as recognized by the International Committee in their Report of 1907:

International Atomic Weights.

Name.	Symbol.	Combining Weight.	Name.	Symbol.	Combining Weight.
Aluminium	Al	27·1	Calcium	Ca	40·1
Antimony	Sb	120·2	Carbon	C	12·0
Argon	A	39·9	Cerium	Ce	140·25
Arsenic	As	75·0	Chlorine	Cl	35·45
Barium	Ba	137·4	Chromium	Cr	52·1
Bismuth	Bi	208·0	Cobalt	Co	59·0
Boron	B	11·0	Columbium	Cb	94·0
Bromine	Br	79·96	Copper	Cu	63·6
Cadmium	Cd	112·4	Erbium	Er	166·0
Cæsium	Cs	132·9	Europium	Eu	152·0

International Atomic Weights (continued).

Name.	Symbol.	Combining Weight.
Fluorine	F	19·0
Gadolinium	Gd	156·0
Gallium	Ga	70·0
Germanium	Ge	72·5
Glucinum	Gl	9·1
Gold	Au	197·2
Helium	He	4·0
Hydrogen	H	1·008
Indium	In	115·0
Iodine	I	126·97
Iridium	Ir	193·0
Iron	Fe	55·9
Krypton	Kr	81·8
Lanthanum	La	138·9
Lead	Pb	206·9
Lithium	Li	7·03
Magnesium	Mg	24·36
Manganese	Mn	55·0
Mercury	Hg	200·0
Molybdenum	Mo	96·0
Neodymium	Nd	143·6
Neon	Ne	20·0
Nickel	Ni	58·7
Nitrogen	N	14·01
Osmium	Os	191·0
Oxygen	O	16·0
Palladium	Pd	106·5
Phosphorus	P	31·0
Platinum	Pt	194·8
Potassium	K	39·15
Praseodymium	Pr	140·5
Radium	Ra	225·0
Rhodium	Rh	103·0
Rubidium	Rb	85·5
Ruthenium	Ru	101·7
Samarium	Sm	150·3
Scandium	Sc	44·1
Selenium	Se	79·2
Silicon	Si	28·4
Silver	Ag	107·93
Sodium	Na	23·05
Strontium	Sr	87·6
Sulphur	S	32·06
Tantalum	Ta	181·0
Tellurium	Te	127·6
Terbium	Tb	159·2
Thallium	Tl	204·1
Thorium	Th	232·5
Thulium	Tm	171·0
Tin	Sn	119·0
Titanium	Ti	48·1
Tungsten	W	184·0
Uranium	U	238·5
Vanadium	V	51·2
Xenon	Xe	128·0
Ytterbium	Yb	173·0
Yttrium	Yt	89·0
Zinc	Zn	65·4
Zirconium	Zr	90·6

The few compounds referred to in the preceding paragraphs are very simple in character. In illustration of a more complex one, limestone may be instanced, which substance is composed of calcium, carbon, and oxygen. When heated, as in a kiln, a gas is given off, which is known as carbonic dioxide, and lime is left behind. Here we have the case of a compound which, by the agency of heat, is resolved into two other compounds; for carbonic dioxide is composed of carbon and oxygen, and lime is composed of calcium and oxygen.

Heat is by no means the only agency which may be employed to effect the decomposition or synthesis of compounds. For instance, an electric current may be employed to decompose water into its constituent elements (oxygen and hydrogen), and an ordinary photograph is but the result of a chemical change effected in a silver compound by the agency of light.

Many of the compounds which are present in the bodies of living beings are of a very complicated nature. For instance, albumin (white of egg) is composed of five elements—carbon, hydrogen, nitrogen, oxygen, and sulphur; and by its gradual disintegration, or degradation, a great number of intermediate and less complex substances may be obtained before arriving at the most simple products. Nor is albumin the most highly complex substance, for there are several substances present in brain matter, for example, which have even larger molecular proportions.

The synthesis and decomposition of substances may also be effected by other than simple physical causes; they are often brought about from so-called acts of vitality. Complex substances present in the body of man are thus resolved into simple substances, while comparatively simple substances taken as food are also elaborated in the animal body into highly complex compounds. What is true of man is true also, in degree, of other living organisms, even to the simple forms of cell-life known as microbes, and man may (and does often) become the prey of minute organisms effecting decomposition in his living body.

The well-known process of putrefaction is one of decomposition effected by micro-organisms; and fermentation is another instance of chemical change brought about by microbic life.

Then, again, it is not always necessary to make use of outside agencies to effect chemical change. Chemical affinity, as it is termed, is often sufficient of itself to effect combination or decomposition. The chemical affinity of phosphorus for oxygen is so strong that, ordinarily, it is requisite to preserve phosphorus under water. When exposed to the air or oxygen it greedily combines with the oxygen, and heat is generated so rapidly in consequence that the phosphorus bursts into flame. The remark may here be interposed that flame is commonly defined as gas raised to such a temperature that under certain other conditions it emits light as well as heat. Oxides of phosphorus result from the combination of phosphorus with oxygen. The process itself is known as one of oxidation, but there are degrees of oxidation. For instance, if the phosphorus be partially submerged in water when exposed to the air, the temperature is thus kept down, and the oxidation proceeds much more slowly; and, what is more important to note, the products of the chemical changes that take place are more numerous, and are not identical with those obtained in the dry process of oxidation;

for, in addition to an oxide of phosphorus, there are produced ozone and peroxide of hydrogen, two very interesting substances, about which we shall have more to say later on.

Another example of chemical affinity is shown in the direct decomposition of water as effected by metallic sodium, which enters into combination with the oxygen of the water, hydrogen being, at the same time, liberated in the gaseous state.

The groupings known as chemical elements differ in relative weight or specific gravity. Hydrogen is the lightest known substance (air being 14·43 times as heavy), and platinum is the heaviest known substance.

The so-called density of a chemical element in the state of gas represents the relative weight of a given volume thereof at a standard pressure and temperature, the same volume of hydrogen being taken as unity ; and the densities of all the chemical elements which assume, or may be made to assume, the gaseous state, are identical with their combining weights or multiples thereof.

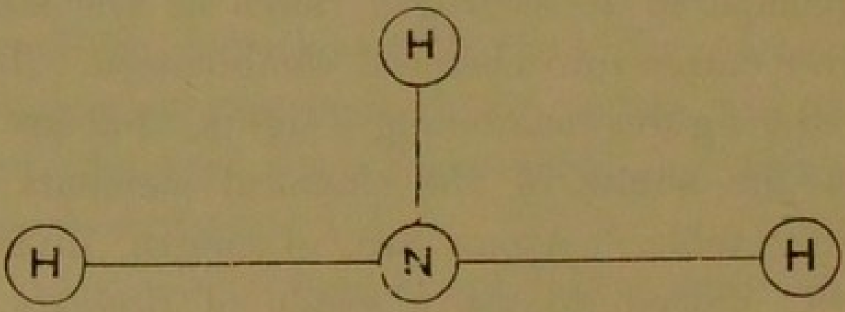
Chemical combination always takes place between definite proportions of the different substances. For instance, when sulphur is burnt in the open air (as in fumigating a room), about every 32 parts of sulphur always combine with about twice 16 parts of oxygen. We say twice 16 parts of oxygen rather than 32, because it is possible for 16 parts of oxygen to enter into other combinations, but less than 16 parts are never involved, so far as is known, in any chemical change.

With respect to the combining proportions of the elements, hydrogen is taken as the unit, since it enters into combination with the lowest equivalent weight, and the combining proportions of the elements represent, generally speaking, their atomic weights. At least, it is found, practically, that they combine in these constant proportions, or in multiples of them. It is in this precise quantitative way that chemical combination occurs. Common salt, for example, contains in every 58·50 parts 23·05 parts by weight of the metal sodium, and 35·45 parts of the gas chlorine. The molecular weight of common salt (chloride of sodium) is therefore 58·50, and it means that in order to produce a molecule of the compound, one atom of each of its two constituent elements must be combined; the atom of each being the smallest relative weight of each (compared to hydrogen taken as the standard) that ever enters into chemical combination. This explains the figures (combining weights) that are placed against the names of the chemical elements in the preceding table. Atoms are, of course, invisible to the eye; indeed, to use a simile of Roscoe's, if the minutest organisms which we can see with the aid of microscopes which magnify from 6,000 to 8,000 times were provided with equally powerful microscopes, these beings would perhaps be able to see atoms.

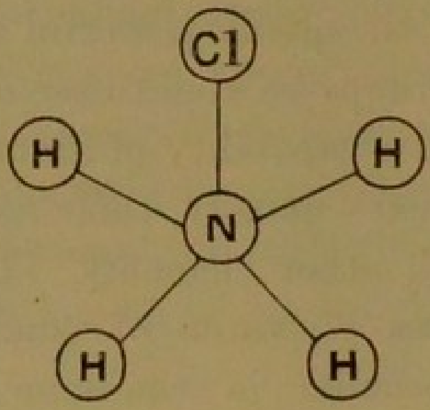
There is another capability of atoms to which attention must be called—namely, their *valency* or power of combination with other elements. The atom of each element possesses a power of combination (*adicity*) more or less peculiar in character. For instance, *hydrogen* is a so-called monatomic or *univalent* element; that is to say, it has only *one* capability of attachment to another element; thus, hydrochloric acid is composed of one atom of hydrogen and chlorine, as is here represented:

On the other hand, *oxygen* behaves generally as a diatomic or *divalent* element, and combines, that is to say, with either two atoms of hydrogen or other univalent element, as here shown:

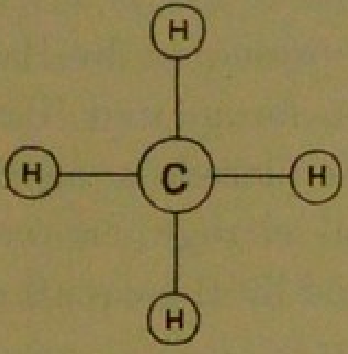
Nitrogen is generally regarded a triatomic or *trivalent* element, the formula for ammonia, one of its combinations with hydrogen, being as follows:



In some of its combinations, however, as in chloride of ammonium, it is to be regarded as *pentavalent*, thus:



Carbon is a so-called *tetrad;* that is to say, it has the power of combining with four atoms of hydrogen, or with two atoms of oxygen, as in the following examples, and so on :



MARSH GAS.

CARBON DIOXIDE.

We are now in a position to understand the use which is made of symbols and formulæ in chemistry. For the sake of brevity, chemists indicate the metal aluminium by the symbol Al ; bromine by Br ; sodium by Na (derived from the word *natrium*) ; potassium by K (derived from *kalium*), and so forth. But Na does not merely indicate sodium, but it stands for what is called the relative weight of the element ; that is, 23·05 parts by weight, that being its combining proportion. Similarly, chlorine is represented by the symbol Cl, which means 35·45 parts by weight, or its combining proportion, that being the quantity which invariably combines with 1 part of hydrogen, represented by the symbol H, and taken as unity. Thus, HCl stands for hydrochloric acid ; its molecular weight is 36·45, and every 36·45 parts by weight are found upon analysis to yield 35·45 parts by weight of chlorine, and 1 part by weight of hydrogen. From such analytical facts, the percentic composition of any substance may, of course, be readily calculated.

The formula, then, for hydrochloric acid is HCl; that for sulphuric acid is H_2SO_4; that for nitric acid HNO_3.

Baryta, or oxide of barium, is represented by BaO; peroxide (di-oxide) of barium is formulated BaO_2. Now, when peroxide of barium is placed in contact with hydrochloric acid, a chemical change or *interaction* takes place, and it is indicated by the equation :

$$BaO_2 + 2HCl = BaCl_2 + H_2O_2.$$

This chemical equation is intended to represent the fact that 1 molecule of peroxide of barium, when placed in contact with 2 molecules of hydrochloric acid, results in the production of 1 molecule of chloride of barium, and 1 molecule of peroxide of hydrogen. It is evident that the sum of the products is equal to the sum of the substances originally employed. Thus we have employed :

1 atom or 137·4 parts of barium	Present in 1 molecule of peroxide of barium.
2 atoms or 32 parts of oxygen	
2 atoms or 2 parts of hydrogen	Present in 2 molecules of hydrochloric acid.
2 atoms or 70·90 parts of chlorine	

And we obtain as the result of the chemical action :

1 atom or 137·4 parts of barium	Present in 1 molecule of chloride of barium.
2 atoms or 70·90 parts of chlorine	
2 atoms or 2 parts of hydrogen	Present in 1 molecule of peroxide of hydrogen.
2 atoms or 32 parts of oxygen	

It will be seen that altogether there are employed 242·3 parts by weight, and that there are obtained 242·3 parts by weight.

This equation affords an incidental proof that matter is indestructible; its form and combinations may be changed, but the substance cannot disappear or be destroyed. If, therefore, in the study of any chemical change the sum of the products found upon analysis is not equal to the parts by weight of the substances originally used, it is known to the operator that the analysis is imperfect, or that some product has been missed.

There is one further consideration worth mentioning in connection with this subject of chemical combination. The formula H_2O not merely implies that 2 parts by weight of hydrogen are combined with 16 parts by weight of oxygen in each molecule of water: it also expresses a relation by volumes of the chemical elements in combination. If a molecule of water be subjected to analysis, it yields 2 volumes of hydrogen and 1 volume of oxygen.

Again, the formula HCl (hydrochloric acid) implies a combination of equal volumes of hydrogen and chlorine; and the formula NH_3 (ammonia) implies a combination of 3 volumes of hydrogen with 1 of nitrogen.

From this it will be seen that equal volumes of different elementary gases have the relative weights represented by their chemical combining proportions, taking hydrogen as unity; or, to put the matter in another way, 1 gramme of hydrogen, 16 grammes of oxygen, 35·45 grammes of chlorine, and 14·01 grammes of nitrogen, all occupy the same volume when examined in the gaseous condition at the same temperature and pressure. In other words, equal volumes of gases, when so compared, contain the same number of molecules.

Chemistry has been well defined as 'the study of the laws of changes of matter'—that is to say, of the interactions which take place between substances under all sorts of conditions. This study concerns living matter and vital processes, just as much as lifeless materials and the chemical changes to which they are subject.

Hygiene is so largely concerned with the chemical composition and properties of air, water, and animal and vegetable substances, that what has gone before must be known and understood if the reader is to duly understand what has to be said in relation to these subjects in later portions of this treatise.

Temperatures are usually determined according to two scales: Centigrade and Fahrenheit. On the Centigrade scale the freezing-point of water is regarded as 0°, and the boiling-point of water is 100°; whereas on the Fahrenheit scale the freezing-point of water is 32°, and the boiling-point is 212°. Temperatures determined by these scales are usually indicated by the letter C. or F., as the case may be.

To convert a Centigrade reading into a Fahrenheit reading, multiply by 9 and divide by 5, and then add 32. To convert a Fahrenheit reading into a Centigrade reading, subtract 32, multiply by 5, and divide by 9.

Comparison between Centigrade and Fahrenheit Scales.

Centigrade.		Fahrenheit.
– 273·0°	(Theoretical zero)	– 459·4°
0·0°	(Freezing-point of water)	32·0°
15·5°	(Mean atmospheric temperature)	60·0°
36·6°	(Blood heat)	98·0°
100·0°	(Boiling-point of water)	212·0°
1530·0°	(Cast-iron melting-point)	3280·0°

CHAPTER II.

THE CONSTITUENTS OF THE ATMOSPHERE—OXYGEN AND OXIDATION—OZONE—NITROGEN AND NITRIFICATION—CARBON DI-OXIDE—HYDROGEN—WATER—PEROXIDE OF HYDROGEN; THE OCCURRENCE OF THESE SUBSTANCES IN NATURE, AND THEIR GENERAL CHARACTERS—CONTACT ACTIONS.

Oxygen.

Symbol O. Combining Weight 16.

IN the early days of the Royal Society, when its meetings were held at Oxford, the Hon. Robert Boyle directed the attention of its members to a number of interesting experiments which he, together with his assistant, Dr. Hooke, had made with ordinary air. He showed, for example, that animals which were confined in a limited volume of air died after a short time. John Mayow, who attended these meetings, became greatly interested, and continued the research thus originated. He ascertained (1674) that in breathing, animals do not consume the whole of the air which is inspired, but only its oxygen, and that, indeed, the air consists of two gases, one of which, viz., nitrogen, is of no direct use in sustaining life, and is expired.

of combustion. In other words, Lavoisier was the first to give the true explanation of the phenomenon of combustion, by showing that it is simply a process of combination with oxygen, or, as we now call it, a process of oxidation.

Oxygen may be prepared in the laboratory by a number of methods, the simplest of which consists in exposing certain metallic oxides* to high temperatures, when decomposition occurs; oxygen is thus liberated in the gaseous state, while the metals or their lower oxides are left behind.

Oxygen is best known, however, as a constituent of the air we breathe, serving in the process of respiration to oxidize or burn up the carbonaceous and other matters present in the blood and tissues of animals, with which it comes into contact through the medium of the lungs. The details of this process and its results will be studied in another chapter.

At the ordinary atmospheric temperature and pressure, oxygen is a colourless, tasteless gas; but it has been demonstrated in recent years by M. Raoul Pictet and M. Cailletet severally that when reduced to a temperature of −140° C. under a pressure of 320 atmospheres, oxygen assumes the liquid form. More recently Dewar has succeeded in obtaining it in the solid form.

As Liebig is reported to have said that the best test for ammonia is the nose, so it may be said oxygen is characterized by its power of oxidation. In cases where this process is carried on rapidly, so that it is

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* Combinations of metals with oxygen.

attended with the evolution of light and heat, combustion is said to occur. For instance, if a piece of charcoal be heated to redness and then placed in a globe filled with oxygen, the oxidation, which in the atmosphere merely kept the charcoal at a dull red heat, is now so intensified that the combustion is continued with much greater avidity.

In an ordinary grate fire we have the best illustration of the process of oxidation: coal and wood, being of a carbonaceous nature, only require the application of heat to enable the oxygen in the atmosphere to enter into chemical combination with the constituent particles of the burning mass, and when once this process of combination has commenced, the heat with which it is attended is sufficient to keep the combustion (oxidation) going. In this way the carbon of the fuel combines with the atmospheric oxygen to form carbon dioxide, thus:

$$C + O_2 = CO_2.$$

Much the same process goes on when ordinary illuminating coal-gas or candles are burned.

All acts of purification throughout Nature are acts of oxidation. The refuse that is carried to the domestic hearth or garden fire is destroyed by oxidation; the garbage and refuse collected by our public health authorities for consumption in the destructors which are now so commonly used in this country are also destroyed by oxidation, for combustion is nothing but oxidation at a high temperature. The sewage that is conveyed at much expense in many places for

It will be seen that Mayow had discovered oxygen gas, in a negative sort of way; but, owing to the erroneous views then prevalent, his discovery was allowed to be forgotten, or nearly so, for a hundred years. Then Priestley, who occupied himself with continued observations upon gases, succeeded—it may almost be said accidentally—not only in rediscovering oxygen, but also at the same time in making it from a solid substance. It will be remembered by all students of chemical history that, in 1774, Priestley obtained this gas by exposing the red oxide of mercury to a high temperature; and it further appears that Scheele (a famous Swedish apothecary) made the same discovery both simultaneously and independently. Priestley not merely collected oxygen gas; he also ascertained its powers of supporting combustion and maintaining life. At that time he wrote: 'Who can tell whether this pure air may not at last become a fashionable luxury? As yet, only two mice and myself have had the privilege of breathing it.'* In spite of all this, it is now obvious that he very imperfectly understood his own results.

Lavoisier (a Parisian, born in 1743) was a man of the time. After revolutionizing chemical science, he himself was sacrificed to a political revolution. He introduced the balance into chemistry, and whereas Priestley had obtained oxygen and mercury from the red oxide, Lavoisier reconstructed that compound from its elements, and showed that upon heating a given quantity of the oxide, it evolves just

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* See 'Short History of Natural Science,' Buckley, p. 234.

the same amount of oxygen gas as is consumed in its preparation. In short, he thus demonstrated the fact that mercury and oxygen combine in definite proportions. The masterpiece of Lavoisier's work, however, was his explanation of the phenomenon of combustion. The most generally accepted theory on this subject at that time was what is known as the 'phlogiston' theory, the chief exponent of which was the great German chemist Stahl.

According to this theory, all metals and combustible bodies generally contained a subtle principle called 'phlogiston,' which they gave up when heated or calcined; thus, when lead was heated in the air it gave up its 'phlogiston' and was converted into a yellow-looking powder, litharge, which was called dephlogisticated lead.

Lavoisier, with the aid of his chemical balance, struck a fatal blow at this theory. He showed that when a metal is heated in the air, instead of diminishing in weight owing to the loss of 'phlogiston,' it actually increases in weight; thus the litharge that is formed on heating lead is found to weigh more than the original lead; in other words, this calcination is a process of combination, and not of decomposition, as was previously supposed.

The discovery by Priestley, in 1774, of oxygen—a gas eminently adapted for supporting combustion—enabled Lavoisier very soon afterwards to complete this theory by first proving that this gas is a constituent of the air, and then by showing that it is this constituent with which bodies combine in the process irrigating land is likewise ultimately destroyed by the process of oxidation (intermediately through the agency of bacterial life); and, similarly, the more modern system of sewage disposal, consisting of exposure to the action of filter-beds in which have been assiduously cultured myriads of bacteria, depends for its success upon their very agency, in association with the same process of oxidation. Oxygen is the great purifying agent and most important element in Nature, because all life depends upon it. In fact, as was pointed out by Professor William Stirling in a recent address at the Royal Institution, air is Nature's most important food, the whole vitality of the human body being sustained and maintained in health by the oxygen which is contained in it, and which is carried by the blood to all the tissues and cells of the human body, burning up and destroying the effete products of life by the act of oxidation.

Oxygen is the chemical element in Nature by which all decayable, putrescent, and dangerous organic matter, no matter how derived, whether from our living human bodies or from the development of bacteria in particular media, is destroyed and converted into harmless ultimate inorganic principles.

Beyond its powers of maintaining life and supporting combustion, oxygen gas furnishes but few direct chemical reactions that are not also exhibited by ozone and peroxide of hydrogen. It differs from these two last-named substances, however, in being less active in its properties. Thus, when brought into contact with a solution of iodide of potassium, it exercises no influence upon it. It has no colour, taste, or smell. It is only slightly soluble in water, 100 volumes of this fluid dissolving 4·11 volumes of the gas at 0° C., and 2·99 volumes at 15° C. (the ordinary temperature of the air).

Oxygen has no action on litmus-paper, and does not oxidize silver, while it is stable at all temperatures. In oxygen, therefore, we have a substance of such marked general negative characters that we can readily and unmistakably discriminate between it on the one hand and ozone and peroxide of hydrogen on the other hand.

Ozone.

Molecular Symbol O_3. *Molecular Weight* 48.

About ten years after the discovery of oxygen Van Marum, of Holland, observed that when that gas was subjected to the passage of electric sparks it acquired a peculiar fishy odour; and it is said that Cavallo shortly afterwards discovered the disinfecting value of the product, and applied it as a remedy to fœtid ulcers.*

In 1826 Dr. John Davy recognized the presence of a similar principle in the atmosphere, thus explaining the odour often referred to in history as having been observed during storms and periods of electrical disturbance. It was not, however, till 1839 that any precise knowledge was obtained regarding the substance in question. M. Schönbein, of Basle, who

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* See 'Ozone and Antozone,' by Dr. Cornelius B. Fox, p. 4.

was then engaged in an investigation of the electrolytic decomposition of water, noticed the same odour in the apartment in which he conducted his experiments, and this led him to a prolonged research, having for its object the elucidation of the nature and properties of this gaseous principle, which from its odour he named ‘ozone.’

He ascertained that a certain amount of this substance is mixed with the oxygen which is evolved at the positive pole during the voltaic decomposition of water, and further observed a number of its oxidizing effects.

The nature of ozone proved a very difficult problem for chemists to solve, and the task was only accomplished by the several investigations of men, some of whom are yet living.

Schönbein at one time considered ozone to be a compound of oxygen with hydrogen. Peroxide of hydrogen being oxygenated water,* or a substance containing in its molecule more oxygen than water does, and its oxidizing characters being considered as due to the ease with which it parts with the extra oxygen, Schönbein was led to regard ozone as peroxygenated water, or, in other words, a still more highly oxygenated compound than peroxide of hydrogen. Thus, to use the notation now employed by chemists, Schönbein represented ozone as H_2O_3, peroxide of hydrogen being H_2O_2, water being H_2O.

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* This must not be understood as aerated water, or water containing dissolved oxygen, but water chemically combined with more oxygen, and not simply admixed.

Williamson supported Schönbein in this opinion, which was afterwards proved to be erroneous by a long series of investigations conducted by numerous chemists, among whom may be named Becquerel, Frémy, Marignac, De la Rive, Andrews, Soret, and Brodie. It was, first, shown that pure ozone yields no water during combustion, and is therefore free from hydrogen; next, it was demonstrated that the matter of ozone is identical with the matter of oxygen; and finally, by the classical researches of Andrews and Brodie (the latter of whom particularly investigated the volumetric relations of ozone), that ozone is oxygen in a condensed state. Not condensed in the sense that a given volume of gas may be made to occupy a smaller space by the influence of compression, but in the sense that the constituent atoms are so innately arranged that each whole molecule of ozone contains three atoms in the space occupied by a molecule of oxygen consisting of two atoms. While this demonstration was due to Andrews and Brodie, the view which it proved to be correct is to be credited to Odling, who, with a characteristic keenness of intellect, discerned the truth before it was experimentally established.

The superior oxidizing powers of ozone, as compared with those of ordinary oxygen, are supposed to be due to the state of its corpuscular density, to which reference has just been made.

The best proof that can be given of the identity of the matter of oxygen with that of ozone consists in the ease with which it is possible to convert oxygen into ozone, and to effect also the converse change. Suppose that we take 100 volumes of oxygen gas, and subject it to the electric discharge until it measures 92 volumes, we shall by this time have produced a definite amount of ozone. This can be shown by removing some of the gas and submitting it to different tests. But if, instead of taking away any of the condensed gas, we raise it to a temperature of, say, 240° C., we shall find that for the 100 volumes of oxygen originally employed we now once more obtain 100 volumes when measured at the same temperature and pressure. In other words, ozone is resolved at an elevated temperature into ordinary oxygen.

This identity of oxygen and ozone is not the least more remarkable than the identity presented by carbon in its ordinary forms, and is only an example of so-called *allotropy.* As another example of allotropy we have carbon in the forms of the diamond, graphite, and lamp-black ; and the properties of these substances are as diverse as those of ozone and oxygen.

One fact in particular must be stated here, because, when we get further on, we shall find it of considerable importance. It is this : whereas, when ozone is exposed to contact with many chemical substances, it suffers decomposition, yielding up its third part to the oxidizable matter and becoming ordinary oxygen, yet when submitted to contact with ordinary turpentine the whole molecule of the ozone is absorbed ; no oxygen remains behind. For a knowledge of this fact we are indebted to Soret.

The presence of ozone in the atmosphere was first assumed when Dr. John Davy obtained certain reactions with ordinary air, which were then considered to be characteristic of ozone; and as Cavallo and others had found ozone to possess marked disinfecting powers, more importance was attached to atmospheric ozone than the subject, perhaps, deserved.

The observations of Dr. Davy were repeated and extended by others, and as the oxidizing powers of ozone became better known, there arose in the minds of men the idea that this substance constitutes Nature's great purifier. This idea received the more credence since Schönbein had taught that every process of slow oxidation occurring in Nature is accompanied by the formation of ozone, and because Kossman and Daubeny had stated that, under certain conditions, the same substance was produced by the green parts of plants.

The amount of work which has been devoted to the study of ozone as occurring in the atmosphere, and in relation to storms and winds, is almost beyond belief, and the task of collecting or summarizing such investigations would be, perhaps, one of supererogation. It will certainly not be attempted here, and more particularly since Dr. Fox has very carefully performed the task already. To his work* we refer the reader who may feel disposed to proceed further with this study, while for the present purposes it will suffice to bring some few facts prominently to the reader's attention. In the first place, then, in the past

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* 'Ozone,' etc., by Dr. Cornelius Fox. Churchill.

the majority of persons have undoubtedly attached great importance to atmospheric ozone, regarding it as the greatest purifying influence in nature; many going so far as to assert that zymotic disease exhibits a definite relation to ozone in the sense that when ozone is absent from the atmosphere, disease occurs and spreads, and that where present, zymotic disease is almost unknown. It seems a vast pity to upset notions which have taken so deep a root in men's minds, but the truth must be told by scientific men, and the truth is that nearly all the observations which have been made on the subject are inconclusive.

It was pleasant enough to resort annually to the seaside in the firm belief that there ozone was to be met with in plenty, and miasmatic poisons could not endure; but, as a matter of fact, there is little evidence to show that, so far at least as ozone is concerned, the seaside is any healthier than the flats and marshes of Lincolnshire or the hills of Devonshire.

And now one word in explanation. The chemical reagents and tests which were applied by different observers in determining the presence and amount of ozone in the atmosphere under various circumstances are not alone affected by ozone; they are also indicative of peroxide of hydrogen, and there is at present no reliable and practicable method for testing and estimating the one substance without including the other.

There is, however, generally some germ of truth in any doctrine or belief which may be held by a large number of persons. and as readers of the foregoing sentences may have suffered some discomfort in feeling that their pet theory is thereby demolished, it is pleasant to restore their comfort, and place it upon a more enduring basis. My readers, then, may rest content with the assurance that even if ozone does not occur in the air so freely as previously believed, yet another substance does, and one, too, of greater sanitary value, viz., peroxide of hydrogen.

Although it cannot be said with absolute certainty that ozone ever occurs in the atmosphere at all, its presence in minute amount is extremely probable, and more particularly because there are times and conditions when ozone must, presumably, be produced in the atmosphere. It should, however, be distinctly understood that there is no applicable test for ozone as a constituent of the atmosphere which is not also affected by peroxide of hydrogen, although in the laboratory these substances may be readily distinguished.

When Dr. Daubeny in 1866* stated that his researches tended to show that atmospheric ozone is generated almost exclusively by the green parts of plants, he was guided by the fact that the oxygen which is emitted by plants in the daytime, when brought into contact with iodide of potassium, liberated iodine therefrom ; this result, however, is producible by peroxide of hydrogen, and also by ordinary oxygen in the presence of sunlight.

Dr. Daubeny was supported in his views by M.

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* See *British Association Report*, also *Journ. Chem. Soc.*, 1867, 19.

Kossman and others; but M. Cloez, from some carefully conducted experiments, arrived at the conclusion that the liberation of iodine and consequent coloration of the ozone test-papers in Daubeny's experiments was due to the combined action of humid oxygen and solar light upon the iodide of potassium, and this conclusion was confirmed by the more recent observations of the late Dr. Angus Smith.

Bellucci* passed currents of air (free from ozone) through bell-jars containing living plants or recently cut branches and leaves, and he also found that if the tubes containing the air were protected from daylight, when it came in contact with the potassium iodide test and after contact with the plants, then no ozone reaction was obtained, thus supporting the statement of Cloez.

In experiments of the kind just described care must be taken not to employ plants of an aromatic nature, since, as will be afterwards explained, peroxide of hydrogen is certainly produced by them. As plant life, therefore, does not seem to generate atmospheric ozone, its source must be looked for elsewhere.

Now, as in the laboratory ozone is most easily prepared by the action of electrical discharges upon oxygen or air, and as electrical discharges are constantly occurring in the atmosphere, it is most probable that we shall find in this fact the explanation we are looking for. Moreover, there are

* *Compt. Rend.*, lxxviii. 362.

numerous sources of atmospheric electricity. Of course, in storms attended with lightning there is the strongest reason for believing that ozone must necessarily be produced, together with peroxide of hydrogen.

A. Houzeau calculated* that country air contained a maximum of $\frac{1}{450000}$ of its weight, or $\frac{1}{700000}$ of its bulk of ozone, and considered it to be produced by atmospheric electricity constantly acting in the manner of a huge-sized condenser between the soil and the clouds.

It is very probable that the friction of waterdrops as they fall in the form of rain against the air produces negative electricity, as it is also certain that the spray of a fountain, waterfall, or cascade, likewise gives the surrounding air a negatively electrical character, which may so influence the oxygen of the air as to give rise to the formation of ozone. That this is so, is supported by various experiences which have been summarized by Bellucci in a most interesting paper.† In this communication he calls attention to the following circumstances :

1. Lender noticed an ozone reaction in the air near the columns where the concentration of brine is carried on at Kissingen, at which place the air is filled with the spray of the salt water.

2. Gorup-Besanez found that a similar reaction could be observed with a spray of water (not containing salt), and that the ozone formed by a spray of

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* *Compt. Rend.*, March 11, 1872.

† *Gaz. Chimica Italiana*, vi. 88-97.

water issuing under pressure was greater in proportion as the evaporation was more rapid.

3. Morin and Monte also found that ozone is produced during the pulverization of water.

4. He (Bellucci) observed at Terni, near the falls, a similar ozone reaction, and concluded that it is traceable to the electrical state induced by friction of the minute waterdrops.

Now, if it be true that the friction of waterdrops against the air is sufficient to give rise to the production of ozone, then how great must be the quantity produced over the surface of the oceans! Thus, after all, it may be that sea air contains ozone. At the same time, it must be remembered that the fact has not been demonstrated by unequivocal tests.

In concluding this part of the subject, it may, then, be safely assumed that ozone is a tolerably constant ingredient of pure air, although never present except in traces. The amount of it present in different places is extremely variable, as its production is dependent upon conditions not always in operation, and because it is readily destroyed by oxidizable matters generally, and particularly by organic matter in a state of change or decomposition.

In the laboratory, ozone is prepared by the action of electricity upon air or oxygen. Andrews and Tait found that, to produce the maximum amount of ozone, it is best to transmit the electrical discharge silently, as the passage of the spark itself destroys a quantity of the ozone previously formed. Or, as Siemens first showed, ozone may be obtained by submitting a current of oxygen to the action of induced electricity. It forms no part of the present work to describe the different arrangements of apparatus for preparing ozone. Many of these have been described by Dr. Fox in his work on ozone (to which reference has already been made), while all of them are constructed upon the principles stated above. We pass on, therefore, to consider the properties of ozone.

It its natural state ozone is a gas of greater density than oxygen, so that a given amount of it occupies a less volume than that of the oxygen from which it is made. Indeed, the preparation of ozone from oxygen may for purpose of illustration be thus written: $3O_2 = 2O_3$. That is to say, 3 volumes of ordinary oxygen become, under the influence of electrical action, transformed into 2 volumes of ozone. At temperatures a little above the boiling-point of water, ozone is slowly retransformed into oxygen, and this change is instantaneous at 300° C. With the change back into oxygen there is an increase of volume exactly corresponding to the diminution observed when oxygen is converted into ozone; and, of course, all the ozonic properties are simultaneously lost, being substituted by those of ordinary oxygen.

There still seems to be some doubt as to the solubility of ozone in water. Most writers state that ozone is quite insoluble in water, while Soret asserted that water absorbs a certain amount of ozone. This statement of Soret was confirmed by L. Carius,*

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* *Phil. Mag.* (4), xliv. 544.

who passed ozone (obtained from the electrolysis of a large surface of dilute sulphuric acid at 0° C.) through water maintained at from 2° to 4° C., and found that in this way the water absorbed about 4 or 5 c.c. of ozone per litre. He also found an 'ozonized water,' sold as such in Germany, contained a similar quantity of ozone per litre, and was quite free from peroxide of hydrogen. On the other hand, C. Rammelsberg[*] found that it contained 0·16 per cent. active chlorine (which would give the same reaction with potassic iodide as that by which Carius estimated his ozone), and that such a product could be obtained by passing air first through a solution of bleaching-powder (chloride of lime), and then into water. In all his experiments made with a view of obtaining true ozonized water he failed.

Em. Schöne,[†] however, experimenting with ozone got by the silent discharge method, found that ozone is soluble in water to the extent of about 8·81 c.c. per litre, and that no peroxide of hydrogen is formed by action of the ozone upon the water.

Air highly charged with ozone exerts an irritating effect upon the respiratory organs; and when an excess of ozone is breathed, certain symptoms reminding of catarrhal and bronchial affections are induced. This is not surprising, for even pure oxygen cannot be breathed with impunity, and, naturally, ozone must exercise in the system a much more powerful action than ordinary oxygen. Of course, it will be readily understood that these facts express the patho-

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[*] *Deut. Chem. Ges. Ber.*, vi. 603-605.

[†] *Ibid.*, vi. 1208, 1224-1230.

logical rather than the physiological influences of ozone, and that, as a matter of fact, they are only exhibited by such an excess of ozone as can never occur in nature.

An old prevalent idea that ozone is naturally generated in the blood through an action exerted by the red corpuscles upon oxygen, is one which does not rest upon a satisfactory basis.

Ozone exhibits powerful bleaching powers, and converts blue indigo into colourless isatin : curiously enough, however, it seems to have little action upon the colour of flowers, a fact pointed out by A. R. Leeds,* and noted by him as an economical feature in 'Nature's purifier and disinfectant.'

The oxidizing effects of ozone are very powerful, and are exhibited even towards such metals as silver and mercury ; silver becoming peroxidized under its influence, whereas that metal is not at all affected by oxygen. Ozone also oxidizes iodide of potassium, setting free the iodine from its solution ; and it is by this reaction that the estimation of ozone is most readily effected. There are easy chemical methods by which free iodine can be estimated ; hence, when ozone is present in sufficient amount, nothing is easier than its determination by estimating the quantity of iodine set free by it. If it be very small, it can be judged of by the depth of colour it imparts to a paper previously steeped in a mixture of iodide of potassium and starch. Unfortunately, however, other chemical principles act upon potassium iodide in the same way, and thus

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* *Chem. News*, vol. xxxviii., pp. 224, 235, 249, 257.

experiments of this kind, except under special circumstances—as, for instance, when the substance is known to be pure ozone—are of little conclusive value.

The oxidizing effects of ozone are very readily demonstrated by the ease with which it deodorizes putrid meat and effusions. Thus, in 1854 Drs. Wood and Richardson* exposed a pint of coagulated ox blood to the air for a whole twelvemonth, by which time the mass had become a most offensive fluid. In 1862, and when it was still most horribly offensive, it was subjected to a current of ozonized air, as generated by Siemen's apparatus. By this means the evil odour was gradually and entirely removed, and the resulting product was perfectly sweet to smell.

Schönbein observed† that air containing only $\frac{1}{3240000}$ of ozone has the power of deodorizing its own volume of air loaded with the effluvium emitted in one minute from 4 ounces of flesh in a highly putrid state.

A. Boillot‡ also noticed that fresh beef could be preserved in ozonized air for more than ten days, while in ordinary air a part of the same beef went bad in five days.

The experiments described by Schönbein, and the views that he expressed, led chemists generally to believe that nearly all slow processes of oxidation are attended with the production of ozone. By the expression 'slow processes' it is intended to indicate

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* See Fox's work on Ozone, p. 30.

† *Ibid.*, p. 94.

‡ *Compt. Rend.*, lxxxi. 1258.

the chemical changes that result when such substances as turpentine, eucalyptus oil, ether, and phosphorus are exposed to the air, or to air and water.

I have made some of these processes the subject of careful investigation for many years, but the matter is one which, from its nature and extent, demands and receives exhaustive treatment in special chapters.

As regards the slow oxidation of the ethers, I studied this process to a limited extent some years ago, on which occasion I satisfied myself that ozone never results from such interactions. On the other hand, the process was found to yield peroxide of hydrogen, exhibiting all its well-known reactions and qualities.* More recently, M. Berthelot has stated that when ether is exposed to the action of ozone there is obtained a peculiar compound, which he styles 'ozonized ether' and this, when shaken with water, produces peroxide of hydrogen.†

Some further information concerning the production of peroxide of hydrogen from ether has since been afforded by Dunstan and Dymond,‡ and A. Richardson.§

In the first edition of this work I had to give expression to the doubts that then existed concerning the supposed production of ozone by the aerial oxidation of phosphorus, and reasons were stated why

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* *Chem. News*, vol. xxxiv., p. 135.

† *Compt. Rend.*, lxxxvi. 71-76.

‡ *Journ. Chem. Soc.*, 1890, pp. 574, 988.

§ *Ibid.*, 1891, pp. 51-58.

peroxide of hydrogen might be expected to result from the process. Since then the whole subject has been very carefully studied, and in a report* which I presented to the Chemical Society in 1880 an account is given of my own researches and those of others, including the investigation conducted simultaneously by Dr. A. R. Leeds. It is now quite certain that when phosphorus is partially submerged in water and exposed to a current of air, both ozone and peroxide of hydrogen are produced in considerable amount. The ozone is carried off in the current of air, and the peroxide of hydrogen dissolves mainly in the water in which the phosphorus is placed.

The manner in which these facts were ascertained may be briefly described in this place.

The apparatus used in my experiments was specially constructed for the purpose, and consisted of a number of wide-mouthed bottles, each of 300 c.c.† capacity, and provided with well-fitting solid glass stoppers having two apertures. Through these apertures with ground surfaces passed tubes which were enlarged and ground at the requisite positions, so that when they were properly inserted, the joints were perfectly tight, and could be easily disconnected or renewed. This special form of apparatus was adopted in order to avoid the use of oxidizable materials in the construction of the joints, and it is apparent that a perfect battery of such oxidizers could be used, the tubes of the various

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* *Journ. Chem. Soc. Trans.*, 1880, p. 792.

† 300 cubic centimetres.
1,000 c.c. = 1 litre, and 4·54 litres = 1 gallon.

members being connected in the manner described by the late Sir Benjamin Brodie—viz., by coupling them together with larger glass tubes coated internally with melted paraffin wax.

In each of five such oxidizers there was placed a stick of phosphorus, scraped clean just before use, and then sufficient water to half submerge the phosphorus, leaving the other half exposed to the air in the bottles. The sixth vessel was charged with 200 c.c. of water, to serve as a wash-bottle, and then the series was connected together, and a current of air, previously filtered through cotton-wool and washed in water, was in each experiment blown through by means of a rotating fan.

Operating thus, it was found that the air which had passed over the phosphorus contained ozone, which substance was identified in a thoroughly satisfactory manner. It possessed the characteristic odour of that principle; it was entirely absorbed by oil of turpentine, and was destroyed at a temperature of 240° C. It liberated iodine from an acidified solution of potassic iodide, and by determining the iodine thus set free the amount of the ozone was ascertained.

The presence of peroxide of hydrogen in the water in which the phosphorus was partially submerged was proved also by a practical examination, in which it was found that the solution could be concentrated by evaporation, and it gave all the qualitative and quantitative reactions, which will be described in greater detail when we come to describe that substance and its properties.

Nitrogen.

Symbol N. Combining Weight 14·01.

Nitrogen constitutes the larger proportion of the atmosphere, apparently serving the purpose of a diluent of the life-sustaining oxygen. It may be prepared in the pure state, among other methods, by the combustion of phosphorus in a vessel containing air standing over water. The phosphorus burns at the expense of the oxygen with which it enters into combination, leaving nearly pure nitrogen gas behind. It is colourless, tasteless, inodorous, and almost insoluble in water. At an extremely low temperature and when subjected to a great pressure it liquefies, in common with hydrogen and oxygen gases.

While nitrogen cannot be described as a poisonous gas, it has no power to maintain life; on the other hand, when breathed in the pure state it destroys life, for the same reason that it cannot sustain combustion—viz., because it puts an end, for want of oxygen, to both processes, which are, as we have seen, dependent upon active oxidation.

In respiration nitrogen is not assimilated by the blood as oxygen is, but is expired in the breath. Notwithstanding this, it enters very largely into the composition of animal and vegetable tissues, being obtained in the human body from the nitrogenous constituents of the food. It also occurs in the mineral world in the state of nitrates of sodium, potassium, and calcium.

The production of nitrates in soils is of a continuous character, and proceeds more actively in the hotter climates. The manner of their formation is extremely interesting, and the investigations of MM. Schlœsing and Muntz, in France, and of Mr. Robert Warrington in this country, have led to some important results. It is now known that 'nitrification' is due to the action of two living ferments, which cause the oxidation, in the soil, of ammonia and the nitrogen of organic bodies. Ammonium carbonate is oxidized, and the nitrogen converted into a nitrite by one micro-organism; while another converts the nitrite into nitrate. If a small quantity of fresh soil be added to a dilute solution of urine, active nitrification is induced, and the ammonia or urea is converted into a nitrate. It is necessary for the production of nitric acid in this way that some base should be present wherewith it may enter into combination. The presence of gypsum (native sulphate of calcium, $CaSO_4$) greatly facilitates the nitrification of urine. The solution of urine, nitrified as above described, then possesses the power to induce the process in other solutions of urine. These facts are comparable with the more widely known and better understood features of alcoholic fermentation, in which, as a correlative phenomenon of a vital act, sugar is converted into alcohol.

Although it appears that the nitrifying micro-organisms may exist to a depth of about 6 feet, nitrification is practically confined to the surface soil, air being essential to the process.

The production of nitre on the artificial plan has for a long period been carried on in Europe. Mould, rich in nitrogenous matter, is formed into heaps of a porous character, so as to allow free admission of air, and treated from time to time with urine and water in regulated quantities. After two years of such treatment (care being taken to protect the heaps from rain), they become sufficiently rich in nitrates to be worth extracting. The chief nitrate thus formed is nitrate of calcium, the potassium salt being made from it by treatment with wood ashes or with carbonate of potassium. In this way about 5 pounds of nitre can be obtained from each 1,000 pounds of the nitrified soil. It is worthy of remark that it is from nitrates present in the soil that plants, in the main, derive their nitrogen, and thus we can appreciate the importance of nitrates from a manurial point of view, or, what is equivalent thereto, the importance of using nitrogenous manures.*

At present our knowledge concerning nitrogen as the main constituent of the atmosphere, and in its natural relations, is of a very limited character. There is no proof that the nitrogen of the air contributes in any way towards the formation of nitrates in the soil, and the extent to which free nitrogen is contributed to the air by animal and vegetable matters in a state of decay or putrefaction has not been accurately determined. It is known, however, that

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* See Mr. Warrington's paper read before the Society of Arts, vol. xxx., p. 532, and his remarks on the Chemistry of Bacteria in the *Chem. News*, vol. lxvii., p. 175.

in ordinary putrefaction some nitrogen gas is evolved, and that an abundance of oxygen causes the evolution of much nitrogen; indeed, it then becomes the principal gas.

Combustion of nitrogenous organic matters also gives rise to the production of some free nitrogen.

Many attempts have been made to utilize the nitrogen of the air in the manufacture of nitrogenous manures, and Sir William Crookes has pointed out that with an electric current costing one-third of a penny per Board of Trade unit a ton of nitrate of soda can be produced for £26, while if the unit could be produced by means of large natural sources of power, such as the Falls of Niagara, at one-seventeenth of a penny, then the cost of such artificial nitrate of soda should not be more than about £5 per ton.

Attempts have also been made to utilize the substance known as *nitragen*—which consists of organisms of the nodules of the roots of leguminosæ—as an agricultural manure. It is used in two ways, being either applied directly to the fields, or mixed with water and brought into contact with the seed before sowing; but so far as practical trials have been made, it appears that an increase of crop is only obtained when the *nitragen* is used on land containing much humus.*

A better result, however, appears to have been obtained by proceeding in another way—namely, by cultivating the bacteria in a medium that imparts to

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* See address of Dr. William Somerville to the Botanical Section of the British Association, 1904.

them the necessary power of resistance, such as skim-milk, grape-sugar, and peptone. The whole matter, however, may be regarded as at present in an experimental stage.

A series of papers contributed by Professors Nernst, Foerster, Le Blanc, Klaudy, and Frank, were communicated to the thirteenth annual meeting of the German Society of Electro-Chemists, held in May, 1906, concerning the fixation of atmospheric nitrogen.

It was pointed out in one of these that the oxidation or combustion of nitrogen produces no heat, and in this respect it differs from the usual type of combustion, so that the flame requires to be fed with a continuous supply of electric energy, the duty of the electric current consisting in maintaining the nitrogen at the temperature at which it becomes chemically active towards oxygen.

One of the most promising methods referred to, consists in passing a current of air through an electric flame-arc, made to take the shape of a disc, the flame-arc being produced by an alternating current of 5,000 volts. Twenty-five cubic metres of air are led per minute through the flame, and a concentration of 2 per cent. nitric oxide is thereby attained in the issuing gas.

A calculation submitted in the paper by Professor E. Foerster showed that the cost was equivalent to 0·29 mark for the electrical energy required to produce 1 kilogramme of nitrogen in the form of nitric acid, whereas in sodium nitrate (Chilian saltpetre) the same amount of nitrogen cost 1·25 marks (1s. 3d.).

According to another method of procedure, calcium cyanamide ($CaCN_2$) is first of all produced, and this compound is of itself of direct value as a manure, apart from its value as an intermediate product in the manufacture of nitrates and ammonia.

The calcium cyanamide is prepared from carbide of calcium, which in a pulverized state is heated for about seven hours in closed retorts into which pure nitrogen (made by the Linde process from liquid air) is circulated, and which becomes absorbed by the carbide. The chemical formula of calcium carbide is CaC_2, and in this process half the carbon is displaced by nitrogen, producing cyanamide, which has the formula $CaCN_2$. The process is said to be an exceedingly simple one, and to be working very satisfactorily.*

Carbonic Anhydride (*Carbon Dioxide; Carbonic Acid*).

Formula CO_2. *Molecular Weight* 44.

Carbonic anhydride is a constant constituent of the atmosphere, although its proportion differs with place and time, varying from 2 to 10 parts in 10,000 of air. The amount present in the air is greater in summer than in winter; it increases during the night, and decreases after sunrise. It is given off from the human body as an excretory product in the breath, and it is formed by the slow decay, as also by

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* See a short treatise on 'Artificial Fertilizers,' issued by the North-Western Cyanamide Co., Ltd., London, E.C.

the rapid combustion, of organic matters generally. Carbonic anhydride is decomposed by the leaves and other green parts of living plants, but the decomposition takes place only during daylight, and to the greatest extent during bright sunshine. In this process, oxygen gas is set free and the carbon is assimilated by the plants in some manner at present imperfectly understood. During darkness plants evolve carbonic anhydride, and this may account for the increased amount of that substance which is found present in the atmosphere by night.

The quantity of carbonic anhydride contained in the air of houses and closed inhabited spaces is in excess of the amount found in the open air, and one of the objects of ventilation is to reduce the amount as far as possible.

In the laboratory, carbonic anhydride is best prepared by acting upon marble (carbonate of calcium) with hydrochloric acid, as illustrated by the following chemical equation :

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

Carbonic anhydride (carbon dioxide) is a colourless and nearly inodorous gas, which can be readily reduced to the liquid and solid states. It is about 1·5 times heavier than air, and is soluble in water to a very considerable extent ; one volume of water at 0° C. dissolves 1·797 volumes, but at 20° the quantity dissolved is only 0·901 volume.

When present in the air in any considerable proportion, carbonic acid acts as a poison, as will be more fully explained when dealing with the subject of Respiration, and on account of its poisonous effect, fuel (of any kind) should never be burned in rooms except in fireplaces connected with properly constructed chimneys, and because carbonic acid is one of the products of burning gas, the necessity of efficiently ventilating dwelling apartments is at once apparent.

Although air contains on the average only 4 volumes of carbon dioxide in 10,000 volumes, the absolute amount thus presented in nature is enormous, as may be readily proved by calculation. It also occurs in the air of mines and old wells, and is commonly known as 'choke-damp.' Common chalk and marble (carbonate of calcium, $CaCO_3$) are compounds of carbonic oxide with lime.

Soda-water of commerce is an aqueous solution mechanically charged with a large amount of carbonic anhydride, and it is this gas which escapes so briskly when the cork is removed from a bottle containing that fluid.

Spring water is often charged with carbonic anhydride, derived from the gradual oxidation, by the action of the air, of vegetable organic matters held in solution, and it is to its presence that the so-called 'hardness' of water is in part due (see chapter on Water and Water-Supply).

Hydrogen.

Symbol H. Combining Weight 1.

In 1766 Cavendish first obtained hydrogen gas by the action of dilute sulphuric acid upon zinc, thus:

$$Zn + H_2SO_4 = ZnSO_4 + H_2,$$

and upon examining its properties, he found that a mixture of it with ordinary air exploded upon the application of a flame, with the consequent production of water. But it was not until after Priestley had discovered oxygen that Cavendish became fully aware of the fact that the explosion in question was owing to the combination of hydrogen with oxygen. He repeated his experiments with pure oxygen, and thus formed water.

The production of water in this way may be expressed as follows:

$$H_2 + O = H_2O.$$

Hydrogen is the lightest known body in nature, being fourteen and a half times lighter than air; but notwithstanding this, it has of late years been reduced to the liquid state, as already mentioned.

Its properties do not call for any extensive treatment in this place, since it is only important (in connection with the subject of this volume) as a constituent of water and peroxide of hydrogen.

Hydrogen gas is combustible, and when it is burned in the air or in oxygen it enters into combination with the oxygen, yielding water as the product. This reaction is remarkable in so far as it illustrates the direct formation of a liquid substance by the chemical combination of two gases.

Hydrogen is not poisonous in the ordinary sense of that expression, although of course it cannot support life, in which respect it resembles nitrogen.

Water.

Formula H_2O. *Molecular Weight* 18.

The occurrence of water in nature, and its general properties, are matters of such common knowledge that it is altogether unnecessary to dwell upon them. It is important, however, to bear in mind that it exists in the air in the vaporous state, a matter to which more particular reference will be made hereafter.

Water is always produced by the combustion of organic substances containing hydrogen, and it accompanies carbon di-oxide, as a product of respiration. As its formula implies, it is a combination of two volumes of hydrogen with one volume of oxygen. It may be described as a perfectly neutral substance, exhibiting no active characters, and possessing no power as an oxidizing agent, although every 18 parts by weight contain 16 parts of oxygen. All its oxygen is utilized, so to speak, in retaining the hydrogen in combination, and in this respect it is widely different from peroxide of hydrogen or chemically oxygenated water, which is the substance that will be next considered.

Water plays an important part as an atmospheric constituent, inasmuch as it acts as a screen in preventing radiation of heat from the earth. In this direction the observations which were made by Tyndall are of special interest. In the forms of ice and steam its uses and properties are perfectly well understood, and are of the most important order. It is indispensable to animal and vegetable life, and it enters very largely into the composition of animal and vegetable tissues, even to the extent of from 80 to 90 per cent., or more.

As a potable substance and in its relations to the subject of hygiene, we shall deal with it hereafter (see Chapter V.).

Peroxide of Hydrogen (*Hydrogen Dioxide*).

Formula H_2O_2. *Molecular Weight* 34.

This substance was discovered by Thénard in 1818. He obtained it by acting upon barium dioxide with dilute hydrochloric acid, thus:

$$BaO_2 + 2HCl = BaCl_2 + H_2O_2.$$

In many of its properties it resembles ozone, and is, indeed, formed together with that substance during the electrolysis of acidulated water. When water is electrolyzed, the theoretical amount of oxygen that should be obtained according to the equation $H_2O = H_2 + O$ is not yielded; there is always a slight deficiency, a fact which is explained by the formation of peroxide of hydrogen.

Peroxide of hydrogen differs essentially from ozone and oxygen in being a liquid at the ordinary temperature and pressure of the atmosphere (although, in point of fact, a pure solution—that is, undiluted with water—has not, so far, been obtained). Moreover, whereas ozone is a gas which is very slightly soluble in water, peroxide of hydrogen is extremely soluble in water.

It will be seen from what has preceded that the composition of these two substances is perfectly distinct, but some few years ago their chemical nature was less clearly understood; hence some of the confused ideas that still prevail. F. Le Blanc believes that the peroxide of hydrogen which is produced during the electrolysis of acidulated water is due to the action of ozone upon the water.* This, however, is very improbable, and while there is no evidence in favour of the notion, Schöne has expressly satisfied himself to the contrary by careful experiments.

Peroxide of hydrogen may be prepared by suspending barium dioxide in water and passing a current of carbon dioxide gas through the mixture. The following equation represents the changes which occur :

$$BaO_2 + H_2O + CO_2 = BaCO_3 + H_2O_2.$$

That is to say, the carbonic gas unites with baryta to form the insoluble carbonate, whilst the second atom of oxygen in the dioxide of barium unites with the water to form the peroxide of hydrogen.

As made in this way, the peroxide is very dilute, so that for all practical purposes it is better obtained

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* *Compt. Rend.*, lxxv., 537.

by treating the peroxide of barium suspended in water with the theoretical amount of dilute sulphuric acid required to fully react upon it, as follows:

$$BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2 ;$$

or, as better shown:

$$BaOO + H_2OSO_3 = BaOSO_3 + H_2OO.$$

The sulphate of barium forms a white insoluble precipitate, while the peroxide of hydrogen passes into solution at once.

For commercial uses, it is generally prepared by a similar process to that just described, only in the place of sulphuric acid, hydrofluoric acid or hydrofluosilicic acid are sometimes used, in which latter cases insoluble fluoride or fluosilicate of barium are formed, peroxide of hydrogen alone remaining in solution.

The occurrence of peroxide of hydrogen in nature attracted but little attention until I took up the study of the subject about thirty years ago, and this fact is not surprising if it be reflected that there were but slight means of distinguishing between it and ozone. Moreover, many of the natural processes now well known to generate peroxide of hydrogen were up to the last few years regarded exclusively as sources of ozone. In fact, peroxide of hydrogen, giving the same tests, was mistaken for ozone.

Not only Schönbein and Dumas thought it probable that peroxide of hydrogen should occur in the atmosphere under certain circumstances more guessed at than determined, but Professor Struve* claimed, in

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* *Compt. Rend.*, 1869.

1869, to have demonstrated its presence in the air as a product of simultaneous formation with ozone, and stated that the colouring of iodized starch-paper, when exposed to the atmosphere, is the joint result of the influences of ozone and peroxide of hydrogen. He also pointed out that peroxide of hydrogen may be condensed in rain-water.

Since that time much attention has been given to this subject by various observers, and particularly so since I discovered that all kinds of aromatic plants produce peroxide of hydrogen liberally. The way in which they do this is reserved for special description in a later chapter, and here the mere statement may be submitted that probably all plants and flowers of perfume (at least, all those which are known to secrete essential oils) generate peroxide of hydrogen into the atmosphere, by the joint or successive action of air and water upon their essential oils.

Em. Schöne* found more peroxide of hydrogen in a litre of dew or hoar-frost during the summer months than during the winter months. In a lecture-hall which had been closed for some weeks he also found about 0·17 c.c. peroxide of hydrogen (H_2O_2) in 1,000 cubic metres of the air.

It will be understood that, as peroxide of hydrogen is abundantly soluble in water, its presence in rain-water or dew is not at all surprising. As the rain or waterdrops fall through or condense from the air containing the peroxide of hydrogen, this substance, of course, dissolves in the water.

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* *Ber. Deut. Chem. Ges.*, No. 6, 1878.

In a subsequent investigation* Schöne found that 'the higher above the earth's surface the condensation of atmospheric aqueous vapour takes place, the richer in peroxide of hydrogen is the resulting precipitate.' This also is quite intelligible, since peroxide of hydrogen, like ozone, is unstable, and is readily decomposed by organic matters generally, and these are most abundant near the earth's surface.

Then, again, Schöne found† that in the strata of the atmosphere accessible to investigation the amount of peroxide of hydrogen is greater the higher the sun rises above the horizon (both during the day and the year), and the smaller the obstructions to the sun's rays. He considers, therefore, that the amount of peroxide of hydrogen should notably increase towards the Equator. This consideration is very probably a correct one, for in the tropical regions vegetation abounds most freely; and there it is that we meet with the greatest known source of peroxide of hydrogen. In those huge areas of vegetable life every oil-secreting tree or plant is continuously giving rise to the production of peroxide of hydrogen, as before mentioned.

M. Sergius Kern, following up the experiments of Schöne, has more fully examined rain-waters,‡ and he finds that equatorial winds bring rains much richer in peroxide of hydrogen than the rains carried by polar winds, thus lending confirmation to the above-expressed views.

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* *Ber. Deut. Chem. Ges.*, No. 8, 1878.

† *Ibid.*, No. 9, 1878.

‡ *Chem. News*, vol. xxxvii., p. 34.

Further, it has been pointed out by A. R. Leeds* that papers which have been moistened with potassic iodide and starch (Osann's test-papers) are not generally coloured at Hoboken, but only tinted on rare occasions. On the other hand, in Keene Flats, New York, the days were few on which no indication was obtained. It should be stated that the place of investigation in Keene Flats was 700 feet above the sea-level, and the surrounding vegetation was chiefly deciduous. At a point near the upper end of Upper Saranac Lake, which is even at a much greater altitude, and surrounded with miles of primitive forestry, embracing hemlocks, pines, larches, and spruces, the woods being often redolent with balsamic odours and extensively used as a health resort by large numbers of patients, Mr. Leeds found the most intense and frequent reaction with the test-paper. Although, in his published papers, he assumes this active constituent of the air to be ozone, the test employed, as already explained, is one equally sensitive to peroxide of hydrogen, whose very home is forestry embracing pines and spruces. It is certain, indeed, that, as I have shown, the coloration of the test-paper was due to peroxide of hydrogen.'†

S. Cohné‡ has described some few simple experiments which, according to his interpretation, go to show that certain parts of plants, by contact with peroxide of hydrogen, give rise to ozone. In the

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* *Chem. News*, vol. xxxviii., pp. 224, 235, 249, 257.

† *Ibid.*, vol. xxxvii., p. 243 (critical note by the author).

‡ *Ibid.*, vol. xxxiv., p. 4.

same journal* I have critically examined Cohné's experiments, and have shown that his results admit of another and more plausible explanation. Peroxide of hydrogen, even in dilute solutions, undergoes slow spontaneous decomposition into water and free oxygen, and this decomposition is accelerated by contact with many substances. For instance, meat fibrin exhibits this contact-power in a remarkable degree; and it is not improbable that the fibrin of plants possesses a similar power, more particularly since, as Cohné himself shows, a stem is most active where it has been cut through. Now, in such a decomposition of peroxide of hydrogen, the oxygen escapes from a solution which is known to react with the test-mixture employed, and as the bubbles of gas escape from the fluid, they are probably saturated with the peroxide of hydrogen, just as ordinary air contains moisture. It is this escaping peroxide of hydrogen (which might also be carried up as spray) that Cohné evidently mistook for ozone. Thus, there is as yet no proof either that ozone in the presence of water yields peroxide of hydrogen, or that ozone is ever formed from peroxide of hydrogen.

Nevertheless, A. Houzeau† thinks that in certain cases—for instance, when ozone acts upon sulphindigotic acid—peroxide of hydrogen is intermediately formed in solution. This is by no means improbable; indeed, it is certain that other processes of oxidation also give rise to peroxide of hydrogen, both inter-

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* *Chem. News*, vol. xxxiv., p. 20.

† *Compt. Rend.*, lxxv. 349-351.

mediately and finally. Thus, P. Schützenberger, in the course of some interesting experiments,* obtained results which led him to the conclusion that peroxide of hydrogen is intermediately produced by the action of air or oxygen upon hyposulphite of sodium. It is also formed, as I have demonstrated, as a final product of the atmospheric oxidation of the class of hydrocarbons known as terpenes (of which turpentine is illustrative).

Having now briefly considered the various processes by which peroxide of hydrogen is formed, we may examine its nature and more important reactions.

It has been stated (see p. 58) that water was found by Cavendish to consist of hydrogen in combination with oxygen. In other words, two volumes, or atoms, of hydrogen, when exploded with one atom, or volume, of oxygen, combine and form one molecule (two volumes) of water :

$$H_2 + O = H_2O.$$

Now, peroxide of hydrogen contains one more atom or volume of oxygen, than does water in its molecule, and so it is represented by the formula H_2O_2.

It is this additional atom of oxygen that gives to peroxide of hydrogen its important character as an oxidizing agent.

The constitution of peroxide of hydrogen is not thoroughly understood. Generally, its constitution is structurally represented as follows :

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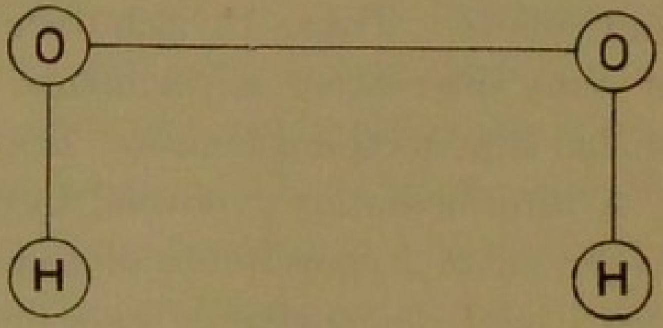
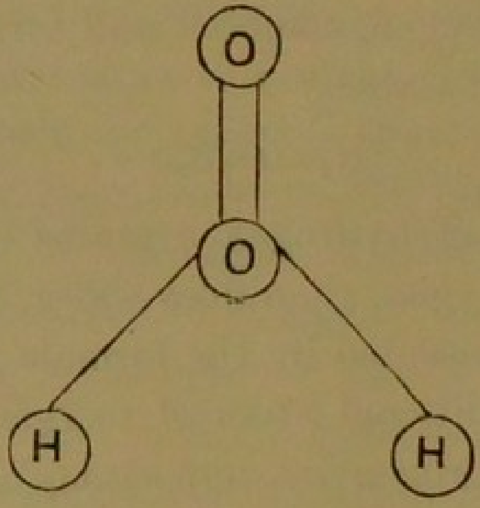
* *Bulletin de la Société Chim. de Paris*, vol. xx., p. 135. (1873.)



—which would signify that each atom of oxygen (here regarded as a dyad in atomicity) is directly combined with the other atom of oxygen, and with one atom of hydrogen. Such a formula altogether fails to explain the oxidizing effects of the substance, and in my opinion it is to be regarded not so much as a peroxide of hydrogen in the strictly chemical sense, as an oxide of water, or oxygenated water. If my view be correct, then the constitution of peroxide of hydrogen may be represented thus:



Here one atom of oxygen is represented as a tetrad in atomicity, the one part being directly combined with the other atom of oxygen as also with two parts of hydrogen; whereas the second atom is combined only with the other atom of oxygen, thus readily accounting for the best known properties of the substance. My view* is, I think, supported by certain observations which were made by M. Berthelot.†

By careful evaporation of a dilute aqueous solution of hydrogen dioxide *in vacuo* at low temperatures, it may be concentrated to a syrup which is colourless, and has a faint odour reminding both of chlorine and ozone. The product is, however, very unstable, and slowly undergoes decomposition, even at ordinary temperatures, as follows:

$$H_2O_2 = H_2O + O,$$

the oxygen gas escaping in the form of minute bubbles. This decomposition is assisted by the presence of many substances in a fine state of division (and particularly by substances which are themselves in a state of change or decomposition) as also by alkalies. On the other hand, the presence of a little ordinary ether restrains the decomposition; and, not unlikely, the reason for this is to be found in the fact, elsewhere noticed, that ether itself gives rise to the production of peroxide of hydrogen by contact with air or oxygen and water.

If the syrupy solution of peroxide of hydrogen be heated to the boiling-point of water, it suddenly decomposes, and the oxygen escapes with explosive violence.

Peroxide of hydrogen is miscible with water in all proportions, and it is generally stated in chemical treatises that, although dilute solutions are more stable than strong ones, yet even they are immediately decomposed on ebullition. Indeed, this method has been advocated for estimating the strength of

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* *Chem. News*, vol. xlvi., 141.

† *Compt. Rend.*, 90, 572-577.

solutions by measuring the evolved gas. Experience does not bear out this statement. Early in my researches on the oxidation of the essential oils of plants there was occasion to compare the properties of peroxide of hydrogen otherwise obtained with some of the products obtained in my experiments, and it was then found* that not only might dilute solutions of peroxide of hydrogen be boiled for some minutes without any appreciable decomposition, but that the presence of a quantity of chloride of zinc did not increase the amount of change. Mr. G. E. Davis later obtained similar results,† and found that a dilute solution may be concentrated, by evaporation, to half its bulk without driving off more than two-thirds of its active oxygen.

To illustrate the rate of decomposition of solutions as kept in the laboratory, Mr. Davis's figures may be quoted. The solution he operated upon was what is known as a 'ten-volume' one—that is to say, it was capable of evolving from its own solution ten times its own volume of gaseous oxygen when fully decomposed. Thus, 100 c.c. would evolve 1,000 c.c. oxygen; in other words, it would contain 3·04 per cent., by weight, of peroxide of hydrogen (H_2O_2), and evolve 1·43 per cent. of oxygen by weight:

On August	2,	1878,	the strength	of the	solution	was	9	volumes.
,,	9	,,	,,	,,	,,	,,	8·4	,,
,,	24	,,	,,	,,	,,	,,	8·0	,,
September	1	,,	,,	,,	,,	,,	7·9	,,
,,	24	,,	,,	,,	,,	,,	7·8	,,
October	24	,,	,,	,,	,,	,,	7·2	,,

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* *Journ. Chem. Soc. Trans.*, 1874, p. 14.

† *Chem. News*, vol. xxxix., p. 221.

By adding a few drops of ether, this strength was maintained, for on testing two months later it was found to be the same as on October 24.

Dilute solutions of peroxide of hydrogen, then, are tolerably stable, and particularly if they be of slightly acid reaction; if, however, they be alkaline, owing to the presence of traces of soda, potash, or ammonia, then they are much less stable, and in particular evince a tendency to decompose entirely upon heating. The growing importance of the substance for commercial and surgical employment led me to make a careful investigation respecting the influence of a large number of substances upon it, and in the end I was successful in devising a chemical means of preserving it from any appreciable loss of strength by spontaneous decomposition. Full particulars of my observations will be found in the paper referred to at foot,* and the 'Preserved Peroxide of Hydrogen' is now available as an article of commerce.† An alkaline solution of peroxide of hydrogen is partially decomposed by mere agitation, and the statement has been made that agitation with air is sufficient to entirely decompose even pure peroxide of hydrogen in course of time. Mr. Davis failed to corroborate this result, and, indeed, found that by the passage of 15 cubic feet of air per twenty-four hours through a dilute solution, no peroxide was destroyed; but, on the other hand, he found at the end of the

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* *Journ. Soc. of Chem. Industry*, January 31, 1890.

† It is made and sold under that name by the Sanitas Co., Ltd., of London.

experiment an excess, even in the presence of caustic soda.

Two facts in connection with the last-named circumstance may be cited with interest. One has been pointed out previously—viz., that of the apparently well-ascertained production of peroxide of hydrogen or ozone by friction of waterdrops against atmospheric air. The other fact may have some connection, perhaps, with the possible behaviour of the caustic soda. Cuprous oxide (Cu_2O) shows no tendency to absorb oxygen and pass into cupric oxide (CuO) when it is suspended in water and subjected to a current of air. If, however, the water contains a very minute quantity of caustic soda, then, as I have ascertained, cupric oxide begins at once to form,* and goes on increasing until the whole of the red cuprous oxide is converted into the black (higher) oxide.

It is difficult to explain these facts, except on the supposition that caustic soda has the power, under given conditions, to absorb oxygen, and pass temporarily into a higher state of oxidation. From this state it may be immediately reduced to its former condition by the action of the cuprous oxide, which seizes its excess of loosely-combined oxygen for itself. No more attention can here be given to this subject, except to remark that, in common with many similarly interesting instances of slow oxidation, it calls for much further study and observation before an absolutely satisfactory explanation can be obtained.

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* *Chem. News*, January 5, 1872.

There are several methods by which the strength of pure peroxide of hydrogen may be determined:

1. A given volume of the solution is taken and placed in a tube with excess of potassium dichromate; on agitation over mercury, a quantity of oxygen gas is evolved, which, supposing 1 c.c. of the peroxide of hydrogen has been taken, expresses its strength in so many volumes. Thus 1 c.c. of a ten-volume solution would yield 10 c.c. of oxygen at 0° C. and 760 mm. bar.

2. A given volume of the peroxide is treated in a measured tube over mercury, with excess of acidified solution of permanganate of potassium, when oxygen gas is instantly evolved, according to the equation:

$$Mn_2O_7 + 5H_2O_2 = 2MnO + 5H_2O + 5O_2.$$

It will be seen from this equation that only one-half of the evolved oxygen is derived from the peroxide of hydrogen; and if this quantity be corrected for temperature and pressure, it agrees with the result furnished by the next method.*

3. When peroxide of hydrogen is added to a solution of potassium iodide acidulated with pure dilute sulphuric acid, there is a liberation of iodine, which is revealed by the red colour acquired by the solution. The ultimate result of the reaction may be expressed thus:

$$2KI + H_2SO_4 + H_2O_2 = K_2SO_4 + 2H_2O + I_2.$$

If starch be added to the mixture, the free iodine combines with it to form a splendid blue compound,

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* In illustration of both these methods I have given examples in my papers published in *Journ. Chem. Soc. Trans.*, 1875 (p. 9 of paper), and *ibid.*, 1880 (pp. 10-15 of paper).

which, by its depth of tint, serves to render the determination of the iodine more accurate. This estimation is effected by ascertaining how much hyposulphite of sodium of known strength is required to decolorize the solution thus :

$$2Na_2S_2O_3 + I_2 = 2NaI + Na_2S_4O_6.$$

Before passing on to other considerations, it must be stated that the action of peroxide of hydrogen upon potassium iodide is by no means instantaneous in character. A certain amount of decomposition occurs at once, but the rest of the decomposition is effected only very slowly, so that often half an hour or more is required for its completion. The process is therefore tedious as ordinarily practised, and for many purposes the second method is preferable. I more recently ascertained that the process may be greatly expedited by the free use of acid, and if a great excess of acid be employed, the decomposition is completed almost immediately, so that the determination may be made at once with fair accuracy.* When the solution to be tested is stronger, it should be first of all diluted down to about two-volume strength—that is to say, of such a strength that when appropriately decomposed it shall not be capable of giving more than twice its own volume of oxygen gas. It then suffices to take 10 c.c. of this dilute solution, and add it to a previously prepared mixture of 20 c.c. of a 10 per cent. solution of potassium iodide with 20 c.c.

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* See also my report (part iv.) in *Journ. Chem. Soc. Trans.*, 1880, p. 802 ; and my more recent paper on the 'Estimation of Peroxide of Hydrogen' in *The Analyst*, 1887.

of dilute sulphuric acid (strength 1 : 5 of water). Decomposition of the H_2O_2 is almost instantaneous and certainly thorough after a few moments, and the iodine thus liberated may be at once estimated by titration in the usual way.

In contact with pure potassium iodide, no acid being present, peroxide of hydrogen is resolved into water and oxygen, but iodine is not set free.

The decomposition that occurs between peroxide of hydrogen and permanganate of potassium in the presence of acid is not always explained by chemists in accordance with the equation given on p. 73, but in a recent paper* Messrs. Carpenter and Nicholson have confirmed the entire accuracy of the results, not only of my previously conducted study of the same reaction, but also those attending the estimation of peroxide of hydrogen generally.

The other reactions of peroxide of hydrogen are both interesting and numerous; but attention will be confined in this place to the more important ones only.

Peroxide of hydrogen furnishes a beautiful reaction with chromic acid, which first of all gives a blue colour with the peroxide of hydrogen; oxygen is then gradually evolved, the colour fading at the same time:

$$2CrO_3 + 3H_2O_2 = Cr_2O_3 + 3H_2O + 3O_2.$$

If an excess of peroxide of hydrogen be used in this experiment, then a further reaction occurs, in which

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* *The Analyst*, vol. ix., p. 36.

the H_2O_2 loses exactly double the amount of oxygen lost by the chromic acid, so that the ultimate result is:

$$2CrO_3 + 6H_2O_2 = Cr_2O_3 + 6H_2O + O_9.$$

Peroxide of hydrogen bleaches litmus and many other vegetable colours, and is largely employed for bleaching human hair, to which it imparts a golden hue; it is also used as an antiseptic tooth-wash.

It oxidizes sulphides, and thus converts black sulphide of lead into the white sulphate:

$$PbS + 4H_2O_2 = PbSO_4 + 4H_2O.$$

It is decomposed by many metals when these are added to it in a state of fine division: gold, silver, and platinum, all occasion its decomposition in this way without being themselves thereby apparently influenced. This kind of action is well known in chemistry as contact action, but is at present without a satisfactory explanation.

The oxides of the three metals just named also decompose peroxide of hydrogen; and not only this, but they are themselves thereby reduced to the metallic state. If the peroxide, in a very concentrated state, be allowed to fall, say, upon argentic oxide, this double decomposition is attended with explosive violence, owing to the rapidity with which the large quantity of oxygen gas is liberated.

Peroxide of hydrogen, as we have seen, unless specially protected against such an occurrence, gradually undergoes spontaneous decomposition from the moment of its formation, and immediately that it comes in contact with bodies like argentic oxide, it appears to give a similar impulse to their molecular constituents, with the consequence of double and accelerated decomposition.

Brodie explained this fact by assuming that the second atom of oxygen in the hydrogen peroxide exists in a polar condition different from that of the oxygen in the oxide of silver; consequently, one being negative and the other positive, they exert a mutual tendency to combination, thereby forming a neutral molecule of oxygen.

All such actions and reactions may be explained in a general way which assumes nothing, while it suffices as an explanation. It is this: All substances, as we know and recognize them, exist subject to certain conditions; and the more easily these conditions can be influenced from without, the more easily do such substances undergo change. In brief, mechanical, chemical, or any other kind of force, exerts an influence on the powers which determine the state of a body.

Peroxide of hydrogen is not alone decomposed by metals and their oxides, but by almost every substance which admits of being oxidized. Thus, ferrous sulphate is oxidized to ferric sulphate, and sulphuretted hydrogen is decomposed as follows:

$$H_2O_2 + H_2S = 2H_2O + S.$$

That is to say, water is formed in solution and sulphur is deposited.

Peroxide of hydrogen, as prepared by chemical processes, is now largely used in commerce for bleaching straw goods, woollen and other fabrics, oils, wax, ivory, tobacco, blood-serum, and engravings and paintings. For such purposes, or some of them, it is employed after being rendered strongly alkaline by the addition of caustic ammonia.

The therapeutic properties of peroxide of hydrogen will be more particularly described hereafter, and readers who are interested in this subject and the industrial applications of the same substance will find a good deal of information in my paper on that subject,* which is referred to below.

All animal and vegetable substances in a state of change or decomposition are rapidly acted upon by peroxide of hydrogen, much more vigorously, indeed, than by ordinary air or even pure oxygen; and hereafter we shall see what an important part this substance plays as a natural disinfectant. It not only exercises a disinfecting action by virtue of its power to give up oxygen to decomposing matters, but it can absolutely arrest decomposition, and is destructive of the micro-organisms that breed putrefaction and various contagious diseases, as also the poisonous (toxic) bodies which are often produced by them when growing in suitable media.

These valuable properties of peroxide of hydrogen are well exhibited in the treatment of diphtheria by that substance, for, when applied locally, it destroys alike the micro-organisms which are intimately concerned with the disease, the so-called false membrane

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* *Journ. Soc. of Chem. Indus.*, January 31, 1890.

which otherwise forms in the throat, and the poisonous products, the absorption of which into the system constitutes the greatest danger to be apprehended in cases of this disease.

Peroxide of hydrogen, as known in commerce, is perfectly innocuous, being non-poisonous, and without deleterious action on the skin or clothes, and it may be justly described as Nature's own bleaching and purifying agent; for it is often found present in dew and white frost, while as an atmospheric constituent it constitutes the active principle in the so-called grass-bleach.

The natural production of this substance by certain processes has already been described, but the exact manner in which it is produced on a prolific scale in the atmosphere of pine, eucalyptus, and camphor forests, is reserved for special description hereafter.

CHAPTER III.

CHEMISTRY AND HYGIENE OF THE ATMOSPHERE—RESPIRATION — DIFFUSION OF GASES — VENTILATION.

It has already been shown that the atmosphere is a mixture of gases, consisting chiefly of nitrogen and oxygen. Argon, carbon dioxide, aqueous vapour, ammonia, nitric acid, ozone, peroxide of hydrogen, and other substances, are, or may be, present in small proportions; while in the air of towns are also to be found carburetted hydrogen, sulphuretted hydrogen, and sulphurous anhydride, which substances are derived from the combustion of fuel (coal and coke) and gas containing sulphur. Ignoring, for the moment, the substances that are present in minute quantity, air may be described as a mechanical mixture, containing in each 100 volumes about 79 volumes of nitrogen and 21 volumes of oxygen.

The water (hygroscopic) present in the air exists in a dissolved condition in the other gases, and its amount varies with the latitude and season, being chiefly dependent upon temperature. Air, in nature, always retains the gaseous form, but the aqueous vapour which it is capable of absorbing may be more or less condensed or separated therefrom, a fact which accounts for considerable variations in the composition of the atmosphere. The circulation of the air constantly exposes it to fresh conditions; at one time a part of the aqueous vapour may be precipitated as dew, or absorbed by dry tracts of land; while at other times an additional quantity may be assimilated from rain, or from the ocean, or moist surfaces of land. Obviously the density of the air depends in part on the quantity of its contained aqueous vapour.

The amount of aqueous vapour present in the air varies with the latitude and the season, and in some localities, as, for example, the British Isles, even from day to day: one day we may have a cold, dry east wind blowing and the next day we may have a south-west wind coming off the Atlantic, saturated with moisture. The amount of moisture which the air can contain increases with a rise of temperature, and *vice versa;* so that if we have a quantity of warm air nearly saturated with moisture, and gradually cool it, we shall very soon reach the dew-point, or point of saturation, after which, on still further cooling, we shall find that the air, being no longer able to contain all its moisture, gives it up in the form of a fine rain. Thus, in England we get most of our rain with a south-west wind, the reason being that the air after coming over the Atlantic is both warm and saturated with moisture; therefore, when it reaches us and gets cooled down by contact with colder masses of air, or the cold sides of mountains, etc., it becomes supersaturated, and is thus forced to give up some of its moisture in the form of rain or snow. On the other hand, if we take a mass of fairly moist cold air and heat it up, it becomes dry in character; thus in winter, on going into a room heated with a stove, a very unpleasant sort of feeling is often experienced, in order to avoid which it is usual to evaporate a little moisture into the air by placing a saucer full of water on the top of the stove.

It is therefore evident that air containing a certain amount of moisture will, if heated, become what we call dry, whilst air containing the same amount of moisture when cold would be wet.

The amount of moisture present in the air has a marked effect on health, and it is found that most persons can stand very much greater extremes of both cold and heat when the atmosphere is dry than when it is moist.

The weight of 1 litre of dry air at 0° and 760 mm. of pressure is 1·2932 grammes. A cubic foot of air weighs at 60° F. and 30 inches bar. 536·96 grains, but its density is known to diminish as we recede from the earth, which it surrounds as an atmospheric envelope to a calculated height of about 45 miles. We are enabled to register the constantly varying pressure of the atmosphere at the surface of the earth by means of the barometer.

The average composition of the atmosphere in this climate is expressed in the following table:

Oxygen - - - - - -	20·61
Nitrogen - - - - - -	77·95
Aqueous vapour - - - - -	1·40
Carbonic anhydride - - -	0·04
	in 100·00 volumes.

It is upon the oxygen which is contained in air that all animal life depends, supporting as it does the process of respiration. It is also of great importance to plants, to which, in part, it is carried by the solvent action of water.

A part, at least, of the ammonia which is found present in the atmosphere and upon nearly all articles exposed to the air (including the furniture of dwelling-houses), is produced by the decomposition of organic matter which is constantly taking place. This fact formed the subject of some interesting speculations and practical observations by the late Dr. R. Angus Smith,* and, indeed, he attempted to make the ammonia detected upon exposed surfaces serve also as the measure of organic matter present. Not only is ammonia derived from living organisms, but it results also from the decay of vegetable and animal matters, and being volatile, it escapes into, and can always be detected in, the air, and generally in all water-supplies also. 'A room that has a smell indicating recent residence will, in a certain time, have its objects covered with organic matter, and this will be indicated by ammonia on the surface of objects.' 'When a room is shut up even for a day, unless the room be very large indeed, there is always that peculiarity observed by sensitive persons to which there is given the name of closeness. To me,' Dr. Angus Smith wrote, 'it seemed perfectly clear that the character of closeness was connected with the existence of organic matter, and the organic matter with the

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* See *Sanitary Record*, October 15, 1883.

ammonia.' Oxygen, as contained in fresh air, removes this closeness by freely oxidizing the organic matter, the gaseous products being carried away in the currents of air which we admit into our dwelling rooms with the very object of getting rid of the closeness. The precise mode of action of the atmospheric oxygen involved in this process and that of purification generally is dealt with elsewhere.

It will suffice in this place to state that oxygen in one form or another is the great purifier that nature has provided for cleansing the air, the earth, the waters that are on the face of the earth, and all things that are in our houses and upon our bodies, from the impurities that are more or less intimately associated with organic life and the production of disease. No matter how concentrated the organic matter or disease-producing filth, atmospheric oxygen is all-powerful, if time and sufficient quantity be employed, to rob these matters of their power for evil, and even to transform them by oxidation into innocuous and useful products.

No better example of the beneficent action of atmospheric oxygen can be taken than that afforded in the process of respiration.

This process is of such high importance in relation to health, that we must now consider it somewhat in detail. By the action of the heart, the blood is pumped through the lungs at a rate which has been variously estimated as equal to from 10 to 27 pounds in one minute. The blood thus conveyed into the pulmonary capillaries is venous in character; that is to say, it is dark in colour and is charged with carbon dioxide, which it has collected throughout the system as a product of the oxidation which is continually taking place within our bodies. This carbonic gas is an excretory product, and it is the very essence of respiration to get rid of it and aqueous vapour, and to introduce into the blood a new supply of oxygen, thus converting it into bright-coloured arterial blood.

The carbon dioxide present in blood is there in two conditions. It partly exists in the state in which the uncombined gas is present in soda-water, and partly in combination with alkaline bases, notably soda. By certain chemical changes that occur, the whole of the carbonic anhydride is set free in the lungs; it escapes along with watery vapour through the lung tissue into the respiratory passages and is exhaled. In exchange, the oxygen present in the inspired air is absorbed by the blood, where it enters partly, at least, into combination with its colouring matter, and is in consequence conveyed thereby to all parts of the body.

The manner in which arterial blood performs its oxidation in the system has been beautifully illustrated by an experiment devised by Schützenberger. He caused bright red arterial blood to circulate through a long system of hollow tubes constructed of gold-beater's skin, immersed in a mixture of yeast diffused in fresh serum (without globules) at a temperature of 35° C. (95° F.). As the blood traversed the tubes, it gradually parted with its oxygen to the yeast through the walls of the tubes, and then passed out at the end black and venous.

This parting with oxygen through the walls of the gold-beater's skin tubes serves also to illustrate the manner in which the blood becomes oxygenated in the lung tissue. The blood in the pulmonary capillaries (which are wide and thin-walled, forming an extensive network of small meshes) is separated from the air only by their own walls and the delicate lung membrane. Under these circumstances, it is easy to appreciate how the blood parts with its carbonic acid and becomes oxygenated. Gas which is mechanically held in solution has a tendency to diffuse into any atmosphere until it is present therein in a proportion corresponding to that remaining in solution. In this way the carbonic gas escapes from the blood. Again, gases separated from each other by a porous partition, diffuse into each other with a rapidity inversely proportional to the square roots of their densities. This law applies to the carbonic gas set free from the blood, and to the oxygen contained in the air on the other side of the lung membrane. Indeed, the exchange in question is promoted and not prevented by the intervention of the membranes of the lungs and the coats of the bloodvessels.

The composition of 10,000 parts of ordinary air, and the same quantity of expired air, respectively, is set forth in the following table :*

10,000 *Parts Ordinary Air.*		10,000 *Parts Expired Air.*
Oxygen	2,100	1,500—1,600
Carbonic Acid	4	470
Nitrogen	7,900	7,900

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[*] Huxley's 'Elements of Physiology,' p. 85.

The quantity of air that passes through the lungs of an individual in twenty-four hours varies with individual habits and bodily conditions. Dr. E. Smith gives from 804,780 cubic inches to 1,568,390 cubic inches; whereas Huxley, in his book already quoted, states that, taking no exercise, it is estimated at 350 to 400 cubic feet.

The water given off through the lungs in twenty-four hours has been estimated by Smith at an average of 311 grammes, or nearly 11 ounces, and the carbon (as carbonic anhydride) at from 7·144 to 11·7 ounces.

Oxidation in the human body is more active in youth than in advanced age; it is increased by cold and decreased by heat. Muscular exertion is the great incitive to active respiration, and by it the amount of carbon dioxide which is expired may be doubled or even trebled.

Asphyxia results whenever the amount of carbonic anhydride present in tidal air reaches 10 per cent.; but uneasiness and headache are caused when even less than 1 per cent. of the atmospheric oxygen is replaced by other matters. This is important, as indicating the necessity of keeping the air we breathe, and particularly that of sick-rooms, fully oxygenated; the smallest diminution in the amount of oxygen present in the air suffices to cause serious results.

Poisoning by carbon dioxide is rather the result of interference with the ordinary functions of oxygen than that of any direct action.

According to Huxley, every man, in order to be supplied with sufficiently pure air, should have at least a breathing space of 800 cubic feet, and that space should be in direct and intimate contact with the open air, as otherwise the oxygen originally contained in the air of the apartment becomes seriously diminished in quantity.

Of the total oxygen consumed by the body, about 85 per cent. is given off therefrom in combination with carbon as carbon dioxide, and the remaining 15 per cent. combines with hydrogen, and is given off as aqueous vapour, also in respiration. Altogether, then, we find that 26·7 ounces, or more than 1½ pounds, of oxygen are consumed daily by every adult. This weight of oxygen measures, at the ordinary temperature and pressure, no less than 529,400 cubic centimetres, or about 117 gallons.

The figures above given give a concrete idea of the process known as respiration, and lead to the perception that it is not adequately expressed by saying it maintains life. It is seen to mean something more than this; for if we take the quantity of oxygen absorbed daily by each individual, and multiply it by the number of the world's inhabitants, we shall obtain an astounding figure representing the sum total of oxygen daily removed from the atmosphere by human beings. Of course this quantity is increased by the amount also consumed by other animals and in other natural processes, and it at once becomes evident that there must exist some natural compensating process of restoration to the atmosphere of the oxygen thus removed, or otherwise in the course of ages the atmospheric proportion of this gas would get so small that life would become impossible.

Upon inquiry, it is found that plant life gives back to the atmosphere the oxygen which animal life takes away from it. It is a fact that the growth and development of vegetation depends upon its elimination of oxygen from the very carbon dioxide which animal life pours into the atmosphere. Priestley, who discovered oxygen, observed, for instance, that a pot of mint kept under a bell-jar containing air which had been rendered impure by breathing, influenced the air in such a way as to make it fit to breathe over again. In short, the mint decomposed the carbonic gas, assimilating the carbon and restoring the oxygen to the air. What mint did in this simple experiment is also performed by the green parts of all plants and vegetables, and particularly by the leaves. In this way the composition of the atmosphere is kept practically constant and universal.

Of course it will be understood that, although the composition of the atmosphere is of a fairly constant nature, yet its actual percentage composition is not entirely uniform. For instance, in the midst of a dense assembly of men in a room, there is found proportionately more carbon dioxide and less oxygen in the air than in fresh country air, in addition to its taint of organic matter ; but there exists a law of nature which militates against such circumstances, and eventually overpowers all such localized effects. If we mix castor-oil and water together, they will eventually separate, in spite of any amount of shaking, into two layers; but a similar behaviour is not observed with gases of different densities. Thus, if a heavy gas be brought into contact with a much lighter gas, the two will uniformly diffuse into each other, and will not afterwards separate. This power or force of gaseous diffusion serves to prevent any evils which might arise from variations in the composition of the atmosphere owing to local circumstances. In the vicinity of limekilns, as in the neighbourhoods of human habitations, much carbonic acid is generated into the surrounding air; but, instead of remaining in these localities, it is carried away by the power of diffusion, and uniformly distributed in atmospheric space. Aerial currents (winds) materially assist, of course, in carrying out this process.

If we consider that oxygen is truly what the ancient chemists termed it—viz., vital air—it is not surprising that a small animal should be able to live longer in a confined space filled with that gas than in an equal volume of air containing, as it doos, a large proportion of nitrogen. Nevertheless, oxygen cannot be breathed with impunity for any length of time; and, indeed, when inhaled in the pure state, it exercises a severe poisonous effect. The late M. Paul Bert, who devoted much time to the study of this subject, found that oxygen acts as a rapid poison when arterial blood contains 35 per cent.—that is, nearly double the normal amount; the convulsions and death which result are due to a great exaggeration of the excito-motor power of the spinal cord. Compressed air behaves similarly. In dogs convulsions begin when the external pressure of oxygen is about 3½ atmospheres, or 17 atmospheres of air, and death occurs at 5 atmospheres of oxygen.

As found, however, in nature, the oxygen of the atmosphere is diluted to a large extent with nitrogen, which is innocuous to health. It is by this dilution that the oxygen is rendered powerless to produce the evil results which follow when the pure gas is breathed, while its power to oxidize the matters presented to it in the blood is not in any way impaired.

Respiration is a sort of combustion, since the same kind of thing goes on in the two processes, and is attended with identical results; the only difference between combustion and respiration being one of outside conditions.

If the atmosphere consisted entirely of nitrogen, it would be just as impossible for a fire to occur as it would be for animals to exist, because combustible matters and the oxidizable matters present in the blood and the tissues equally require oxygen wherewith to combine. This process of oxidation or combustion is one which will have to be considered more fully hereafter, and the few words said about it here will pave the way for more important considerations.

Water and carbon dioxide are not the only excretory products which result from oxidation within the living body. Other excretory products are passed through other channels ; thus, urea, uric acid, and a number of allied compounds are carried away in the urine, and there is exudation through the skin. Now, if the requisite amount of oxygen cannot be obtained by the body, two evil consequences result : on the one hand, active oxidation is repressed and vitality is lowered ; and on the other hand, waste substances accumulate in the blood, instead of being carried off regularly, so soon as produced. Such a state of things inevitably leads to disease ; the tissues of the body do not obtain proper nutrition, and headache, palpitation, and hurried breathing are among the less serious results. Anæmia and consumption are among the diseases to which the regular breathing of air deficient in oxygen is conducive.

Ventilation is therefore designed to replace vitiated air with a fresh supply, care being taken at the same time to avoid a draught. From the results of some observations made by the late Dr. De Chaumont and others, the limit of respiratory impurity allowable is 2 parts of carbon dioxide per 10,000 parts of air over and above that which is ordinarily contained, viz., 4 parts. In other words, when air becomes charged with carbon dioxide to the extent of 0·6 per 1,000 parts, it is not longer fit for breathing. As on the average an adult exhales 0·6 of a cubic foot of that gas per hour, it follows that, in order to maintain the air of proper purity, fresh air must be admitted to the extent of 3,000 cubic feet per hour. It is not requisite to describe here the innumerable devices that have been made for ventilating purposes: they necessarily vary with circumstances and many local conditions.*

In practice it is found that in our climate the air of a living-room cannot be changed more than from three to four times in the hour without causing a draught. If, therefore, a room has a cubic capacity of 750 cubic feet, it should be changed four times in the hour; while if the cubic capacity be 1,000 cubic feet, it should be changed three times per hour. For hospitals it is better to allow a cubic space for each individual of from 1,500 to 2,500 feet. It is, of course, desirable, where practicable, to warm or cool the air, according to circumstances, before it enters the room; the inlet should be in the lower part of the room, and the distribution should be made as uniform as possible, so as to avoid the production of a draught; on the other hand, the outlet for the fouled and heated air should of course be in the upper part of the room.

Artificial ventilation may be effected either by extraction of the fouled air, or by propulsion of fresh air into buildings. As a rule, however, neither of these methods is required for ordinary dwellings, into which it is sufficient, as a rule, to make adequate provision for the admission of the fresh air from without, to replace the impure air that is within. The superior density of the air gaining admission, thus effects the replacement of the lighter foul air.

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* A description of some of the better-known forms of ventilators will be found in 'Laws of Health,' pp. 36-44, by the late W. H. Corfield, M.A. (Longmans, Green and Co.)

Three hundred cubic feet for each adult is the quantity of air-space specified in the Model Bye-Laws relating to Common Lodging Houses, while two children under ten count as one adult.

For our soldiers, an air-space of 600 cubic feet is allowed, and Allan* states that in consequence of this limited quantity, phthisis is very prevalent in the army. He also considers that the ideal initial air-space should be from 1,000 to 1,200 cubic feet for each person. In connection with this subject, it must be borne in mind that gas-flames use up oxygen in burning, and allowance must be made for this loss in calculating the amount of fresh air that should gain access to a room in a given time. Corfield† states that 'two hard candles or one good oil-lamp consume as much oxygen and give out as much carbonic acid as one man,' and that one gas-burner is as prejudicial in fouling the atmosphere in this way as four or five men. As a rule, a means of escape for the vitiated air is provided by the chimney or flue. No doubt the open fireplaces which are generally used in this country are wasteful of fuel and baneful when viewed with regard to the production of smoke in towns; but they are beneficial to the extent that by their use the air of dwelling rooms is kept in constant change.

These facts are sufficient of themselves to indicate the great importance of having dwelling apartments

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* 'Aids to Sanitary Science,' by Dr. Francis J. Allan. (Baillière, Tindall and Cox.)

† 'Laws of Health' (Longmans), p. 30.

properly ventilated; but they may be extended. It is known beyond all doubt that infection occurs through the air—that is to say, that the air may serve as the carrier of infectious material; and in proportion as the air is foul, the danger of infection increases, for the very foulness serves as food for the germs which indirectly produce many diseases. The poison of typhoid fever, whatever its nature, whether it be a living micro-organism (*Bacillus typhosus*) or a chemical compound produced by or in association with it, is particulate, and in the dry state it can float in the air and be sucked into the living body with the air we breathe. When the poison thus imbibed finds a home in the intestines, typhoid fever may result. The same is in all probability true of the cholera poison, and of other infectants. By efficient ventilation, if such poisons be present, they are either carried off from the immediate neighbourhood of our bodies, or the air containing them is diluted by the fresh air to such an extent that the poisons are robbed of their power to produce disease.

It will be shown in a later chapter that mere dilution serves also to kill disease germs that may be present in water.

It is with the view of preventing infection by the passage into the system of poisons floating unseen in the air that we resort to fumigations, and to the employment of respirators. By fumigation we seek to evaporate into the air chemical compounds known to be inhibitive to infectants, and by respirators we endeavour to strain off such infectants from the air we breathe, by means of a filtering medium, such as cotton-wool (preferably impregnated with a suitable disinfectant).

Air may be rendered impure in various ways. It is greatly polluted, as we have seen, by the breath of animals ; it is polluted by the chemical products that are evolved from decaying and putrefying animal and vegetable matters, and also by the micro-organisms which originate these processes and are themselves multiplied thereby. It is further polluted by the smoke which is emitted from fires in dwellings, and by sewer gas which often escapes from the ventilators that are attached to sewers in towns, and sometimes, too, from the closets in our houses.

The atmosphere in the neighbourhood of chemical works for the manufacture of soda is generally contaminated with hydrochloric acid, which substance is very destructive of vegetation, and liable to produce lung and throat troubles.

Carbon dioxide (CO_2), mixed with other gases, is of course given off from every chimney, and is produced by the burning of gas, coal, coke and wood, not only in dwelling-houses, but also in factories. When present in the air to the extent of 50 to 100 parts per 1,000, it is capable of producing fatal results, while even 2 or 3 parts per 1,000 generally produces headache and other indications of sickness.

Carbonic oxide (CO) is given off into the air from iron and copper furnaces, also from brickfields and cement works. It is an extremely dangerous substance, but fortunately, by reason of the natural law of diffusion of gases, it is rarely present in the air in any dangerous quantity.

Sulphuretted hydrogen (H_2S) is another very poisonous substance which is sometimes found present in the air. It is evolved from certain chemical works, and it is also formed in smaller quantities during the ordinary combustion of coal and coke containing sulphur.

Sulphurous anhydride (SO_2) is a very objectionable impurity of the air, and it is known to produce anæmia and bronchitis when present in any considerable proportion, while it is almost as destructive of vegetation as hydrochloric acid. It is not only given off from copper-smelting works, but also in the combustion of fuel in locomotives and furnaces. The air, for instance, of the tunnels of the Metropolitan and District Railway Companies in London was, until lately, largely impregnated with this dangerous gas.

Decay and putrefaction are processes that should not be allowed to proceed in the vicinity of human dwellings, for not only are some of the immediate products poisonous, but filth is known to afford the best nutriment to the micro-organisms which prey upon mankind. To prevent such processes from occurring in our midst we employ antiseptics and disinfectants.

The presence of smoke in the atmosphere is objectionable because it is unnatural, and because it causes irritation in the pharynx and air-passages of the lungs, through the introduction therein of matters for the disposal of which nature has not made any provision.

Closely related to the presence of smoke in the air is the production of town fogs, which prevail for the most part under the joint influences of a high barometer, freedom from wind, and a cold moist state of the atmosphere. Under these circumstances, the moisture is deposited in a particulated condition, and the particles aggregate and envelop the carbonaceous matters that may be present in the air at the same time. The increase of black fogs in London, Manchester, Glasgow, and other large towns, has been shown to bear relation to the increased consumption of coal. Such fogs are terribly injurious to animal and vegetable life, both by the stoppage of light as also by the toxic effects of the solid impurities and the sulphurous acid and other impurities that are locked up in them.

While fog prevails, the proportion of sulphurous acid present in the atmosphere is enormously increased, and according to experiments carried out by a committee of the Manchester Field Naturalists' Society, the ratio of the minimum to the maximum was determined as 1 to 26. During a three days' fog analytical observations proved that more than 1½ cwts. of sulphuric acid per square mile was deposited in the centre of Manchester, while at an outlying station 1 cwt. of the acid and 13 cwts. of 'blacks' per square mile were deposited in the same time. Such fogs are well known to cause a large increase in mortality from certain chest affections and anæmia, although Dr. Theodore Williams has alleged that persons suffering from bronchitic asthma have, in some cases, benefited from London fogs and the air of the Metropolitan Railway.*

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* This was before it was electrified.

Asthma is, however, a very capricious disease, and as Mr. Ernest Hart* then pointed out, such a factor has no serious weight in considering the influence of black fogs on public health — an influence which may be regarded as entirely bad in character.

As for sewer gas, when regarded as a contaminating ingredient of the atmosphere, it is not merely objectionable because it contains a number of ingredients poisonous in themselves; it is more especially to be dreaded inasmuch as it is liable to contain in suspension some of the micro-organisms, or their toxic products, which are known to be associated with communicable diseases. It is not too much to say that sewer gas should not be allowed to escape into the atmosphere of residential neighbourhoods at all, until it has been subjected to some treatment which has been proved to be efficient for the removal or destruction of the organisms to which reference has been made. Water-closets, as they were too often constructed in the past, served only, through their connection with the sewers, as ventilators thereto, and were instrumental in admitting direct into the air of dwellings the very poisons that are to be most dreaded. Where such arrangements cannot be readily remedied, we again rely upon the use of antiseptics or disinfectants to supplement the action of atmospheric oxygen.

The precise manner in which the oxygen of the air acts as a purifying agent is one which will be further studied in the next chapter.

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* See *British Medical Journal*, August 15, 1891, p. 372.

CHAPTER IV.

OXIDATION — PHYSIOLOGICAL COMBUSTION — NATURAL DECAY — FERMENTATION — PUTREFACTION —SANITARY BEARINGS OF THESE PROCESSES — MICRO-ORGANISMS AND THEIR RELATIONS TO THESE PROCESSES.

IN a previous place it has been pointed out that the processes of respiration and combustion may be regarded as identical in essence, both being of the nature of oxidation. It will be necessary here to define this latter process somewhat more fully, and to follow out its natural history.

Oxidation, then, may be said to occur when one substance gives up oxygen to a second one, and the substance which receives the oxygen is said to undergo oxidation; in other words, it is oxidized.

Charcoal, in burning, combines with oxygen from the atmosphere; it is oxidized, and the product of the combustion is carbonic anhydride, thus:

$$C + O_2 = CO_2.$$

If a jet of hydrogen gas be inflamed in an atmosphere of air or oxygen, oxidation also occurs, and water is produced, thus:

$$H_2 + O = H_2O.$$

Again, if any hydrocarbon, such as benzene or turpentine, be burnt in contact with sufficient air or oxygen, it undergoes oxidation, and yields water and carbonic acid gas as the ultimate products. For instance—

$$C_6H_6 + 15O = 6CO_2 + 3H_2O,$$
$$\text{and } C_{10}H_{16} + 28O = 10CO_2 + 8H_2O.$$

In the same way, every organic substance which exists in nature or can be produced in the laboratory, is amenable to this process of combustion. It is only necessary to properly mix the substance with something capable of giving up oxygen, or to subject the substance to a current of air or oxygen at a suitable temperature, in order to decompose it by the act of oxidation which always results in the production of carbonic acid and water.

Of course, substances like sugar, which contain some oxygen as a constituent, require relatively less oxygen to burn than they otherwise would, since the self-contained oxygen serves, in a measure, to consummate the process; thus, sugar, in burning, becomes oxidized as here represented:

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O.$$

It is seen that if the sugar contained no oxygen in itself, its carbon and hydrogen would require 18 atoms of extraneous oxygen for perfect combustion, instead of 12, as is the case.

Even with carbon compounds of the greatest complexity, as also with organic substances of animal and vegetable origin, the law of combustion holds good. For instance, albumin—which contains, besides carbon and hydrogen, nitrogen, sulphur, and oxygen, is, during combustion, similarly decomposed. The carbon forms carbonic anhydride; the hydrogen forms water; the sulphur forms sulphur di-oxide (SO_2), (and finally sulphuric anhydride SO_3); the nitrogen may be also oxidized, at least in part.

These, then, are the changes which organic compounds undergo when burnt or combusted in air or oxygen.

Respiration is combustion under different conditions and at a lower temperature; and in this process a number of carbon compounds, or waste products of the living body are, in the blood or tissues, converted by oxidation into carbonic anhydride and water, which are given out in the breath. It must be observed, however, that this process does not take place with the living matter of the body, or, at least, it has not been proved to take place therewith.

The actual process of physiological combustion is one about which there has been a deal of dispute. While Carl Voit* insisted that oxidation in the body results as a consequence of tissue decomposition, and forms products by the combination of the inspired oxygen with the substances resulting from tissue change, other physiologists, such as Hoppe-Seyler,† maintain that the combustion of albuminous matters in the organism takes place in the living cells of the tissues, and not in the lymph in which they are bathed, or in the blood, as held by others.

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* *Zeitschrift für Biologie*, viii. 297-388.

† *Pflüger's Archiv*, vii. 399-428.

The bulk of evidence seems to be in favour of Voit's opinion, that the primary cause of tissue change is due either to ferments or some inherent cause which results in the production of certain proximate products of change, and that these being liberated into the juices of the body, combine with the oxygen there presented to them.

However that may be, it is accepted as generally true that no organic tissue, whether it forms part of a vegetable or an animal, is subject to oxidation while it is vital. But, apart from the component parts of living tissues, there is no organized substance which can resist the process of oxidation as it is carried on in nature.

While life lasts, vital substances are protected from ordinary chemical influences of the kind under consideration, by reason of the concatenation of forces called vitality which govern their molecules; but when these combined forces are sufficiently disturbed, disease results and when they are annihilated then death ensues, and the matter which was previously invincible by air and moisture now succumbs to their and other influences.

Respiration involves a rapid process of oxidation (seeing that 8·5 ozs. of carbon are daily oxidized in the body), but is a slower one than that of ordinary combustion, and ordinary decay is very much slower than respiration. Nevertheless, it acts universally, and is omnipotent in its results.

In many places where mighty forests once stood, and where the soil must have been heavily impregnated during countless ages with humus and loaded with vegetable substances, there can now be found no trace of organic remains. It is said that a few years suffice to clear the soil once occupied by the primeval forests of America of organic matters.

Under ordinary conditions, humus slowly decomposes, and the carbonic anhydride and other products are absorbed by the roots and other parts of plants, and converted into starch, gum, sugar, etc.; but if the plant life be cleared away, then the access of air to the soil is facilitated, and the molecules of organic matter are rapidly acted upon by the air and moisture, and leave the soil as carbonic anhydride and water.

The same process of slow oxidation occurs in cemeteries, where the dead bodies are gradually burned up, leaving only their mineral parts behind in the earth.

Naturally, there are conditions which specially favour this process, as well as others which militate against it. Eremacausis (as Liebig termed it) proceeds most favourably in the presence of water, and at a slightly elevated temperature. On the other hand, if the access of air be limited—as it is, for instance, in a clay soil—then (as compared with a sandy soil), the process goes on comparatively slowly. Accordingly, it is found that under such conditions, or where the air has been entirely precluded, organic matter may exist for a very long time. Thus, it is a matter of common knowledge that dead bodies may be preserved to a large extent from decay by a method of embalming and wrapping, which keeps away the air, moisture, and micro-organisms, which are so essential to slow oxidation. Indeed, the very existence of a mummy is, in its way, the best negative proof that could be submitted of the power of slow decay.

This marvellous process of oxidation is of infinite importance. By its action, the remains of animal and vegetable life are converted into the carbonic acid and water that are so necessary for plant life, and this, in its turn, gives back to animal life the oxygen which is essential to it. Thus, the round of nature's operations is completed, and living matter is continually and for ever being reproduced from the same original substances.

The process of natural decay, however, does not complete itself in one direct step, and this it is very important to understand. That is to say, compounds of vegetable and animal origin are not, by mere contact with the air, resolved by one direct step into carbonic anhydride and water. This undoubtedly occurs in combustion — at least, for all practical purposes, it may be assumed so to do — but it is otherwise with eremacausis. That process is gradual, and it occurs in several steps or by degrees.

In some cases, the oxygen of the air so influences organic matter that, by its combination, two or three or more distinct substances result, and only one or all of these may be subject to a further degree of oxidation, and each may take a different time to fully undergo the process.

Again, a complex substance such as albumin (white of egg) may be split up, by certain influences (as by hydration), into several distinct substances, before the oxygen of the air exercises any action whatever. That action, however, afterwards sets in, its work being concerned with the derived or secondary compounds thus ready prepared for its effects.

To make this clearer, it may be stated that when white of egg or blood albumin is boiled in the laboratory with certain reagents (maybe under a little pressure or otherwise), it is resolved into a number of distinct substances, all of which undergo oxidation if they are then exposed to suitable influences, giving rise to quite a new (second) series of substances; and these again can, by suitable means, be finally resolved into carbonic anhydride and water.*

No doubt, within the body (in respiration) and in other phases of nature, these conditions obtain, since within the body there are ferments, which serve the purpose, while widely distributed in nature there are very low forms of life (micro-organisms), both of which agencies are of sufficient influence to split up albumin into a number of proximate constituent principles before the air (or oxygen) has exerted any kind of influence. Indeed, it appears from the lifelong labours of Pasteur and others that the process of slow decay of organized substances really depends upon the development of organisms in their interior or upon their surface, and that in the absence of such organisms decomposition cannot occur.

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* Here, of course, for the sake of argument, we are only dealing with the carbon and hydrogen.

Just as the acetification of wines and beer depends upon vegetable growths (such as *Mycoderma aceti*) which possess the property of exciting oxidation in the solutions into which they may be introduced, so all other processes of slow combustion depend upon similar causes; and here we get a glimpse of the utter inutility of using agents like carbolic acid and other strong germicides in certain circumstances for the destruction of such living forms. For they are ubiquitous, and have a great function: it is their natural province to cause slow oxidation in refuse matters—that is to say, in matters of animal and vegetable origin; and if we could by any possible means exterminate this branch of natural beings, we should interfere with the way which was created and intended to serve as the greatest sanitary measure for human welfare. We may, however, rest assured that this is not possible.

Putrefaction is a somewhat different process, although it is allied to slow oxidation. The germs which initiate putrefaction cannot exist in the free presence of oxygen, and, as we shall see hereafter, the chemical act which they perform is not one of oxidation, but, so far as has been ascertained, only a splitting up by hydration (absorption of the elements of water).

Since, in the first edition of this work, the processes of slow decay and putrefaction were emphasized as the grandest natural measures afforded by Providence for the disposal of organic matters, the same subject was discussed by the late Dr. Angus Smith, who took up the consideration of this subject in an address delivered before the Sanitary Institute in 1883. Speaking of the impurities that pollute the Clyde, and of the population that has grown up along the banks of that river, he said, 'If nature 'has contrived no method of destroying such seeds 'of death, populations such as this is would never 'have grown up. And what is the method? The 'method, is, first, putrefaction; at least, I know of 'none other, except the concluding portion of the 'work—viz., thorough oxidation. When, therefore, 'you see the Clyde seething with gases of putrefaction, 'and when you smell it to such an extent that a 'feeling of loathing is produced, you may remember 'this—that the work of destruction is going on with 'a wonderful rapidity, and that the enemies of life 'are being slaughtered there, millions upon millions, 'never to appear again in a similar form, though other 'generations of them may rise up.'

It is not to be assumed that putrefaction *must* be the preliminary step to all processes of natural oxidation. Dry rot in wood is not preceded by putrefaction, and yet it is an active process of atmospheric oxidation carried on through the agency of micro-organisms. Again, the fermentation of alcohol into acetic acid is a process of oxidation carried on directly by the action of a cryptogam of the genus *Mycoderma*, and it is typical of a number of processes initiated by living organisms, which serve as media between atmospheric oxygen and the fermentable matter.

While, therefore, it is to be admitted that putrefaction often, and very largely, precedes the oxidation of organic matters, it does not necessarily precede it. There are many other processes of fermentation carried on by the life-agency of micro-organisms which equally suffice to prepare the subject-matters for thorough oxidation.

In any case, putrefaction is a process which should not be allowed to proceed in and about human dwellings, because many of the intermediate chemical products are poisonous in character and are capable of producing disease in man. The process is a sanitary one in its ultimate results when it is carried on at a proper distance from the dwellings of men, but only direct processes of oxidation should be allowed to proceed in and around our dwellings.

The chemistry of putrefaction will be studied more intimately in a later place, but it is worth while adding here, that sewage intended for use as manure is injuriously affected by putrefaction, for the process causes, and indeed is correlative with, a loss of valuable substances, and that process constitutes the best preparation for a further loss of value by the more direct and rapid process of ultimate oxidation which it induces.

Now, whatever oxygen, as air, is capable of doing in nature, in the shape of harmless oxidation, ozone and peroxide of hydrogen can do much more actively. Whereas air is a mixture of gases containing only 21 per cent. oxygen, ozone is many times more active than even pure oxygen; moreover, when present in sufficient amount, it is fatal to those particular low forms of life which cause putrefaction, as also to others which are very intimately concerned with the production of disease. In support of this, it may be mentioned that Tyndall found that when infusions of highly putrefactive matter were subjected to the action of ozone, they remained quite sterile, while the action of condensed air neither prevented their putrefaction nor kept them free from germ life.

Peroxide of hydrogen also contains oxygen in a powerful and active form: it no sooner comes into contact with oxidizable matters than it at once gives up its oxygen to them, in not only a pure but also a nascent state; and be it remarked that this is, universally, the most active state of gases. Moreover, owing to its liquid form (its wetness, so to write) it is particularly qualified to come readily into absolute contact with substances. It has also been shown that peroxide of hydrogen is fatal to many kinds of germ life, including those known to the associated with the production of certain specific diseases. Putrefaction cannot occur in animal or vegetable substances protected by it.

The influences of ozone and peroxide of hydrogen in nature, and so far as they concern sanitation, will be more fully discussed later on; here it is sufficient to point out that, as compared with the atmosphere, and weight for weight, they act far more rapidly and powerfully as oxidants. The importance of this fact becomes at once apparent when we consider that, although some germs cannot live without oxygen, yet when it is presented to them in the form either of ozone or peroxide of hydrogen, they are either killed, or else prevented from carrying out their normal functions in compounds of an animal or vegetable origin. Septic organisms certainly cannot exist in the presence of peroxide of hydrogen.

It has been already stated that there are degrees of oxidation. If turpentine be heated in contact with water and a stream of air, it suffers a change of a definite kind, but it is one which is gradual, and, amongst other products, peroxide of hydrogen is produced; but if turpentine be heated with nitric acid (also an oxidant, but far more violent in its action than air) it suffers a radical and quick change; the whole of the oil disappears in course of time, and if continued sufficiently long, the process gives only carbonic acid and water as ultimate products.

Now let us pass from turpentine to albumin. If this substance be exposed to the air, it softens, and by the united action of water and air (under the primary influence of ferments) undergoes the complex process termed putrefaction which is attended with the production of a number of substances, some of which are known, and some of which have not been determined. In course of time, however, the putrefaction passes away, and oxidation proceeds further, until the whole of the mass is oxidized into ultimate products. But if the albumin, instead of being exposed merely to the air, be boiled with dilute nitric acid, the end result is reached in a period of time which is infinitely more brief than that occupied by the more natural process of destruction.

Ozone and peroxide of hydrogen being similarly stronger agents of oxidation than the air, although not destructive and caustic like nitric acid, have also the power of preventing the putrefactive process to which allusion has been made; or if that process has already occurred, then of burning up or oxidizing its products which are of a noxious character.

If, now, it be reflected how much matter of animal and vegetable origin is given back to nature—and particularly among human populations—for disposal in a way which shall restore their elementary principles to a useful purpose without the attendance of disease, we obtain an appreciation of the importance of the process of oxidation, and can see why, at particular times and in special places, peroxide of hydrogen and ozone, both of which substances are generated naturally, should exercise notable and beneficial influences.

Putrefaction is a process of such vast importance that it is necessary in this place to bestow upon it some little further special study.

In the first place, it may be remarked that the number of putrescible substances is not great, but they are universally distributed, derived, as they are, from every organized being. Indeed, putrescence is a property almost or quite exclusively confined to the albuminous substances of which the flesh of animals is mainly composed, and which also enter into the composition of vegetable matters. It is these very substances which succumb most readily to decomposing influences. To understand this subject clearly, it must be borne in mind that no kind of substance has an inherent tendency to change except real living germinal matter. No distinctly chemical substance has any tendency to change, although we often speak of certain substances being unstable, or having such a tendency. What is really intended is to express the fact that some matters are more sensitive to extraneous influences than others.

Albumin is a chemical substance which, like all other chemical substances, exists in virtue of certain forces of combination acting between its constituent atoms; and by protecting it from outside attacks, it may be kept unchanged for an indefinite length of time. But when it is exposed to ordinary air in the presence of water, it is open to the attacks of certain low forms of life which abound in both, and to which it becomes pabulum, and under their initial influence putrefaction sets in, and oxidation into ultimate products ends the history.

Liebig knew very well that if blood be protected from the air it does not pass into putrefaction; but he was wrong in supposing that it was the air itself which caused the blood to putrefy in course of time. It is not the air, but something which is in the air—viz., germs, or minute forms of life (micro-organisms or microbes)—which are invisible to the naked eye under ordinary conditions, but which are known to form part of the motes to which a ray of light passing through a darkened chamber owes its visibility (*Tyndall*). That this is so was well confirmed in some later experiments made by Lister, in which he demonstrated the fact that newly-collected blood or milk neither coagulates nor putrefies if care be taken, while collecting it, to exclude the presence of the micro-organisms which are contained in ordinary air. This may be done in several ways well known to scientific men. Air can be sterilized or freed from its contained living matter either by heating it to a temperature sufficiently high to destroy it, or by filtering it through plugs of cotton-wool, the meshes of which retain the micro-organisms.

Recent researches have shown that germ-life is ubiquitous, and embraces a great variety of species, so that the atmosphere is ordinarily loaded with a large number of forms. Accepting, therefore, the views of Pasteur, who devoted a large part of his life to such studies, and taking blood serum to illustrate a putrescible substance, the history of putrefaction may be thus described: one or more micro-organisms (vibriones) fall into the fluid, and by feeding in the medium which is suitable to their development, they propagate their species. Since they live upon the albumin which is in the serum, they thereby decompose it, splitting it up into a variety of products. Simultaneously, a film of other micro-organisms forms on the surface, due to the casual introduction of other germs (bacteria, mucors, and mucidines). Now, the life act of the vibrione is the impulse requisite for the decomposition of the albumin —for the initiation of putrefaction—and it may be fairly compared with the power of the liver to prepare bile from the albumin presented to it in the blood. It is even conceivable, if not probable, that the vital function of the vibrione is one of hydration (fixation of water)—that is, an act which results in the same products, or some of them, as are obtained when albumin is boiled in the laboratory—say, with baryta water or dilute sulphuric acid.

Oxygen is more or less fatal to the vibriones which are here mentioned, but being beneath the surface of the fluid, they are practically protected from its action. On the other hand, the bacteria which grow on the surface of the serum require oxygen for their very existence, so that they excite and accelerate the slow combustion of the first products which are generated by the initial impulse communicated by the vibriones to the albumin. As a final result of these changes vibriones and bacteria also die, pass into putrefactive change, and become oxidized with the rest of the matter.

Now, the particular forms of life which thus induce putrefaction, and those other living germs by whose agency slow combustion is eventually carried out, are, apparently, quite harmless in themselves when present in their ordinary numbers and environment, since, being ubiquitous and freely inspired with the air we breathe and contained in the water we drink, no evil result is produced. Nevertheless, vibriones can convert serum of blood, which is perfectly harmless when fresh, into a poisonous mass. It was shown by Panum and Burdon-Sanderson that putrilage. even when absolutely freed from every kind of germ-life, yet contains a particular chemical product which, if introduced into the blood system of animals, produces septicæmia.

The reader, to thoroughly appreciate the meaning of these facts, which have been ascertained with extreme care and with great precision, must keep his mind free, for the time, from all other considerations. Here a clear issue is presented: germ-life, harmless in itself under ordinary conditions, produces in the process of putrefaction a blood or septic poison. Whether this is the direct consequence of a vital act—the septic poison thus resulting as a chemical product of the pabulum consumed — or whether, as seems more likely, the organisms secrete a ferment which does all the chemical work, has not yet been satisfactorily decided. Such a chemical ferment or secretion may possibly have for its function the preparation of the dead matter as pabulum for the organisms, just as gastric juice prepares food for assimilation in the human body.*

Hereafter, more particular attention will be paid to the subjects of germs and infectious diseases.

In concluding this chapter, it is only proper to once more emphasize the great extent to which we are indebted to Pasteur for his masterly researches on putrefaction and fermentation. It is no exaggeration to say that we owe the larger part of our knowledge of these processes to his investigations. It was in 1863 that he defined† putrefaction as a fermentative process induced and sustained by animal ferments derived from members of the genus *vibrio*, a definition which received confirmation from Traube and Gscheidlen‡ (among many others) in 1874.

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* See Dr. Drysdale's Essay on the Germ Theories of Infectious Diseases, pp. 5 and 6.

† *Compt. Rend.*, lvi. 1189; *Jahresb. f. Chem.*, 1863, 579.

‡ *Dingl. Polyt. J.*, ccxxii. 352.

More recently, Pasteur found it desirable to divide micro-organisms into two large classes, which he designated *aerobies* and *anaerobies*. The first class require for their growth the presence of oxygen; while the second group can entirely dispense with it. Thus, as has already been shown, septic vibriones are killed by free oxygen and, in point of fact, putrefaction cannot be induced in a substance until certain other organisms (mucors) have first of all used up any oxygen which may be present. It was my privilege to confirm the general history of putrefaction and oxidation, as herein related, by some special experiments, of which a description was communicated to the Chemical Society in 1880.* The results of a later investigation which I made concerning micro-organisms in relation to the chemical processes which they are capable of initiating will be found in a later chapter.

Finally, it must be remembered that slow oxidation or eremacausis is a process which must be deemed to occur in nature apart from putrefaction, at least in most cases. The two processes are in essence quite distinct and depend upon entirely different micro-organisms, although at times, undoubtedly, putrefaction either precedes or progresses simultaneously with slow decay.

Sanitary science cannot materially interfere with nature's grand law of slow combustion; but it can and does aim at preventing putrefaction, together with all the evils that are apt to follow in its train

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* Contributions to the History of Putrefaction, Part I., *Journ. Chem. Soc.*, January, 1880.

from occurring in or near human habitations: when it takes place far away from populated places, putrefaction itself must also be considered as a sanitary process of the very first order.

The use of chemical substances for preventing the process of putrefaction in or near our homes is a subject which will be considered at some length in another part of this work. Many of the substances selected for this purpose act as direct poisons to the micro-organisms which induce the process; others render the substances upon which they prey and would otherwise putrefy, unfit food for them and so on. It will, however, be seen that the use of germicidal disinfectants for the purpose of preventing putrefaction is absolutely inexcusable and valueless apart from the main object of conserving the health of the people.

In other words, the use of germicides as applied to organic refuse generally is not to be advocated but to be deplored, inasmuch as they postpone or prevent its desirable destruction by the processes of nature. In fact, the use of germicides should be restricted to preventive measures necessary in surgical operations and infectious cases, and even then it is advisable to employ them on a strictly limited scale.

CHAPTER V.

RAIN WATER—SPRING WATER—SEA WATER—RIVER WATER—WATER SUPPLY—SEWAGE CONTAMINATION—OXIDATION IN RUNNING STREAMS—MICRO-ORGANISMS AND WATER—NATURAL PURIFICATION OF RIVERS—THAMES WATER—PURIFICATION OF DRINKING WATER—FILTERS—CHEMICAL EXAMINATION AND ANALYSES OF WATERS.

WATER is not found in nature in a perfectly pure condition. Its solvent powers are so great that it dissolves from the atmosphere and from the earth, a variety of substances which, from a strictly chemical point of view, must be viewed as impurities—that is to say, they have nothing to do with the composition of water as such, and are, indeed, foreign to it. Nevertheless, they are not necessarily objectionable from a sanitary point of view.

Rain water collected after some continued fall, is as nearly pure as it can be found in nature, but even then it contains about 2½ volumes of air dissolved in each 100 volumes by measure. Such rain water is to be regarded as practically pure, and it is a great pity that its collection for domestic employment is not more extensively carried out.

The earlier fall of rain water which is collected after dry weather, is contaminated with traces of nitrates and nitrites, some free ammonia and salts of ammonia, and some organic impurities; but none of these impurities are of very serious moment, and efficient filtration would make such rain water quite fit for many purposes, while the later collections would be perfectly safe for drinking use.

After water has once come into contact with the soil, it becomes a solution of a number of saline substances which are contained therein, and it may also take up, from animal and vegetable sources, a considerably larger proportion of organic matter. The nature of the salts thus entering into solution depends, of course, upon the character of the soil, but among the most usual impurities are chloride of sodium (common salt), carbonate of calcium (chalk), sulphate of calcium (gypsum), and sulphate and carbonate of magnesium. The increase in the quantity of nitrates and salts of ammonia found present in town waters results from contamination with decaying organic matters or with sewage in course of oxidation.

Most spring waters are charged with a considerable quantity of carbon dioxide, which increases the solvent action of the water in respect of calcium carbonate. This explains why the waters derived from calcareous springs around London contain from 18 to 20 grains of chalk per gallon; this quantity is diminished upon exposure to the air, as during such exposure, some of the carbon dioxide escapes from the water, thus causing the precipitation of part (amounting on the average to one-third) of the chalk. The so-called 'hardness' of water is due to the presence of these dissolved substances collectively, and in the main to the mineral constituents. The mineral (inorganic) constituents, however, are otherwise comparatively unobjectionable in drinking-water; it is the organic matter that more often renders the water unfit for potable purposes. A general support is given to this statement by the well-known fact that so-called 'mineral' waters are taken on account of their reputed medicinal value, which is due to the salts that are present in more or less large quantities.

Of course it is not to be understood that all mineral constituents are harmless; their nature and quantity have to be considered. Lead and copper are very objectionable, and even salts of magnesia and calcium may be present in unsafe or undesirable amounts.

Still more largely impregnated with dissolved salts is sea water; this has a specific gravity of about 1025 to 1027, and contains very large quantities of common salt and chloride of magnesium. The water of the British Channel contains 28·05 parts of common salt, 3·66 parts of magnesium chloride, and 4·7 parts of other mineral substances in each 1000 parts.

River water is of the greatest importance from our point of view, since it is from rivers that most of our large populations derive water for drinking purposes. It often contains less saline matter than spring water, but is much more liable to be contaminated with organic matter derived from the extensive tracts of land which are drained into it. This organic matter is partly suspended and partly dissolved. The coarser suspended parts (weeds, fish-spawn, leaves, twigs, grass, and fine mud) can be readily removed by subsidence and filtration, but ordinary filtration does not materially affect or remove dissolved organic matters, and is not supposed to remove micro-organisms in any great numbers, although they are in suspension.

The further elucidation of this subject may be as well carried out by taking up the study of Thames water, from which the London water supply is mainly taken.

The Thames is liable to contamination from persons who occupy house-boats during the summer, and who bathe in the stream; also by the dogs and other animals that are washed and drowned in it; it also derives a great deal of organic matter from the land on its banks, and particularly after the application of night-soil and other manures thereto, followed by a downfall of rain. Further, and chiefly, it is polluted by the treated, partially treated, or wholly untreated sewage of towns which in the upper Thames basin alone had, some years ago, a collective population of 72,628 persons, and the treated sewage of towns with a total population of some 196,593 persons. The treatment of sewage, as here referred to, means the removal therefrom of the whole of the suspended matters, but it does not, in the main, affect the composition of the liquid part (effluent) which is subsequently discharged into the river.

At first sight, it would appear reasonable to condemn such a river as the Thames, as the chief source of the water supply for London off-hand, upon the mere evidence that sewage is conveyed into it, but the analysis of the water which is actually delivered does not lend strong confirmation to this view; for the total solid matters contained in the water amount to about only 28 parts in 100,000, and of this quantity only 0·174 consists of organic carbon, and 0·031 of organic nitrogen; that is to say, the organic substances present in 100,000 parts of the water furnish, upon analysis, the recited quantities of carbon and nitrogen.

The dissolved organic matter in potable water rarely amounts to more than from $\frac{1}{5000}$ to $\frac{1}{1000}$ of a per cent., and it cannot be pretended for a moment that anything more than a minute fraction of this small quantity is of a living nature; the bulk of it is certainly innocuous.

The following table is taken from a paper by Odling:*

MEANS OF EIGHTEEN MONTHLY ANALYSES, 1883-1884.

Source.	Proprietary.	Organic Carbon.		Organic Matter.
		Parts per 100,000.	Grain per Gallon.	Grain per Gallon estimated.
Chalk Springs - -	Kent Company - -	0·047	0·033	0·083
River Lea and Springs	New River Company -	0·087	0·062	0·156
Mixed - - -	Birmingham Corporation - - -	0·132	0·093	0·231
River Lea - - -	East London Company	0·139	0·098	0·245
Loch Katrine - -	Glasgow Corporation -	0·147	0·103	0·257
River Thames - -	The Five Companies -	0·164	0·115	0·286

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* *Journ. Soc. Arts*, vol. xxxii., p. 934.

A consideration of these analytical figures shows that the organic impurities present in Thames water amount to barely twice the quantity which is contained in unpolluted waters, and the conviction is forced upon us that some great system of purification must be at work in the River Thames, and, indeed, in all running streams.

One of the opinions of the River Commissioners, expressed in their Sixth Report, was as follows: 'Rivers which have received sewage, even if that sewage has been purified before its discharge, are not safe sources of potable water.' It is our province in this chapter to seek to ascertain wherein lies the danger, or whether that opinion is not to be accepted as representing the truth.

There can be no doubt of the fact that the Thames is heavily contaminated throughout a great part of its course with organic matter (say sewage). How is it, then, that the water taken from the river, and delivered for consumption in the Metropolis, is so comparatively pure, anyhow as regards the actual quantity of foreign substances present therein? No doubt, a very large proportion of the solid parts of excremental matter carried into the river becomes deposited upon the bed of the stream and upon its banks, while the soluble impurities are diffused in the mass of the water, which is diluted from time to time by heavy falls of rain; for it must be remembered that the Thames drains an enormous area of country, and, although it receives impurities throughout its course in consequence, it also receives continually increasing quantities of comparatively unpolluted water derived from the rainfall. This water is naturally aerated—that is to say, it contains dissolved oxygen; and then, again, the water in the river is exposed over its whole surface to the atmosphere, and being a running stream, new surfaces are being continually brought into direct contact with the oxygen of the atmosphere. Under these circumstances, oxidation rapidly proceeds by the operation of those laws which have been described in some detail in a previous chapter, and its progress is at least comparable with the rapidity with which nitrification takes place in soils which are laden with organic refuse. Further, it must be borne in mind that the vegetable growths which line the banks and bed of the river, as also the fish which inhabit the water, and the birds and winged insects which resort to the water for food, all act as scavengers to the stream, and assist in its purification.

That oxidation does proceed in the manner referred to, is best proved by the analysis of Thames water as delivered to the consumers. The late Dr. Meymott Tidy endeavoured to obtain direct evidence upon this point;* and while he, in my opinion, claimed too much for the process—that is to say, he sought upon several occasions to credit the process of oxidation with an amount of work it cannot perform in a given time—yet he materially assisted the education of the public upon this important subject. In his experiments he employed 'a series of twenty troughs each 10 feet long, and constructed of two pieces of wood joined together at a right angle. Each trough was so placed that it

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* *Journ. Chem. Soc. Trans.*, 1880, p. 307.

had a fall of 1 inch, the water from one trough being discharged into a second placed under, but a few inches distant from it.' Subsequently, he was compelled to line the trough with glass, and to take many precautions to keep out 'blacks' and other impurities. In one of his experiments water was allowed to flow from a cistern placed above the uppermost trough, over the entire length of troughs, and then pumped up again to the highest trough, and so forth. In this way six gallons of New River water, containing 5·55 per cent. of added sewage, travelled one mile in 8½ hours, the temperature of the air ranging from 57° to 64° F., and that of the water from 55° to 61° F.

Analysis:

	Oxygen required.	Organic Carbon.	Organic Nitrogen.	Chlorine grains.
		Parts per 100,000.		
Before experiment ...	0·391 grain.	0·436	0·156	1·40
After experiment ...	0·181 „	0·274	0·100	1·44
Results	−0·210 „	−0·162	−0·056	+0·04

These results and those of other experiments may be accepted as giving evidence of the oxidation which proceeds in running water freely exposed to the air, but at the same time it cannot be accepted as substantiating the statement said to have been made by Dr. Tidy, to the effect that the polluting matter from sewage entering the river Colne was 'entirely destroyed after proceeding half a mile.' I think this statement represents a very great exaggeration of the power of atmospheric oxidation, and I say this advisedly, having paid much attention to the study of various processes of air-oxidation.

In a communication* to the Chemical Society in 1880, I brought forward some experimental evidence as to the manner in which organic matter present in water is gradually destroyed by the agency of micro-organisms, and I endeavoured to show by analytical figures that the primary chemical act of putrefaction thus induced is one of hydration, the secondary change being one of oxidation carried on by the agency of a distinct class of micro-organisms. Later on, when the subject of water supply was prominently before chemists, I described in another paper† some further observations of the same class, and also an experiment the result of which gave support to Dr. Tidy's experimental results above recited.

An aqueous extract of meat was allowed to pass into putrefactive decay, and periodically its oxygen-absorbing capacity was experimentally determined. Expressing the results in grammes and gallons, it was found that, whereas at the start (when fresh) a gallon of the extract used up 6·656 grms. of oxygen (from the oxidizing agent employed), after thirty-nine days a gallon only used 5·79 grms., and after 155 days only 3·243 grms. The diminution in oxygen thus consumable indicates the amount of oxidation which had proceeded in the meantime, the oxygen being absorbed from the air. A current of air was now blown through a quantity of the putrid extract during twenty-four hours, after which it was found that the oxygen-absorbing capacity had fallen per gallon from 3·243

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* *Journ. Chem. Soc. Trans.*, 1880, p. 15.

† *Chem. News*, vol. xli., p. 254.

grms. to 2·234 grms. oxygen. The difference represents oxygen used up from the current of air during the twenty-four hours.

That sewage, therefore, will under ordinary circumstances be destroyed in a river cannot be disputed. It is only a question of time, temperature, churning (with consequent exposure to the air), and length of the river. It is, however, of the greatest importance to bear in mind the fact that this destruction primarily depends upon the life of certain organisms; indeed, if they be absent, or if they be killed by the application of powerful germicides, the destruction of the organic matter will be postponed, the chief condition requisite for purification being wanting.

Although the oxidation of organic matter dissolved in water is carried out through the agency of micro-organisms, oxygen itself is, of course, primarily necessary as a correlative part of the phenomenon, and in connection with this subject I may quote some figures employed upon one occasion for illustrating the same truth, by Odling.* At a summer temperature of 70° F. water contains 1·8 cubic inches of dissolved oxygen per gallon, and 2·2 cubic inches at a winter temperature of 45° F. The smaller quantity thus held in solution amounts to 2·58 tons of oxygen per 10,000,000 cubic feet of water, and the larger quantity is 3·16 tons. According to another calculation that has been made, 64,000,000 cubic feet of water pass through

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* In a lecture delivered before the Royal Institution on May 16, 1884. See abstract in *Pharm. Journ.*, May 24, 1884.

Teddington Lock in each twenty-four hours during dry weather, and this contains 17¼ tons of dissolved oxygen; by the time this body of water reaches Somerset House it is found to have lost from 12 to 13 tons of oxygen and this loss is supposed to represent the quantity used up in the meantime in the oxidation of sewage matter.

In connection with the subject of the self-purification of water, some observations which were made by Dr. Pehl* upon the water of the Neva are of some interest. This water is stated by him to be poor in bacteria, since it contains only about 300 germs in each cubic centimetre, but after heavy rains the number rises to 4,500 and during the thawing of the river to 6,500. On the other hand, the water in the canals of St. Petersburg which are fed with the water from the Neva, is infested with bacteria, their number reaching 110,000 in a cubic centimetre even in good weather. At the same time the chemical composition of this water is nearly identical with that of the Neva. He explains this anomaly upon the assumption that the purification of water is to be attributed in some measure to its rapid motion, and in order to test the matter he brought water into rapid motion (presumably in contact with air) by means of a centrifugal machine during one hour, and found that the number of developing germs was reduced by 90 per cent.

Personally, I do not attach any very great value

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* Abstract of a paper in the *Journal of the Russian Chemical Society*, given in *Sanitary Record*, vol. v., p. 597.

to such bacterioscopic measurements, although it must be understood that by this remark I do not seek to throw any discredit upon the observations of Dr. Pehl. I rather wish to emphasize the fact that such bacterioscopic measurements may be exact or inexact; there is great doubt about the matter on account of the minuteness of the objects, their possible aggregation, and the very small quantities of materials that are operated upon.

It is different, however, with the larger animals met with in fresh water, a subject which was studied by Sorby,* who endeavoured to ascertain the number contained, per gallon, of the various small animals which are large enough not to pass through a sieve, the meshes of which are about $\frac{1}{200}$ part of an inch in diameter. The chief animals met with in fresh water are various entomostraca, rotifera, and the worm-like larvæ of insects, and he found that the number per gallon and their percentage relationships mark in a clear manner changed conditions in the water, 'the discharge of a certain amount of sewage being indicated by an increase in the total number per gallon, or by an alteration in the relative numbers of the different kinds, or of both.'

Entomostraca will eat dead animal matter, and Sorby kept them alive for many months by feeding them on human excrement, while they soon died without it; this fact, however, must not be taken to indicate that they are entirely dependent upon it. Now, although, as in the case of larger animals, a

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* *Journ. Soc. Arts*, vol. xxxii., p. 929.

considerable part of their own excrements must consist of putrescible organic matter, there can be no doubt that the amount of sewage matter they consume is very great, and as a net result the dissolved organic matter present in water must be considerably diminished by their multiplication and life processes.

Minute plants (diatoms, desmids, and confervoid algæ) may also play an important part in the purification of water, since when exposed to the light they decompose carbonic anhydride, and liberate oxygen.

Dr. Jabez Hogg* expressed the opinion that Sorby's examination of 'the coarser and more palpable contaminations of water will, under any circumstances, be of little moment. It is the minuter forms of organic life with which medical men are much concerned and which are known to be of vital importance as matters of hygiene,' and he called particular attention to the fact that the presence of large numbers of the various entomostraca, etc., is, in itself, the best evidence of the impurity of the water in which they abound, and that they have often been known to produce serious outbreaks of illness (diarrhœa and dysentery). Without disputing the truth of Dr. Hogg's statements, I think they do not diminish the force of Sorby's contention; for it cannot be denied that animal life—no matter in what medium it be carried on—is sustained at the expense of the pabulum upon which it subsists; and although it may be dangerous to drink water at a time when it abounds in animal life of a comparatively high type,

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* *Journ. Soc. Arts*, vol. xxxii., p. 939.

the water is made less dangerous by the fact that it is thus rid of some of its organic impurities, and therefore affords less nourishment for the development therein of those still more subtle and dangerous micro-organisms to which Dr. Hogg exclusively confined his attention.

Mention has been made in an earlier place, of the argument which is advanced by many to the effect that when once a water-course has been contaminated with sewage matter, the water is rendered unfit for drinking purposes for all time. Not that some of the persons who use this argument deny the purifying influences which have been described as being at work in running streams, but because disease germs may be introduced with the sewage matter, and it is contended that such germs are not destroyed along with the dissolved organic matter. In taking part in a discussion of this matter, the late Professor Frankland said: 'From a strictly physiological point of view, the admission of sewage into the water supply of a town did not necessarily affect the health of the inhabitants drinking the polluted water; but if you have fever epidemics occurring upon the banks of such a river, if you have abnormal or infected sewage discharged into it, then you run a very great risk; you run a risk probably proportionate to the number of infected persons contributing to the sewage.'

In the same discussion, Dr. Jabez Hogg, on the same side, referred to 'the remarkable instance which occurred at Caterham Waterworks, where, by the merest accident of one workman who was suffering from typhoid fever and went down into the well and worked there a few hours, and defiled the well, thus contaminating hundreds of millions of gallons of water which were pumped out and distributed to the townspeople round about, four hundred cases of typhoid followed the next week, and seventy or eighty deaths occurred in consequence.'

It may not be out of place to say just a few words here concerning those diseases which it is highly probable are, to a large extent, brought about by drinking impure water. Starting with the inorganic impurities, the cause of goitre has from very early times been attributed to impurities in the drinking-water, the principal evidence on the subject being that in places where goitre prevails there is nearly always a calcareous soil. Thus, in our own country we have what is often spoken of as the 'Derbyshire throat,' Derbyshire being the county where goitre is most frequently met with. The precise cause of the disease has not been quite satisfactorily established ; it has, at different times, been attributed to excess of magnesium and other salts, which contribute to the hardness of water ; again, to an insufficiency of iodine ; but the evidence is very conflicting, and the subject is one which calls for further investigation.

Diarrhœa is also, no doubt, frequently produced by drinking water containing impurities of an inorganic nature in excess, although organic impurities are probably more often the cause. Water containing a considerable proportion of sulphate of magnesium is known to be a strong purgative, as is also water containing certain gases—for example, the Harrogate water, which contains large quantities of sulphuretted hydrogen.

Passing on to the more formidable dangers in connection with the water we drink, we come to cholera and typhoid fever. That these terrible diseases are very largely propagated by waters polluted with excremental matter there cannot be a shadow of doubt, as the evidence on the subject is so extensive and so conclusive. It may, however, be interesting to quote the following case as an example: In 1854 the people of a well-to-do and healthy district of London round Soho Square suffered most terribly from the ravages of cholera, the death-rate for this small district for the month of September being 609, or 14·2 per thousand. In the centre of this district was the Broad Street pump, from which most of the inhabitants obtained their water, and upon inquiry the fact was elicited that a child had died of cholera at No. 40, Broad Street, and that its excreta had been emptied into a cesspool about 3 feet away from the well. It was further discovered that the bricks of the cesspool were loose, and permitted its contents to drain into the pump-well. But this is not all. A woman who had formerly lived in Broad Street was in the habit of having some water sent her every day from this well up to the West End, where she then resided. This woman and a niece of hers, who also took some of the water and afterwards returned to their home at Islington, both died of cholera, though at the time there were no other cases of cholera in the neighbourhood. The

Caterham Waterworks epidemic above mentioned is a very similar instance.

We thus see the danger of drinking water recently contaminated with sewage and which has not, previous to drinking, been exposed to an efficient process of purification. A small amount of excreta from a healthy person does not necessarily make the water dangerous; for example, Dr. Emmerich, of Munich, drank daily for two weeks from ½ litre to 1 litre of very filthy water, in fact, nothing less than sewage, without any ill-effect; moreover, he even claims that it improved a small gastric catarrh from which he was suffering at the time.

It has been urged that neither dilution nor oxidation of bad water will make it good, and a cursory examination of the subject often gives rise to the idea that disease germs are all but indestructible; for some of them, or their spores, are said to require hours of boiling to kill them and to be unaffected by such chemical reagents as cyanogen, sulphur dioxide and other equally poisonous gases. Now, as regards the experiments with poisonous gases, which were conducted for Frankland (as described in Chapter VII.), several excellent reasons can be urged why they should not be regarded as furnishing acceptable evidence of the contention he based upon them, such as the insolubility of some of the gases with which he experimented, the insignificant qualities of other substances, and so forth; but this is not the place for a detailed criticism of that kind. Boiling, even for a short time, may, it is admitted on all hands, be fairly well relied upon as sufficient to kill any living germs that may be present in water.

The living germs that are associated with the production of diseases are of the same order in nature as the micro-organisms which breed common putrefaction and have the same short life-history. The history of their life-actions corresponds in all respects with the history of the vital actions of the vibriones that induce putrefaction, and the bacteria that cause oxidation of organic matter in water; they die themselves and pass into putrefactive decay and just as micro-organisms of putrefaction can be readily killed by a thousand chemical reagents, so, in degree, are the micro-organisms of disease subject to the same or similar influences. Their action can be arrested, diverted, or totally annihilated by the means which are commonly employed in medical practice for the treatment and cure of infectious diseases.

The idea that micro-organisms have such a persistent vitality as is often represented arises from a confusion of facts. The truth is that these low forms of life multiply very rapidly so long as pabulum (food) be afforded and the other conditions necessary to their existence are congenial. The yeast cells, which give rise to the production of alcohol in a solution of sugar, are themselves killed by this very product when its proportion present in the solution rises to a certain definite extent, and so, also, other classes of ferments are destroyed by the products of their own life-actions, not to speak of outside influences which may be brought to bear upon them at will.

It is not to be denied that, as in the Caterham case above mentioned, the introduction of disease germs into a water used for drinking purposes *may* lead to an epidemic, but it should be remembered that in this case the water was *immediately* delivered for consumption, and certainly it was not exposed to those conditions which must be accepted as constituting purifying influences, extending even to the destruction or removal of infectious material and disease germs. Had the contamination, for instance, occurred at Oxford, then, in all probability, the Thames water, as delivered at London, would not have caused further cases of the disease, and the proof is near to hand, if further proof be wanted : it is furnished by statistics, if statistics prove anything at all.

Some years since Mr. Baldwin Latham published a paper, in which he compared the zymotic death-rate of those districts which derive their water supply from the River Thames with others which obtain theirs from the chalk, and taking diarrhœa as a disease peculiarly attributable to bad water, it was shown that the death-rate in the district supplied by Thames water was actually slightly lower than that supplied by the Kent Water Company. Such a fact as this is simply irresistible. The fact is that, apart from the purification which is effected by atmospheric oxygen, that substance is absolutely fatal to a large class of micro-organisms, and it is idle to deny to atmospheric oxygen in nature the properties it has been proved to possess in the laboratory by men like Pasteur, who was a very apostle of the new teachings of sanitary science.

Further, the difference in composition of Thames water and the deep chalk waters of Kent is so slight, and the proportion of organic matter dissolved in Thames water is so small that, even if it could be shown that the liability of different waters to contain disease germs in active vitality was in proportion to the relative amounts of dissolved organic matter, the relative superiority of the one water over the other for potable purposes is practically insignificant.

As directly bearing upon this subject, Odling, some years ago, made an interesting communication to a meeting of the British Association, as joint author with Mr. Crookes and the late Dr. Tidy. The virus of splenic fever (the well-known 'wool-sorter's disease') was disseminated in either sterilized distilled or sterilized river water in order to obtain a dilute infected water, and after standing a certain number of hours, portions of this water were added to a cultivating fluid in which the bacillus is known to be capable of reproducing its kind, in order to ascertain whether or not the virus retained its capability of reproduction. The micro-organisms thus treated, preserved sufficient vitality to allow of their propagating themselves for five or six hours; but the authors found that propagation did not take place after eighteen hours. It would therefore appear that mere dilution effectively protects us from these organisms by impairing or destroying their vitality or capacity for evil.

Thus, it is easy to see how the inhabitants of London escape infection from contamination with the sewage of Oxford and other towns which are situated sufficiently far up the River Thames. To infect the water supply of London with the same proportion of virus which was employed in the experiment just described, 1,000,000 gallons would be required. Computing the water supply taken from the Thames as it passes over Teddington Lock, it may be calculated that 50,000,000 gallons of infected solution would be required to pollute the Thames water to the extent of the pollution employed in that experiment, and even if this enormous and practically impossible quantity of infected matter could be imparted to the water, the experiments would seem to show that the resulting dilution would render it absolutely innocuous. It should be added that these experiments were made with the bacteria and not with their undeveloped spores.

Study of the subject and practical experience, then, alike point to the fact that, while undoubtedly it might and probably would be dangerous to drink Thames water as obtained direct from the river, it is quite safe to drink when purified, filtered, and delivered by the Metropolitan Water Board.

There can be no doubt that the provisions afforded by nature for the purification of the atmosphere are equally effective for the purification of water in a running stream. The air of towns is largely contaminated with organic matter and is directly polluted, in the most real sense of that expression, with the germs which are connected with the initiation of disease. These germs are given off from the bodies of persons suffering from infectious disease, both externally (from the skin) and internally (with the breath and excreta), and must pass, in great measure, directly into the atmosphere. What is the consequence? To some extent, of course, the germs or their associated poisons may infect other persons, but by far the larger number must die either by a process of starvation, or by the action of sunlight* and fresh currents of air. Air which has been contaminated with sewage, or even with the most virulent virus of disease, thus again becomes fit to be breathed, and it is idle to deny that the same process of purification takes place in running water freely exposed to the air. If we are to condemn for all time water which has once been contaminated with sewage, we must equally condemn our air supply, and with the same zeal look out for a new one.

As a summary of what has preceded and in order to resume the thread of our considerations, it may be stated that while Thames water as now delivered to London for drinking purposes, is safe and sound in quality, it is imperative that all possible means should be taken to exclude sewage contamination throughout the entire course of the river—in particular at Oxford and Reading—and thence to the pumping-stations near Teddington. This must be insisted upon most emphatically, because the poisons of cholera and typhoid fever (not to mention any other diseases) are contained in the stools of patients suffering from these affections, and if they be swallowed while active, they may communicate the diseases to further persons; it is also

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* Sunlight has been proved to kill bacteria with tolerable quickness (Koch).

necessary, because all the organic matter that is introduced into the river has to be oxidized or otherwise destroyed, or removed, and the less, therefore, that is introduced, the smaller is the tax made upon the purifying agencies that are at work or have to be pressed into service. Moreover, it may be conceded that an impure water, loaded with fæcal matter, affords much better pabulum for the maintenance and reproduction of germs than a pure water practically devoid of suspended and dissolved organic matter. No untreated sewage, therefore, should be allowed to enter the Thames from its source to its mouth. Wherever there is sewage to be disposed, it should be so treated that the solid parts are first of all removed or separated from the liquid parts. The solid parts should never be allowed to enter the river, and the liquid parts should be passed over land before entering the river, or at any rate be exposed to some well-advised chemical treatment. It must not be forgotten that the impurities conveyed by the liquid parts are insignificant as compared to the solid parts, and are more easily destroyed by oxidation.

In connection with this part of the subject, I am entirely at one with Mr. Cresswell* in thinking that the public at large owe a debt of gratitude to the companies who have risked much capital and expended much labour and time in seeking to remove its solid parts from sewage by precipitation or otherwise, and thus keeping them out of the River Thames. A similar debt of gratitude is due to all reformers in

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* *Society of Arts Journal*, vol. xxxii., p. 450.

sanitary science and to all who increase the means of lessening human suffering, no matter in what direction. It, however, rests with the Thames Conservancy Board to effectually prevent the avoidable fouling of our greatest stream.

As regards the purification of water by artificial means, very few words will suffice. We have seen with what good effects the oxidation of organic impurities is carried out naturally; it is, therefore, justifiable to believe that the purification could be carried still further, when desirable, by an artificial process, in which the water before or after filtration should be exposed to a current of air. This current of air might be pumped, under pressure, into the water contained in a suitable vessel, or led into the water contained in the reservoirs. For this latter purpose all that is required is a series of perforated pipes, lying upon the bed of the reservoirs and conveying air direct from the pump. I have a very strong opinion that the London and other water companies might profitably make use of this suggestion.*

Since the second edition of this work was issued the purification of water supply by means of aeration has been put forward in America as a new discovery. Dr. A. R. Leeds, it is stated, found that the beneficial action of air upon water was increased by bringing the two substances into contact under pressure, the purification, indeed, being to some extent proportionate to

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* This suggestion has been acted upon to some extent since I first made it, but I am sure that it might with advantage be still much further utilized.—AUTHOR.

the pressure. In some experiments made at Philadelphia, where air was forced into the main, the percentage of oxygen in the aerated water was 17 per cent. greater than before; that of carbonic acid was 53 per cent. greater, and that of the total dissolved gases 16 per cent. greater; on the other hand, the free ammonia was diminished 1·5 of its former amount. Public attention in America was directed to these results by a report of Dr. W. H. Wahle, then Secretary of the Franklin Institute.

Mr. W. Anderson, M.I.C.E., has described* the process of purification of water by means of iron, which consists in bringing the water into intimate contact with a mixture of spongy iron and gravel, and which has been applied for some extended period to the water of the River Nethe at Antwerp. Acting upon a suggestion made by the late Sir Frederick Abel, to the effect that, if iron exerted a purifying influence on water, it would obviously exert it to the greatest extent in a given time if the surfaces of the iron and water coming into contact were constantly renewed, Mr. Anderson made use of a revolving cylinder, fitted with inlet and outlet pipes, and with shelves or ledges for scooping up the iron, etc. In actual use he managed to get 166 gallons of water passed through the 'revolver' per minute; this gives a contact of about 3½ minutes, and is said to be amply sufficient. The charge of iron is about 500 lbs., and the water takes up (dissolves) and mechanically carries away about 0·176 grain per gallon. Mr. Anderson adds: 'By making suitable

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* *Society of Arts Journal*, vol. xxxii., p. 963.

arrangements and choosing a favourable time with respect to the demands of the town, we were able to obtain samples of water that have been purified by the "revolver" only, and after proper exposure to the air, followed by filtration through one of the large sand filters, the result obtained has been that the colour was very little different from distilled water, the free ammonia was reduced from 0·032 grain per gallon to 0·001, and the albuminoid ammonia from 0·013 grain to 0·0045.'

The iron used in this process may be supposed to act in several ways; firstly, as a mechanical agency for bringing the particles of water into intimate contact with particles of air contained in the vessel; secondly, as a filtering or screening agent, aggregating to itself the suspended particles of organic matter previously contained in the water; thirdly, by passing to a small extent into solution by the action of carbonic anhydride, so that it may be supposed to act as a chemical carrier of oxygen to the organic matter dissolved in the water; for the iron in solution would presumably be first oxidized to the ferric state, and alternately reduced to the ferrous state. The purification of the water, however, is not entirely due to the action of the iron; it is partly due to subsequent exposure to the air and also to the filtration through sand. Whatever action iron may have, it can only assist in the process of purification, which is really effected by the agency of oxygen, and so far as it exercises a real value, that could be secured by placing iron in the filter-beds or reservoirs through which air could also be pumped at the same time.

These remarks lead us to the subject of domestic filters, which primarily act as strainers. Few of them do more than remove from the water the larger suspended particles, but there is a notable exception to this class of filters, and that is the so-called Berkefeld filter, of which a description is given below. The agents which are used in ordinary filters (such as prepared charcoal, silicated carbon, spongy iron, and so on) are not known to be destructive of toxic products, and, considering their insolubility, it is almost impossible that they can act as germicides. If, therefore, the use of such filters promotes the purification of water, apart from removing the coarser solid suspended particles, it is by bringing the water into intimate contact with aerated surfaces of the filtering medium which is employed; but this implies that due provision is made (and, as a matter of fact, it is not generally made) for renewing from time to time the efficiency of the said medium by freely exposing it to the air. In the absence of such a provision of an effective character, the offensive matter abstracted from the water accumulates in the filter and chokes it, and unless it is removed from time to time, water may be rendered actually more impure, instead of becoming purified by its passage through the filter.

The Berkefeld filter is constructed on the same principle as the older Chamberland-Pasteur filter, in which latter the filtering medium consists of biscuit porcelain, the water being made to filter through a candle or bougie made of that substance from without, the delivery being from within the said candle. The use of this filter in the French army has been attended, it is said, with the most satisfactory results,* particularly in diminishing cases of, and deaths from, enteric fever. The Chamberland-Pasteur filter undoubtedly sterilizes water by mechanically removing the micro-organisms which may be present therein; but, unfortunately, the amount of water that can be filtered in a given time is very limited, even when pressure is employed to assist the passage of the water through the filtering medium. This objection does not lie to nearly the same extent against the Berkefeld filter, in which a different filtering medium is employed. It consists of prepared Kieselguhr (fossil earth), which is composed of the siliceous skeletons of diatomaceæ. These skeletons are ladder-like and interlacing, and furnish an enormous number of very minute pores or spaces, thus affording a free passage for the flow of liquid through them, while at the same time the passage of all solid particles, and even micro-organisms (bacteria, etc.), is arrested. The impurities which are thus removed from water in course of its filtration through candles of the kinds under notice, collect on their outside surfaces, and can be removed from time to time by brushing. Moreover, when required, the candles themselves can be sterilized by placing them in warm water and boiling for an hour or so.

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* See a review of the Army Medical Department Report for 1891 in *Lancet*, September 9, 1893.

The investigations of Mr. William Thomson, F.R.S.E., Dr. Percy Frankland, and many other authorities, have satisfactorily established the fact that the Berkefeld filter really sterilizes water by removing therefrom all microbic life. The importance of this fact is paramount, and the use of the filter by the public especially in connection with water of bad and doubtful quality will beyond question give most material assistance in securing immunity from such diseases as cholera and typhoid fever, which are too often spread through impure water supplies. I do not regard them, however, as of any value whatever for domestic use with good sound water.

In the chemical examination of water, regard is had not only to suspended matters, hardness, and to the determination of the amount of organic matter in the filtered water, but also to the presence of chlorine, ammonia, nitrites, and nitrates. A hard water is understood to mean a water which uses up a good deal of soap before a lather is produced in washing operations; the destruction of soap arising from the formation of insoluble salts by the combination of the fatty acids of the soap with the lime and magnesia present in the water, and it is not until these mineral salts have become exhausted that there is produced a lather. As already explained, this hardness arises from the collective presence of the dissolved matters, including mineral salts, carbon dioxide, and organic substances.

For softening very hard waters which owe their hardness, in part, to carbonate of calcium held in solution by the agency of carbon dioxide, the process originally devised by Dr. Clark, and improved by Mr. Porter and Mr. Atkins respectively, is often employed. The process practically consists in the use of lime either as a filtering medium or added in the form of milk, by which means the carbon dioxide enters into chemical combination with the lime to form insoluble carbonate of calcium, and, as a further consequence, some of the previously dissolved carbonate of calcium is precipitated from the water.

Water may be also softened by boiling; the decrease in hardness thus produced is termed the 'temporary hardness,' while that which remains is styled 'permanent hardness'; together they equal the 'total hardness' of the water. The 'temporary hardness' is due to the presence of carbon dioxide (which escapes upon boiling), and to the carbonates of calcium and magnesium which are at the same time deposited out of the solution in which they were previously dissolved by the agency of that gas; so that softening by boiling resembles softening by means of lime, as in Clark's process.

Chlorine is present in water chiefly in the form of common salt, and it is of importance to determine the quantity, since it may indicate existing pollution with sewage (which always contains a large proportion of chlorine). The amount of chlorine present in good waters varies from 0·22 part to above 5 parts per 100,000, and represents common salt dissolved out of the air and soil by rain. Urine contains about 500 parts of chlorine per 100,000 parts, and 58 samples of sewage from midden and water-closet towns were found by Frankland* to contain an average of 11 parts per 100,000.

Ammonia, when found present in water in any considerable proportion, is supposed to indicate the presence of animal matters in the earlier stage of decomposition. In rain water collected in the country the proportion of ammonia is about 0·03 part, whereas town rain water may contain as much as 0·21 part per 100,000; this larger quantity is dissolved from the air. The average amount in river water is about 0·01 part per 100,000. In sewage the ammonia varies from 2 to 10 parts per 100,000.

The nitrates and nitrites found present in water are derived by oxidation, from the ammonia formed at an earlier stage; or they may be produced directly from nitrogenous organic matter, as explained in an earlier chapter. Rain water may contain about 0·04 part of nitrogen in the form of nitrates per 100,000, but when collected in towns, the quantity is often much greater. Frankland puts down the average quantity present in upland surface waters at 0·009 part per 100,000. Thames water contains about 0·2 part nitrogen (combined in the form of nitrates and nitrites) per 100,000 parts, whereas from the deep wells in the chalk the quantity rises to 0·426 part. No doubt the amount of nitrates found present in deep well water often represents *previous* sewage contamination, but it also indicates

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* 'Water Analysis' (Voorst), p. 19.

the purification that has taken place by oxidation during the filtration of the water through the chalk hills.

Surface wells often yield water which is fouled by recent drainings from cesspools, cultivated land, and refuse matters.

By the logical use of the results obtained from the analysis of waters and a knowledge of their history, together with a microscopical examination, it is not difficult for chemists to form a thoroughly sound judgment as to whether they are or are not fit for and the safest for drinking use, notwithstanding all that has been said to the contrary by engineers and biologists.

If chemists cannot pronounce positively concerning the absence or presence of infectious material in water, they are, at least, as well qualified to express an opinion on this subject as mere bacteriologists. Engineers can do nothing in this direction, and biologists cannot provide any better tests of the purity of water.

It may be remarked that very frequently water is sufficiently pure for all cleansing and washing operations, and yet may be dangerous for drinking. Wherever any such doubt exists, it is best to have recourse to the use of a Berkefeld filter.

The following analytical figures, showing the chemical contents of various waters, are extracted by consent from tables given in Frankland's treatise on water analysis, to which reference has been previously made.

TYPICAL ANALYSIS OF WATER.

PARTS PER 100,000.

Description.	Total Solids.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Chlorine.	Hardness.		
							Tempo-rary.	Perma-nent.	Total.
Rain.									
Rothamsted -	2·16	0·062	0·007	0·027	0	0·10	—	—	0·8
London - -	2·76	0·383	0·040	0·210	0·008	0·50	—	1·1	1.1
Deep Well.									
In Devonian rocks and millstone grit -	32·68	0·068	0·012	0·005	0·294	2·70	8·8	8·6	17·4
In magnesian limestone -	61·14	0·076	0·030	0	1·426	4·31	16·9	26·9	43·8
In chalk below London clay -	78·09	0·093	0·028	0·048	0·068	15·02	9·7	8·7	18·4
River.									
Thames - -	28·03	0·201	0·033	0·0006	0·210	1·73	—	—	20·4
Lea - - -	27·82	0·128	0·023	0·0004	0·201	1·77	—	—	20·9
Shallow Well.									
Twickenham -	82·08	0·739	0·093	0·740	2·708	7·8	22·5	21·8	44·3
Tottenham -	130·44	0·108	0·053	0·002	3·974	8·4	35·2	39·8	75·0

AVERAGE COMPOSITION OF UNPOLLUTED WATER.

PARTS PER 100,000.*

Description.	Total Solids.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Chlorine.	Hardness.		
							Tempo-rary.	Perma-nent.	Total.
Rain water -	2·95	0·070	0·015	0·029	0·003	0·822	0·4	0·5	0·9
Upland surface water - -	9·67	0·322	0·032	0·002	0·009	1·13	1·5	4·3	5·8
Deep well water	43·78	0·061	0·018	0·012	0·495	5·11	15·8	9·2	25·0
Spring water -	28·20	0·056	0·013	0·001	0·383	2·49	11·0	7·5	18·5

* To convert parts per 100,000 into grains per gallon multiply by seven, and divide the product by ten. To convert grains per gallon into parts per 100,000 multiply by ten and divide by seven.

CHAPTER VI.

COMPOSITION OF THE EXCRETA—SEWAGE: ITS NATURE, DISPOSAL, AND TREATMENT BY IRRIGATION AND CHEMICAL PROCESSES—THE AIR OF SEWERS AND THEIR VENTILATION—DRY SYSTEM.

THE sewage of different towns varies in composition, not only according to the system of drainage employed and the amount of water supply, but also with the various trades or manufacturing processes which are carried on locally. In some towns a separate system of drains is employed for sewage proper, the rain water which is collected from the housetops and streets being drained off quite apart and discharged into the nearest watercourse without treatment. There can be no objection to this proceeding provided that the said watercourse is not immediately utilized as a source of water supply for drinking purposes, so that the water may become purified (by the agencies described in the last chapter) before it is abstracted for distribution. This separate system of drainage is to be commended, since, when used, the sewage from any one town is of tolerably constant composition and bulk, and the total quantity to be dealt with is much less than in those cases where rain water is admixed with the sewage and carried off in the same channels. It will be readily appreciated that a plan of treating sewage adapted to a given quantity of a given composition is often not applicable to the same quantity of impurities contained in a much larger bulk of liquid; indeed, as a matter of fact, it not infrequently happens that in times of flood the sewage of towns, where the separate system is not used, cannot be purified for this reason. Moreover, the expense attending the purification or the utilization of sewage is very much in proportion to the bulk to be dealt with, and this consideration is made all the more important by virtue of the fact that the cost of sewage works has, it is said, in many cases exceeded the whole rateable value of the districts immediately concerned.

Before proceeding to describe the various methods of dealing with sewage, it will be well to make ourselves acquainted with its general character and chemical composition.

It contains human and animal excrements, paper, rags, soapsuds, hair, and the impurities removed from human bodies, dwellings, and the streets of towns, by general cleansing operations. In many towns it is also mixed with the effluents from various trades or manufacturing processes. The several constituents are contained partly in solution and partly in suspension in a great volume of water, which is universally employed as the carrying agent to effect their removal. The fluid part is the more valuable in a manurial sense.

An average healthy man excretes by the kidneys about 50 to 60 ounces of water per day, and in this solution there are dissolved about 500 grains of urea (CH_4N_2O) and about 10 to 12 grains of uric acid ($C_5H_4N_4O_3$); other constituents, amounting to from one-third to the same quantity of the urea present, include common salt, chloride of potassium, phosphates and sulphates of potassium, sodium, calcium and magnesium. Urine also contains small quantities of other nitrogenous organic matters, besides urea and uric acid. The phosphoric acid amounts, on an average, to about 54 grains per man per day. The urine of a population of 10,000 adults amounts to about 3,750 gallons per day.

Fresh urine contains, on the average, about 3 per cent. of total solids, and according to Way, the analysis of a sample gave the following results:

Water	97·000
Organic matter (containing nitrogen 0·58; equal to ammonia 0·71)	2·026
Insoluble siliceous matter	0·003
Oxide of iron	0·002
Lime	0·018
Magnesia	0·014
Phosphoric acid	0·040
Sulphuric acid	0·014
Potash	0·055
Chloride of potassium	0·162
Chloride of sodium	0·566
	99·900

Of these various constituents, the nitrogenous organic principles are considered to be by far the most valuable from a manurial point of view; but unfortunately, urea, the principal of them, is rapidly decomposed in the sewage, by a process of fermentation, into carbonic anhydride and ammonia, thus,

$$CH_4N_2O + H_2O = CO_2 + 2NH_3,$$

and both of the products, being gaseous, escape more or less from the solution, and are lost in proportion.

Fæces represent the undigested and altered portions of the food which have refused absorption; like urine, their quantity and composition, therefore, necessarily varies with the nature and amount of the food, as well as other circumstances.

According to other analyses of the late Professor Way, fresh human fæces contain in 100 parts:

Water	75·00
Organic matter (containing nitrogen 1·50; equal to ammonia 1·82)	22·13
Insoluble siliceous matter	0·37
Oxide of iron	0·13
Lime	0·43
Magnesia	0·38
Phosphoric acid	1·07
Sulphuric acid	0·06
Potash	0·30
Soda	0·08
Chloride of sodium	0·05
	100·00

The amount of water contained in fæces varies from 73 to 75 per cent., and the solid matters (dry at 100° C.), therefore, amount to from 25 to 27 per cent., the actual quantities ranging from 17 to 31 per cent. Little nitrogen is present in fæces; according to Dr. Edward Smith, the daily elimination of nitrogen by the bowels amounts, on the average, to about

46 grains. The quantity of fæces yielded by a healthy adult varies from 5½ to as much as 8 ounces; but taking men, women, and children collectively, an average of 4 ounces per day may be taken as approximately correct.

Fæces generally contain but small quantities of salts, consisting of phosphates of calcium, magnesium, sodium, and potassium. Albumin is met with in a soluble form, and in certain diseases (cholera and typhus) the proportion found present is considerable. The bulk of organic matter present in fæces is represented by the altered biliary substances, fat, starch, cellular and muscular fibres, etc. Playfair is stated to have found in a sample of fæces which he examined as much as 15 per cent. of nitrogen and 45 per cent. of carbon,* but quite apart from these figures I entertain a strong conviction that even the solid parts of sewage are not so valueless as they are often assumed to be. I cannot believe that the value of manure is so nearly limited to phosphoric acid, potash, and available nitrogen as is generally represented.†

Curiously enough, no paper is ever seen in the sewage of London at the outfalls; it becomes reduced to an impalpable state of division *en route*, and is deposited from sewage in a sparingly pervious layer on the surfaces of filter-beds and sewage fields.

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* I should think these qualities must have been calculated upon dried fæces of abnormal composition.—AUTHOR.

† See papers in *Journ. Soc. Arts*, May 18, 1877, by Voelcker, on the 'Agricultural and Commercial Value of Prepared Night-soil Manures,' and by Tidy in *Journ. Soc. Arts*, October 8, 1886.

The following analyses of sewage are taken from Frankland's work on water analysis (pp. 115 and 118):

Description.	Total Solids.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Chlorine.	Suspended Matter.		
						Mineral.	Organic.	Total.
Tunstall - -	114·40	4·858	1·692	4·300	14·15	18·12	34·36	52·48
Crewe - -	98·08	5·014	1·780	1·65	16·0	83·72	262·08	346·0
Fresh sewage: Average from 16 water-closet towns - -	72·2	4·696	2·205	6·703	10·66	24·18	20·51	44·69
Fresh sewage: Average from 15 midden towns -	82·4	4·181	1·975	5·435	11·54	17·81	21·30	39·11

Tidy gives in his paper* the following details of the average composition of London sewage as examined by Frankland and him between 1883 and 1884, the results being stated in grains per gallon:

	Maximum.	Minimum.	Average.
Matters in solution -	49·77	28·42	45·213
Matters in suspension -	163·90	21·40	48·65
Ammonia - - -	6·527	2·515	3·012
Chlorine - - -	8·33	5·67	7·21
Organic carbon - -	3·847	2·118	3·069
Organic nitrogen - -	2·676	0·964	1·738

Average ratio of N to C = 1 : 1·77.

These results take no note of storm sewage.

Summarizing these and other results, he shows that, including the water supply, 'every 10,000 persons in London contribute, on an average, 375,000 gallons of sewage daily, and that this includes about 1,671 pounds

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* *Journ. Soc. Arts*, October 8, 1886.

of organic matter, containing 333 pounds of nitrogen, and 335 pounds of mineral matter containing 94 pounds of phosphoric and 69 pounds potash.'

The total quantity of sewage to be dealt with varies in towns with a number of circumstances, and in London 80 per cent. is represented by the water supply.

Upon the estimate that each head of the population (taking men, women, and children collectively) gives 4 ounces of fæcal matter per day, London, calculating its contributory population at about 4,000,000, yields daily 446 tons of fæcal matter, and taking this to contain 75 per cent. of moisture and 25 per cent. of dry solid matters, it is seen that above 111 tons of dry fæcal matter were until recently daily poured into the Thames at Barking and Crossness. This amount of impurity was, of course, greatly increased by the heavier solid matters that are contributed by the street drains, and the whole quantity was contained in a bulk of liquid measuring about 170,000,000 gallons.

Of this quantity, that which is discharged at Barking is collected from the London area north of the Thames measuring 53 square miles, and is temporarily received in reservoirs of 9½ acres, the capacity of which is 35,000,000 gallons, or 5,600,000 cubic feet. South of the Thames the London area is 66 square miles, and the sewage is collected at Crossness in reservoirs of 6½ acres, which are capable of holding 25,000,000 gallons, or 4,000,000 cubic feet.

Thus, in the course of a year the lower Thames received about 60,000,000,000 gallons of sewage, in which the amount of suspended matter was estimated by Frankland, so long ago as 1879, at 1,354,000 tons.

At high-water time, the sluice-gates of the reservoirs were opened for four hours during the ebb, and the sewage was thus conveyed into the tide-water. Some was, no doubt, carried out to sea, but a large quantity, and perhaps the bulk, would only travel a certain distance down the river, and be borne back again by the next tide, while some of it would reach up the river even as far as Chiswick. The fact is, that the volume of the river is insufficient to carry away such an enormous quantity of sewage.

A large proportion of the heavier parts of the solid matters was deposited upon the bed of the river, extending up to Chiswick and down to Southend, while the river between these places became converted into a great sewer, the contents of which, in hot weather, were in a more or less putrid condition.

So serious was the nuisance caused some years since that a great, but natural and perfectly justifiable, outcry followed, the more so since on more than one occasion the country was threatened with an epidemic of cholera. As a result of this outcry, large quantities of chloride of lime and permanganate of potassium were at first thrown into the river, and later on mixed with the sewage as it was discharged ; but such a proceeding on the part of the governing authority could only be expected to mitigate, in a very incomplete measure, the nuisance caused by the emission of gases and the putrefying sewage, and that at a stupendous cost. The quantity of chemicals thus employed was wholly inadequate to oxidize or destroy, in a chemical sense, the enormous mass of organic matter contained in the sewage; indeed, the effect was confined to the deodorization in some measure of the ready-formed products of putrefaction, including gases containing sulphuretted hydrogen, etc. The cost of such a proceeding is much too great, and the effect far too little, to warrant its regular adoption. The sewage of London demands previous chemical treatment, and the clear effluent alone should be discharged into the Thames.

According to experiments made by Mr. W. J. Dibdin (who was then the chemist of the London County Council), no practical advantage accrues from the addition to each gallon of the sewage of London of more precipitating matters than 3·7 grains of lime and 1 grain of sulphate of iron ($FeSO_4 7H_2O$), which he considers is all that is necessary for facilitating the natural tendency of the solids to deposit. Mr. Bailey Denton stated that this conclusion was opposed to all past experience, amounting, in his opinion, to a demonstration of its falsity. These materials and quantities were in use for some time for assisting in the precipitation of the solid matters contained in the sewage of London, and the precipitate was subsequently carried out to sea and discharged into it, the effluent only passing into the river. I am not able to state whether the use of these precipitants is still continued.

The fluid sludge that is produced by this lime and iron process contains 90 per cent. of water, and was pumped direct into the vessels that carried it out to sea. It was said to cost 9d. per ton to get rid of it in this way.

Respecting the average composition of pressed sewage sludge from Crossness, the following analyses are those of Mr. Dibdin :

Moisture - - - - -	58·06 per cent.
Organic matter - - - -	16·69 „
Mineral matter - - - -	25·25 „
	100·00

The organic matter contains :

Saline ammonia - - - - -	0·035 per cent. on sludge.
Organic nitrogen, calculated as ammonia	1·025 „ „

The mineral matter contains :

Carbonate of lime - - - -	7·94 per cent. on sludge.
Free lime - - - - - -	2·45 „ „
Silica - - - - - -	8·08 „ „
Oxide of iron - - - - -	0·97 „ „
Alumina - - - - - -	3·39 „ „
Phosphoric acid (= phosphate of lime 1·44) - - - - -	0·658 „ „
Magnesia - - - - - -	traces.

The sewage sludge of the Metropolis amounted in 1894 to about 4,000 tons per day ; one ton containing 90 per cent. water was yielded by 45,000 gallons of sewage from 1,000 persons, and this quantity is equal to about 2 cwt. of dry precipitate.

Mr. John P. Lord (bacteriologist to the Malden and Coombe Urban District Council), in a contribution* to the subject of 'Microbes and Mud,' has expressed the

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* *Journ. Roy. Inst. Public Health*, February, 1907, p. 103.

opinion that sewage sludge is a dangerous breeding-ground for hurtful organisms, and that there are only two sound ways of treating it so as to render it innocuous. The one method consists of burial, which, however, proves very often inconvenient and certainly in many cases expensive, on account of the quantity that has to be dealt with; whilst the other method, which he thinks more practicable, is to dry the sludge in desiccators, and then sell the residue for manure.*

Mr. Phillips Bevan has expressed the opinion that the only plan, and the cheapest one, of dealing with London sewage, is to convey it across the Essex marshes to Foulness Island, a little to the north of Shoeburyness, and there, if possible, cast it into the German Ocean. Land is cheap, and space is of little account, at Foulness or Wallasea Islands; and Mr. Bevan thinks that if our boasted scientific knowledge is worth anything, it should enable the proper authorities to convert the useful parts of sewage into a good practical manure, in which a brisk trade could be done.

Some few years ago the late Sir John Lawes suggested that, after all, it may prove to be more profitable to cast the sewage of London into the sea than to apply it to land. The broad line of his argument may be taken as follows: enormous quantities of fish are removed from the sea near our shores, and they contain great quantities of phosphate of lime, potash, and nitrogen. The former of these ingredients exists in sea water in very small amount, and yet it is as essential to fish as an article of food as to mammalia.

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* *The Sanitary World*, August 30, 1884.

By discharging sewage into the sea we should thus atone for the food material which is being constantly removed, and Sir John Lawes thought that in this way continued and increased prosperity would be secured to our fisheries.

Such a disposal of sewage would, however, have its attendant evils. The finely-diffused solid particles of sewage are exceedingly hurtful to fish, choking their gills and suffocating them. Moreover, fish absorb the free oxygen which is contained in the water in which they natate, whereas not only does sewage contain no such oxygen, but it deprives the water into which it is discharged of its oxygen also. This fact alone would necessarily limit the amount of sewage that could be poured into any circumscribed area of sea water. Then, again, while fresh sewage is very good food for fish, bad or stale sewage is poisonous to fish. Whatever, therefore, is to be said of the advantages of Lawes' suggested plan of dealing with sewage, its execution would probably diminish the fish supply in the immediate neighbourhood, however it might in a wider area increase the available supply.

For my part, I agree very largely with Mr. Bevan, but I go further, and venture to express the opinion, notwithstanding all past discouraging experiences, that a reasonable sum of money expended on the spot in experimental work would enable chemists to make other valuable commercial commodities from sewage in addition to manure.

One of the greatest difficulties experienced in adequately dealing with sewage lies in the enormous bulk to be operated upon: it is therefore reasonable to suppose that could some simple mechanical appliance be devised by which a considerable proportion of the clearer liquid could be drawn off and separated from the more solid parts, it would greatly assist in the efficient treatment of sewage. Such clear liquid need not necessarily be passed directly into a watercourse; it could be first distributed over a considerable tract of land, for which it would serve as a useful manure, and by which it would be efficiently filtered and greatly purified.

Sewage passes very rapidly into a putrefactive state, and the gases that are generated in sewers are capable of producing a peculiar kind of fever; but whether the illness is to be regarded as the direct effect of inhaling the mixed chemical gases, or as an expression of the consequences of inspiring micro-organisms which are reproduced in the human body, is not precisely known to medical men, who are, however, perfectly familiar with the illness. In course of an investigation, Messrs. Carnelly and Haldane found that the air of sewers which were examined by them was in a much better condition than might have been expected. The carbonic acid was about twice, and the organic matter rather more than three times, as great as in the outside air at the same time, whereas the number of micro-organisms was less. The sewers examined were, it should be stated, well ventilated. Concerning the micro-organic life present in the air of sewers, the authors concluded that it is not mainly derived from the sewage itself, but rather from the outside air.

The number of micro-organisms observed to be present in the sewer air, as compared with those found present in the outside air, was as 9 to 16; further, the number increased with the efficiency of the ventilation, and, as resulting therefrom, confirmatory evidence is furnished by the fact that the average proportion of moulds to bacteria remained the same as in the outside air at the same time.

In a report on this subject to the London County Council, Mr. J. Parry Laws, F.I.C., stated that he had found that the organisms in the gas issuing from sewers were for the most part non-pathogenic, and that *Bacillus coli communis* and *Micrococcus ureæ* were conspicuously absent.

That no sewer is air-tight is certain; consequently, when, for some reason, such as a sudden flow of water into the sewer, we have a rapid increase of pressure, some of the sewer gas will be forced out and often through those openings in respect of which we should least desire any escape to be made—viz., such as faulty traps. It is, therefore, absolutely necessary to provide means of exit for the foul gases, but this should be done, not by gratings opening directly into the streets, but preferably by ventilation shafts of a good height.

Notwithstanding the results obtained by Messrs. Carnelly and Haldane and Mr. J. P. Laws, the extent to which spores and micro-organisms may emanate from sewers and may be disease-producing in character must be regarded as unascertained quantities.

The methods of purifying sewage which are at present in use depend either upon filtration through soil (irrigation) or upon the precipitation of the solid parts by the agency of added chemicals.

In what is called broad irrigation, sewage is distributed over the surface of drained and cultivated land, by which means the solid parts are arrested, and the fluid part gradually percolates through the land, and is finally carried off by natural or artificial drains. The fluid part, however, does not merely soak through the land, but its constituents are subjected to oxidation in the process.

The oxidation is carried on by the agency of micro-organisms, as fully explained in an earlier chapter, and one chief direction in which it occurs is that of so-called nitrification, to which reference has also been made in some detail. The solid parts which are left in the soil are also attacked and gradually succumb to the influences of hydration and oxidation, yielding products which afford food to the plants growing upon the land.

Of course there is a limit to the capacity of oxidation, and so the land has to be divided into plots, which are successively worked, care being taken that too great a tax is not thrown upon the land, as otherwise it becomes choked, and oxidation does not proceed as actively as is desirable.

'Intermittent downward filtration' differs in no wise from broad irrigation except in the fact that the land is drained to a greater depth, and so a greater quantity of sewage may be applied to a given surface of land, which, however, is not worked continuously, but, as in the other case, successively in plots. In the periods of repose, the soil is supposed to become re-charged with oxygen, but it must not be forgotten that the oxidation which is carried on does not altogether result from the mere contact of oxygen with the organic matters, but is, in the main, the result of the vital actions of millions of micro-organisms which utilize the oxygen of the air so bountifully supplied by nature.

The following figures, illustrating the purification of sewage by irrigation, are taken from a table given by Frankland in a paper on Thames water :*

Description of Process.		Average Percentage of Dissolved Organic Pollution removed.		Average Percentage of Suspended Organic Pollution removed.
		Organic Carbon.	Organic Nitrogen.	
Intermittent downward filtration	Best result	88·5	97·5	100
	Worst result	32·8	43·7	100
	Average result	72·8	87·6	100
Broad irrigation	Best result	91·8	97·4	100
	Worst result	42·7	44·1	84·9
	Average result	68·6	81·7	97·7

These results prove that, practically, it does not much matter which kind of irrigation be used, the choice being determined by local conditions, such as the price and character of the land. On the whole, probably, considering the expense of draining land to the greater depth required for intermittent downward filtration, the ordinary process is to be preferred.

According to M. Lefeldt, an acre of land is required

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* *Soc. Arts Journ.*, vol. xxxii., p. 433.

for the excreta of every twenty to thirty-five persons; but even if that quantity of land would serve for each hundred persons, the total acreage thus required is far in excess of the available quantity.

Sewage when kept in motion and brought quickly in limited amount into contact with soil, air, and vegetable life, is, I believe with the late Dr. Carpenter, changed in a direction contrary to that which is necessary for the propagation of disease. All the same, it has been pretty well established that the *putrefactive* decomposition of sewage in soils may give rise to the production of malarial and parasitic diseases when it takes place near towns; moreover when sewage is applied in excess, as is often the case in practice, the solid organic matters, after a time, form a solid cake upon the land, which gives off an offensive and dangerous effluvium. Again, the subsoil water is liable to be charged with decomposing matters resulting from the sewage, and Pettenkofer is not alone in his opinion that there is no more fruitful source of disease than such a subsoil water which is constantly changing in its level.

The mere fact that in this country at least the available land is insufficient for the disposal of sewage by irrigation, is sufficiently condemnatory of the process as an exclusive means of utilizing sewage. London alone would require above 200,000 acres and when it is reflected that some classes of soil are not at all suitable for irrigation, and that great expense has to be incurred in preparing the land by drainage and otherwise to receive sewage, it becomes apparent that for these and local reasons irrigation does not nearly supply the want that is experienced.

At the same time, it is to be clearly understood that, given suitable land, of sufficient extent, and in dry weather, we can by irrigation very completely purify sewage. This is proved by the analytical results obtained by Dr. R. Angus Smith upon the examination of the effluents obtained from sewage by different processes of treatment and communicated to the Local Government Board in 1879.*

As pointed out in a paper on Sewage Disposal † contributed to the Sanitary Institute meeting at Dublin (1884) by Professor Henry Robinson, clay land can be utilized for irrigation purposes by digging it out to a depth of 6 feet, burning it into ballast and replacing it in layers, interposed with an occasional layer of open alluvial soil; if well drained, this prepared filtration area will continuously clarify the sewage of 1,500 people to the acre. The cost of preparation, however, amounts to from £750 to £1,000 per acre, besides which he expresses the opinion that the larger particles in the sewage should be first removed by a process of straining conducted upwards. These separated solids can be utilized for making up low-lying land.

According to the same authority, open porous land with a good free subsoil, drained 6 feet deep, will effectually deal, per acre, with the sewage of from 600 to 700 people.

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* See *Chem. News*, vol. xli., p. 50.

† *Sanitary Record*, October, 1884.

This is, however, a very high estimate of the purifying capacity of land, and, in my opinion, would prove very excessive upon continued use.

I shall not attempt to give an account of all the many chemical processes that have been advocated for the treatment of sewage, but shall be content with describing the so-called A B C process, and a few of the other more prominent ones that are now in use or have been suggested.

The A B C process of the Native Guano Company has now been in work at Kingston-on-Thames for the past seventeen years, and is dealing with the sewage of over 55,000 people, comprising the districts of Kingston, Surbiton, and Hampton Wick. The works are carried on by the company for a fixed annual rate of 3d. in the £1 on the net rateable value of property within the district, which payment relieves the authorities from all further expense, risk, and trouble as regards the purification and disposal of the sewage.

To the sewage (after passage through a grating used to intercept coarse matter), as it is admitted into the works by channels, is first added a mixture of ground clay, charcoal, and blood, previously made into an emulsion with water, and at a later stage a solution of sulphate of aluminium is run in. The particles of clay assimilate the suspended organic matters of the sewage, and when the blood albumin becomes coagulated by the action of the alum solution, the whole solid matters become entangled or enveloped in the meshes of the coagulum, and are deposited to the bottom of the tanks through which the treated sewage slowly flows. The clay is also stated to enter into combination with some of the ammonia present in the sewage, and the charcoal is supposed to absorb a further quantity and to exercise a deodorizing influence. The action of the alum solution in precipitating the clay and blood is promoted by the alkaline nature of the sewage, which causes the separation from the sulphate of aluminium of gelatinous flocks of alumina. As the mass of treated sewage flows through successive tanks, it deposits practically the whole of the suspended matters originally contained in the sewage, together with the added chemicals, and the effluent passes away to the river, clear, purified to a great extent, and nearly odourless. The chemicals used in the process amount in all to about 35 grains per gallon, and the daily flow of sewage is about 2,597,574 gallons, or 47·13 gallons per head of population.

The following analyses are published by the company:

Analysis.

Result in Grains per Gallon.

Suspended Matters.	Sewage.	Effluent Water.							
	Dr. Wallace.	Dr. Wallace.	Dr. Angus Smith.	Dr. Tidy.	Professor Way.	Dr. Keates.	Professor Wanklyn.	Dr. Wallace.	Standards of Rivers Pollution Commission.
Organic - -	24·9	traces	—	0·04	—	—	—	none	0·70
Inorganic - -	12·9	,,	—	0·18	—	—	—	,,	2·10
Total - -	37·8	,,	—	0·22	—	—	—	,,	2·80
Free ammonia -	5·18	2·73	0·714	0·60	1·12	1·75	0·61	1·19	no standard.
Albuminoid do.	0·58	0·12	0·049	—	0·07	0·18	0·3	0·112	0·21
Oxygen required to oxidize the organic matter	2·17	0·91	—	0·25	—	—	—	0·23	—

In a report published by Dr. Angus Smith in 1879, at the request of the Local Government Board, he found, taking samples over a month at unexpected times, that the organic carbon in the dissolved organic matter present in the sewage operated upon was reduced by the process from 6·76 to 0·63, or by 90 per cent.; the albuminoid ammonia was also reduced from 0·66 to 0·07, or very nearly 90 per cent., and the free ammonia from 4·0 to 1·02, or 75 per cent.

These analyses appear to indicate that beyond the precipitation of the suspended organic matters, some considerable part of the dissolved organic matters is also removed from sewage by this process.

The total purification effected is said to be from 75 to 80 per cent. upon a crude sewage of nominal strength; but in view of the greater purification now required by the Thames Conservancy, the Corporation are now laying down 1¼ acres of contact beds, to be filled with coke breeze, which, it is expected, will bring up the total purification of the effluent before its discharge into the Thames to from 90 to 94 per cent. For this use of coke breeze the Corporation are, as it appears to me, indebted to my suggestion (see p. 178).

The precipitated sludge is pumped from the tanks, then deprived by pressure of its superabundant water and further dried by artificial heat, until it attains the consistency and appearance of dry earth, in which state it is sold to farmers and gardeners as Native Guano at £3 10s. 0d. per ton, and judging from the statements published in a pamphlet by Crookes* (who

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* 'The Profitable Disposal of Sewage.' By W. Crookes, F.R.S.

was for some years scientific adviser to the company), and the reports from farmers and others, the product is a more or less valuable manure. It is not so valuable when judged by the somewhat arbitrary standard in common use by chemists, as, according to this standard, value is attached only to the contained ammonia and phosphoric acid. But it is questionable how far this standard is a reliable one as applied to the manurial value of a product, for it ignores to a large extent its collective organic nature and its physical condition.

The late Dr. C. Meymott Tidy and Professor Dewar have also (and more recently) reported favourably upon this process. They found that it completely and immediately deodorizes the sewage, and that there is no escape of offensive odours into the surrounding air. The effluent is described by them as being practically clear, free from suspended matter and devoid of smell, the perfection of the precipitation increasing with the strength of the sewage. The mean amount of suspended matter in the sewage on three separate occasions was 18·8, 59·97, and 234·63 grains per gallon, and practically the whole of this was precipitated. The organic matter precipitated from solution amounted to 61·4 per cent. in the second series of observations, and to 57 per cent. of the whole in the third series.

With respect to the composition of this so-called Native Guano, the same report states that the percentage of combined nitrogen is remarkably constant, and amounts on the average to 3·8 per cent. calculated as ammonia in the perfectly dry manure, or with 20 per cent. of water to 3 per cent. of available ammonia.

As to phosphoric acid, which is also an important ingredient from a manurial point of view, it was found in four samples to amount to an average of 5 per cent. reckoned as tricalcic phosphate.

In a paper by Mr. William Santo Crimp, read some years ago before the Institution of Civil Engineers, the author called attention to the use of filter presses at Wimbledon as adapted to dealing with sewage sludge. By the use of two of Johnson's presses the then weekly production of 250 tons of sludge was reduced to about 50 tons of cake containing 50 per cent. of water, at a cost of 2s. 6d. per ton for labour, lime, fuel, cloths, etc., to which has to be added interest on capital and depreciation, say 1s. per ton more. The precipitation of the suspended matters in the sewage was effected by lime and sulphate of alumina, the average daily quantity used being equal to 0·91 ton for precipitating and pressing. As regards the value of this pressed sludge-cake as manure, Professor Munro has stated that it is superior to stable manure of good quality. With crops of hay, potatoes, mangold, cabbages, and swedes, the average production per acre was in the case of sewage sludge-cake 13·15 tons, with superphosphate 12·60 tons, and with farmyard manure 12·27 tons, while the unmanured plot yielded 11·72 tons. Potatoes were especially benefited by the dressing of sewage-cake.

Among other processes officially investigated by the late Dr. R. Angus Smith was one then employed at Coventry, consisting of precipitation by alum, iron salts, and lime, followed by irrigation of the effluent. In consequence of this double system, the water eventually obtained from the sewage was of a very high quality, as the following figures demonstrate :

	Organic Carbon.	Free Ammonia.	Albuminoid Ammonia.	Nitric Acid.	Total Solids.	
Crude sewage -	11·33	2·58	1·70	none	99·0	Parts per 100,000 contained in the water.
Filtered effluent -	1·418	2·40	0·245	,,	71·0	
Effluent after irrigation - -	0·587	2·12	0·205	—	77·0	

Another mode which has been proposed for dealing with sewage consists in heating it with milk of lime, condensing the ammonia that is evolved, and separating and pressing the sludge which remains behind. This sludge has little value (in common with all lime precipitates) as a manure, and it would not pay to burn it with the view of regaining the lime in a caustic condition for use over again. The amount of ammonia that could thus be obtained even from fresh sewage would probably not suffice to cover the cost of production, while from stale sewage much less would be obtained.

'Hanson's process' consists in treating the sewage with lime and alkali waste. At one time it was in use at Aldershot, but judging from the analytical results furnished by P. F. Frankland, it is not so effective as the A B C process.

The following are the results referred to :[*]

RESULT OF ANALYSIS IN PARTS PER 100,000.

	Dissolved Matters.						Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Mineral.	Organic.	Total.
Raw sewage -	132·72	7·441	2·234	0·90	2·975	5·7	4·96	44·70	49·66
After treatment -	120·16	4·777	1·802	0·80	2·461	7·1	2·36	—	—

I do not know if the process is still employed.

In the process devised by the late General Scott, the idea of obtaining a valuable manure from sewage was abandoned, and the total precipitate obtained by the addition of lime, or lime and clay, was collected, dried, and burned, in order to make cement. Precipitation by lime, however, yields an effluent which, from its comparative impurity and alkaline character, soon passes into a state of putrefaction, and the lime which passes into solution is fatal to the fish contained in river water. Moreover, the process is not unattended with nuisance, and it is not profitable.

The following analyses by Dr. R. Angus Smith show what sort of an effluent is obtained from sewage by precipitation with lime :[†]

	Organic Carbon.	Free Ammonia.	Albuminoid Ammonia.	Nitric Acid.	Total Solids.
Crude sewage (Burnley) - -	20·33	1·45	1·20	none	197
Effluent - - - - -	3·737	1·33	0·305	1·2	54
Crude sewage (Birmingham) -	20·44	2·70	1·05	none	177
Effluent from settling tanks -	4·09	3·22	0·66	2·13	100·5
Effluent after irrigation - -	2·303	1·275	0·21	1·19	112·5

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[*] *Journ. Soc. Arts*, vol. xxxii., p. 434.

[†] *Chem. News*, vol. xli., p. 51.

The use of lime is to be deprecated; it gives a sludge which is generally slimy and difficult to deal with in consequence, while it yields an alkaline effluent which is very apt to pass into a putrefactive condition.

Of all the processes of chemical precipitation that have been hitherto suggested for adoption, none have been free from a feature which altogether condemns most of them—viz., the employment of expensive chemicals in considerable quantities (for they must be employed in considerable quantities if they are to be effectual) for the purpose of extracting from the solution certain matters which are therein dissolved in small quantity and with the object of increasing the manurial value of the precipitate. The cost of the chemicals which must be thus employed is at least dangerously near to, if not greater than, the increased value given to the product.

Chemicals, so far as they may be used in the treatment of raw sewage, should be confined to the limit of preventing nuisance. Separation of the solids from the fluid of sewage is essential, and it is to be advocated that the effluent should be disposed of by a process of irrigation over land, where that can be done: the employment of such a process is the more recommendable because, when a process of *separation only* has been employed as contradistinct from a process of *precipitation with chemicals*, the effluent is richer in organic substances available for the nutrition of plant-life. As an alternative, and in the absence of special objections, the effluent may, with practical immunity, be discharged into a tidal or other river having a sufficient volume and flow, for the oxidation which occurs so rapidly in running streams suffices, in a very short time, to render innocuous the organic matters which are held in solution.

In cases where raw sewage is treated by an essentially chemical process, the effect of the chemicals is, unfortunately, by no means confined to the substances which are held in solution; the greatest effect is exercised upon the solid matters in suspension, and, in consequence, the chemicals are largely wasted.

The process of precipitation, therefore, which should be employed for the purpose of separating the solids from the fluid part of sewage, should be as simple and as economical as possible, consistently with preventing nuisance or danger to the public health. I claimed for a process which I some years since introduced (Specification No. 10,879 of 1885) that it was at once the most simple and innocuous, the most effective and the most economical that had so far been proposed for that purpose. It consists in adding to the raw sewage a material in the form of powder, which has the property of absorbing ammonia, sulphuretted hydrogen, and other offensive gases; of deodorizing the sewage as a whole, and (what is most important) of giving to the precipitate which is obtained certain most important physical qualities. The material in question is *powdered coke*, or 'breeze,' which I found, by experiments conducted in my laboratory, to be practically of equal value with animal charcoal, while no material that is so readily and universally obtainable can be procured at such small cost.

In conducting my process of treatment and utilization of sewage, the powdered coke may be first admixed with a certain proportion of clay or ballast (for the purpose of increasing the density of the precipitate) and then added to and well mixed with the sewage in certain proportions. The deposit which is thus obtained, unlike ordinary sludge, can be easily pressed and it constitutes a fairly good manure, which may be usefully employed, where practicable, for making up low-lying lands of a suitable nature, or for incorporation with clayey, chalky, or sandy soils which are naturally deficient in organic matters, thereby improving them for agricultural production. Its peculiar value for this purpose is derived from its physical quality, for, by the use of powdered coke or breeze, the sludge is rendered *particulate* or *granular* in character, so that when applied to land it does not choke up its pores in the way that ordinary sewage sludge does, and, in consequence, the air finds easy access to all parts of the soil, while plants more readily assimilate the organic matters which are contained in the dressing.

The utilization of the precipitate is not, however—and this is a very important matter to public bodies which have to do with the disposal of sewage—confined in any sense to its employment as a manure. After pressure, it may be air-dried and employed as ordinary fuel for use in boiler and other furnaces, for it will be observed that not only have the solid parts of sewage an organic character, but the bulk of the material which is added to the sewage consists of carbon, which is in itself a fuel; or it may be roasted, and thereby reconverted into a carbonized material fit for use again in precipitating and purifying further quantities of sewage. As an alternative, the coke precipitate obtained from sewage may be ground up with more clay and converted into bricks; or it may be admixed with such other materials as are ordinarily employed and converted into ballast for use by sanitary authorities and others in the construction of footpaths and foundations of buildings.

These applications of the precipitate obtained by this process of treating sewage are really practicable, and the process does not involve any great liability for expensive chemicals or elaborate plant.

The liquid part of the sewage remaining after precipitation and settlement of the solids would only require to be passed through a prepared contact filter-bed of coke breeze preparatory to passing into any water-course.

The purifying effect of common coke has been since confirmed by some experiments of Frankland,* in which it was proved that powdered coke exercised a sterilizing effect upon micro-organisms equal to that of spongy iron and far greater than that of animal charcoal.

The system of disposal which was proposed by Captain Liernur, is known as the 'aspiration method.' The excreta, admixed with water, are allowed to fall into an earthenware pipe, which is connected with a smaller iron siphon-pipe, from which they are

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* Proceedings Royal Society, No. 238, 1885.

periodically extracted by exhaustion with air. This plan has been adopted at Amsterdam and other Dutch towns, also to a small extent at St. Petersburg, apparently with very fair success, and it appears well adapted for towns lying in a flat country where sewerage by gravitation is extremely difficult to carry out.

Which of the various methods for removing sewage that have been described is the best depends to a great extent on the situation of the town that has to be dealt with. For London and cities similarly situated on the banks of rivers, where water can be obtained with comparative ease and where there is not much difficulty in getting rid of the sewage water, the most desirable method seems to be the water system; whilst for large inland towns such as Birmingham, where water is scarce and where the removal of the sewage water presents great difficulties, a dry system such as pail-closets seems to present advantages.

Certain experiments which were made by Dr. Angus Smith led him to think that by driving air through sewage matter, in order to produce oxidation, not only would nitrates be readily produced, but the excess of air would be offensive to the micro-zymes, notwithstanding that some air is necessary for their activity. Further investigation concerning the aeration of sewage showed that in all cases putrefaction was delayed by aeration and that ammonia is contained in the air that has passed through the sewage. He continues: 'The dissolved oxygen also recovers itself in the aerated specimens better than in the non-aerated.

This shows that aeration not only prevented putrefaction, but prevented also the chemical action consequent upon it. It had, in fact, to a large extent and for a considerable time, rendered the organic matter inert, or nearly so. Nitrates are also formed more readily in the aerated than in the non-aerated specimens.' In the same communication,* Dr. Angus Smith quoted the results obtained by M. Lauth, who had conducted similar observations (see *Compt. Rendus*, lxxxiv. 617-620). M. Lauth filled two bottles, one with ordinary sewage and the other one with sewage saturated with air, and then placed both aside to watch the results. The non-aerated sewage soon became black and offensive, whilst the aerated sewage was inodorous after two months. He also found that lime had an effect similar to that of air and he studied the effects of liming and aerating the sewage. The following analytical results were obtained by him:

	Insoluble Nitrogen.	Soluble Nitrogen.	Nitrogen as Nitric Acid.	Nitrogen as Ammonia.	Total Nitrogen Volume.
Before aeration -	14·70	20·65	1·176	8·4	38
After aeration -	8·05	26·95	1·122	14·0	38
Treated with lime	10·15	25·55	2·60	18·20	—
Treated with lime and aerated -	6·65	28·87	2·12	21·35	—

It is seen from these results that the process of liming sewage, as also that of aerating it, both result in the increased production of ammonia and nitrates.

According to M. Lauth, sewage contains from 4 to 7 grains ammonia to the gallon, but, unfortunately,

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* *Sanitary Record*, vol. v., p. 159.

this amount of ammonia, though considerable in itself, is insignificant in comparison with the amount of water in which it is contained; hence the difficulty in extracting it.

The late Dr. James Young (of Kelly) found that by the distillation of 5 per cent. of a sewage mixture at 100° C. the bulk of the ammonia was obtained in the distillate; while by increasing the temperature and pressure, it still increased until at 70 lbs. pressure, almost all the ammonia could be obtained by distilling over 1½ per cent., the expulsion of it being accelerated by the injection of a small quantity of air.

Later on, he found that a lower temperature was desirable and that by the use of an exhausting air-pump, at a temperature of 26·6° C. (80° F.), sewage containing 5 grains ammonia per gallon could be almost entirely deprived of it in a few minutes. Instead of passing air through the sewage, it was sufficient to pass steam at a very low tension and consequently with an enormous bulk. 'When he passed the sewage down a coke-filled tower, which was rendered vacuous,* and which gave, from a great expansion of surface, a ready means of evaporation, he considered that he had put the problem in a satisfactory form.'

Up to the present, no commercial results have followed from these various experiments.

Dr. Angus Smith calculated† that, if only 1 grain of ammonia could be taken out of each gallon

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* Vacuum of ½ inch or 12·7 mm. mercury.

† *Sanitary Record*, vol. v., p. 159.

of sewage, there would be obtained from 1,000,000 gallons about 140 lbs. Now, the Glasgow sewers alone convey daily 50,000,000 gallons, and this quantity upon the same calculation would yield 7,000 lbs. ammonia, which would give about 1,100 tons per annum, equal to a value of nearly £60,000, while the London sewage upon the same basis of calculation would yield ammonia equal in value to about £200,000.

Some few years ago a good deal was heard respecting the electrical treatment of sewage, but writing as a chemist, I cannot see how at anything like a reasonable cost, such treatment can do more than deodorize the liquid part to some extent. Indeed, as Dr. Thresh has put it,* sceptical people regard the process merely as 'a roundabout way of producing a soluble iron salt to act as the precipitating agent.'

The so-called 'Amines' process consists essentially in adding a mixture of herring brine and milk of lime, with the result that trimethylamine and other associated chemical products are thus generated *in situ*, and these, it is said, sterilize the liquid part, while the solids are precipitated by means of the lime. Such a process does not dispose of the sewage. The precipitate quickly passes into a putrefactive condition when removed from the active agency of the 'Amines' (which exist in the liquid only), while the liquid part itself requires purification from the purifying agent, either by irrigation or otherwise, before it can be

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* *Brit. Med. Journ.*, August 15, 1891, p. 382.

allowed with safety and freedom from unpleasant smell to pass into any water-course. In the end, at any rate, the solids have to be disposed of in some other way.

Much attention has been paid from time to time to the use, in a number of different forms, of iron salts as precipitating agents for the treatment of sewage, and no doubt they may often be very usefully employed. The preference is probably to be given to so-called ferric salts, rather than to ferrous salts, but their employment is, in common, damaging to the value of the precipitate, so far as its uses for manurial purposes are concerned. I do not think their effect is so beneficial as that of powdered coke, but they have the advantage of not so materially increasing the quantity of the sludge to be afterwards dealt with.

With the view of reducing the total volume of sewage to be dealt with and thus concentrating its valuable constituents, it was proposed to provide London in 1854 with the separate system mentioned at the beginning of this chapter; but the area is so immense, the cost would be so great and the disturbance so enormous, that the suggestion has been considered by high authorities to be hardly practicable.

It is generally admitted that the quantity of sewage proper (that is to say, the quantity that would flow from houses and general drainage, without any admixture of rain or spring water) is fairly measured by the amount of the water supply, which is given in Mr. Baldwin Latham's table at 144,000,000 gallons *per diem*; so that the difference between this quantity and the total quantity actually discharged from London—viz., 170,000,000 gallons, amounts to about 26,000,000 gallons and represents rain and spring water accidentally mixed with the sewage.

In concluding the study of sewage and its disposal, we may sum up as follows:

1. Where practicable, a separate system of drains should be employed for sewage proper and rain water.

2. Rain water thus collected is necessarily polluted with organic refuse, but only to such an extent that it may be adequately purified without danger to the public health, either by filtration through a properly drained porous soil, or by natural oxidation in a running stream of sufficient volume.

3. Sewage, whether admixed with rain water or not, should be so dealt with (by screening, subsidence, precipitation or other treatment), that the solid parts are wholly removed from the liquid parts. The liquid parts should then either receive chemical treatment, so as to obtain, if possible, valuable products therefrom, or be used for irrigation purposes, failing or after which it may be allowed to flow into some watercourse of sufficient volume and preferably one that is not used as a source of drinking water.

The solid parts of sewage merit treatment, whereby they may be made to yield valuable products, failing which they should be at once ploughed into the earth, or be treated in a way that will make them innocuous until they are subsequently utilized as manure or fuel.

If the solid and fluid excreta of human beings really have the value that is ordinarily attached to them, private enterprise would surely be rewarded (at least in places where the water-carriage system is not employed) for their collection and utilization. Thus, a small portable apparatus provided with a strainer might be supplied to each house, whereby the urine would be separated from the solid parts, and this receiver could, under a properly organized system, be collected daily and a clean one left in its place.

The receivers containing the excreta should be taken direct to the factory where ammonia could be profitably obtained from the urine, and the solid parts could be also utilized, either as a source of ammonia and certain salts, or they could be dried and utilized as fuel for distilling the urine. Or again, the excreta collectively could be worked up with other substances into an innocuous and valuable manure ready for immediate application to the soil.

On the other hand, if the human excreta be of little value, one of the arrangements for sprinkling the refuse matters with breeze, coke, dust, ashes or dried earth should be used, and the resulting mixture daily utilized on the spot for gardening purposes or carted away daily with the general house refuse. Treated with powdered coke, ashes or earth, the urine and fæces in a fresh state are no more dangerous to health when contained in an iron or galvanized iron dust-bin, than are the bones and other decomposing vegetable and animal matters that are usually stored therein, until they are removed by the local health authorities. All slops should, under such circumstances, be thrown upon the garden or waste land, or drained off from the houses to a suitable distance and locality.

Connected with the subject of earth-closets, one of the late Dr. A. Carpenter's papers* may be perused with much profit and interest. He therein gives the experience gained with some twenty earth-closets which were erected at a cost of about £3 each; the pails which were used being collected and changed weekly between the hours of 5 and 6 a.m. The expenses of this system during two years and a quarter were as follows:

	£	s.	d.
Man and boy used for collecting - -	47	4	6
Horse and cart - - - - -	14	12	6
Sawdust for urinal pail - - - -	8	9	0
	£70	6	0

The collected excreta was sold at 2s. 6d. per yard, reducing the cost to 8s. 3d. per week.

Thus 22 houses, occupied by 122 persons, were provided for at a cost of £1 8s. 5d. per house, and 5s. 1½d. per person per annum; or, deducting the value of the product, at 3s. 6¼d. per annum — a trifle under £1 per house. From certain considerations which he adduced, he thought the cost on a larger scale could be reduced by one-half. On this basis, a village of 200 houses of average rateable value £15, would entail a rate of 9d. in the £1 to provide for the removal of excreta by a dry system; at the same time no debt would be incurred and no mortgage of rates would be necessary.

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* *Journ. Soc. Arts*, May 18, 1877.

Dr. T. M. Lownds (retired Surgeon-Major H.M.I. Medical Service) has published a very interesting pamphlet, in which he dwells upon the feasibility and the advisability of some proceedings for 'antiseptic drainage and utilization of the whole of the products of excrete,' and, personally, I am strongly inclined to think that a dry system of collection in villages and small towns, even if not in larger centres of population, is to be recommended in preference to the water-carriage system. Upon economical grounds alone it has immense advantages, while for the agricultural welfare of the country it is impossible to estimate the value.

In concluding this chapter, I refer my readers, who may be desirous of making themselves intimately acquainted with the details of many phases of the subject of the treatment and utilization of sewage, to the admirably exhaustive paper of the late Dr. Meymott Tidy,* and to the account of the discussion which followed that communication; also to a pamphlet on 'Sewage Treatment, Disposal and Utilization,' by Douglas Archibald, M.A. (Bowles and Sons).

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* *Journ. Soc. Arts*, October 8, December 3 and 17, 1886.

CHAPTER VII.

INFECTIOUS AND CONTAGIOUS DISEASES — CHEMICAL AND GERM THEORIES — GENERAL RELATIONS OF MICRO-ORGANISMS TO DISEASE—BIOPLASM AND THE GRAFT THEORY— PREVENTION OF INFECTION.

ONE of the most important facts of which history takes note, is the liability of human beings to be attacked by diseases of an epidemic nature. The Sweating Sickness of 1485, as also the Black Plague of London (1499), may be cited as historical illustrations.

According to Short, the historian, there was in 1625 a mortality from plague, in London alone, of upwards of 36,000. Then again, in the years 1635 to 1636 there was a plague mortality of 14,000; while in the years from 1663 to 1665 there occurred in the same city, it is said, between 70,000 and 80,000 deaths.

In brief, from the year 1490 B.C., when 624,000 Israelites were destroyed by plague in the wilderness,* to the present time, history teems with the records of wholesale destruction of mankind by diseases of an epidemic character.

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* Num. xi. Josephus' 'Antiq. Jews.'

Of one disease alone—viz., typhoid fever—it is on record that nearly 100,000 cases occur annually, and of these about 15 to 20 per cent. prove fatal!

If we consider these and similar facts, and 'the almost total impotence of medicine for direct cure, we may indeed consider this a question more for statesmen and governing bodies than for physicians. Nevertheless it is necessary that the efforts of the former should be guided by such knowledge of the nature and causes of these diseases as the science of the day can afford. Nor is such knowledge less to be desired for the people in general, in order to counteract the baneful effects of ignorance and prejudice.'*

Let us now endeavour to ascertain how far science is able to indicate the nature and causes of infectious diseases and to provide the means of preventing or arresting them.

In the first place, it may be useful to remind my readers that the terms 'infectious' and 'contagious' are not absolutely synonymous; all contagious diseases are infectious, but all infectious diseases are not necessarily contagious.

Infectious diseases have been divided into three classes—viz. (1) those which depend upon poisons which originate outside the body and are not contagious; (2) the contagious diseases arising from contagions or specific excitants, which are reproduced in or upon the bodies of the sufferers; (3) diseases in which the contagion is not so readily transmitted

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* 'The Germ Theories of Infectious Diseases,' p. 1. By John Drysdale, M.D. London: Baillière, Tindall and Cox.

from person to person, but which at the same time are, it is believed. always derived from prior cases, the poison being carried in the secretions.

As examples of the first class, we may instance malarial fever and septicæmia. In the first of these it is supposed that under favourable conditions, as regards moisture and temperature, vegetable matter undergoes a process of decomposition, resulting in the formation of a specific poison, which, by its reception (or that of the micro-organisms which produce it) in the living body, produces either remittent or intermittent marsh fever. The disease known as septicæmia is really very similar to this in many respects, although in this case there is no doubt as to the non-living nature of the virus (sepsin),* for the poison is produced during the putrefaction of albuminous compounds, and its introduction into the blood-system gives rise to the disease in question.

Both sepsin and the malarial poison are always generated either outside the body itself or in or upon its external parts, and neither disease is communicable from one person to another, in the ordinary sense of that expression—excluding, of course, inoculation.

Small-pox, measles, scarlet fever, plague and glanders, etc., are members of the more contagious class of diseases. It is said they never originate spontaneously, but are always communicated from one person to another, the specific contagia upon

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* Consult Dr. Burdon-Sanderson's papers contained in the Reports of the Medical Officer of the Privy Council, etc. No. 3, 1874, and No. 8, 1876.

which they depend being disseminated from one person and conveyed to the infected subject. In small-pox, the virus is thrown off from the skin; in measles, from the mucous glands of the nose and air passages; in scarlet fever, by the glands of the throat in particular, and so forth. How the virus, after transplantation, establishes and reproduces itself, will be our study hereafter.

Of the third class, it appears that the virus of the disease may be carried in the secretions and undergo development outside the body. Thus in typhoid fever and cholera the contagion is elaborated or reproduced by or in the glands of the intestines and passes away with the fæces. In these it resides and maybe partly develops, being ready at any future time to attack those persons who may become exposed to its influence. Supposing that such infectious matter be not immediately altered or destroyed, its possibility for harm is unlimited; for as the fæces dry, its particles may be carried either into drinking water or the atmosphere, and woe to the person who either drinks the one or breathes the other when they are so contaminated!

Even in ancient times infectious diseases were supposed by Hippocrates and later on by Diodorus, to be connected with putrefactive processes. So also in the Middle Ages, Fracastori ascribed a host of diseases to the same sources.

Later, there arose in the minds of men a clearer theory of disease, which, however, to do modern investigation justice, until recent years rested upon a most insignificant basis. This theory may be said to have originated with the remarkable investigations conducted by Leeuwenhoek in 1683, in course of which he discovered the existence of active microscopic organisms; it was revived by Henle in 1840 and further referred to in his *Rationelle Pathologie* in 1853. Although since then the classical researches of Pasteur on fermentation and the investigations of Tyndall and many others on germ life, have added much to the data, the theory itself has undergone no material change. In 1840 Henle taught that 'infection in contagious diseases is caused by living beings, and that scabies is to be regarded as a type of contagious diseases.'* To this, Liebig replied that such an opinion was founded on the principle that like effects imply like causes, and he went on to add, 'This is the very principle which for centuries impeded the progress of natural science, and which, even in the present day, leads to so many errors.'

Liebig did not altogether deny the existence of parasitic diseases; on the other hand, he readily admitted that there are many diseases which are caused by parasites which are reproduced in and upon the bodies of animals, and which live at the expense of the constituents of their bodies. Scabies (or the itch) is such a disease, and muscardine, a disease to which the silk-worm is liable, is of a similar nature: in truth, there is no lack of examples. He, however, maintained that, excluding strictly parasitic diseases,

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* Henle, *Zeitschrift*, ii. 305, and Liebig's 'Animal Chemistry,' English edition, 1846, p. 210.

which naturally require no chemical or any other theory to explain their communication, the true contagious diseases (such as small-pox) depend upon perfectly distinct and different causes. He writes,* 'The condition which determines in a second individual his liability to the contagion, is the presence in his body of a substance which, by itself, or by means of the vital force acting in the organism, offers no resistance to the cause of change in form or composition operating upon it. If this substance be a necessary constituent of the body, then the disease must be communicable to all persons; if it be an accidental constituent, then only those persons will be attacked by the disease in whom it is present in the proper quantity and of the proper composition. The course of the disease is the destruction and removal of this substance; it is the establishment of an equilibrium between the cause acting in the organism which determines the normal performance of its functions and a foreign power by whose influence these functions are altered.'

In brief, Liebig looked upon fermentation and the true contagious diseases as processes in which, alike, a substance in process of change imparts by virtue thereof a disturbance to the equilibrium of the elements of other bodies. Beyond this general definition he did not attempt to define the nature of the contagia, but merely contended that all contagia are not parasites. He wrote,† 'In the contagion of

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* Page 205 of his 'Animal Chemistry.'

† *Ibid.*, p. 209.

small-pox, of plague, of syphilis, of scarlet fever, of measles, of typhus, of yellow fever, of dysentery, of gangrene, of hydrophobia, the most conscientious observation has not been able to detect animals, or even organized beings at all, to which the powers of propagation could be ascribed.'

Many years have elapsed since these words were written and although numerous conscientious and untiring workers have laboured in these paths of investigation, to-day's science can give no better theory of contagion, or better indicate the manner in which the contagia act upon the living body.

The further consideration of this subject, which is one of great scope, will be best treated by stating the chief established facts without discussing any but salient features.

Following the discovery made by Leeuwenhoek, there came the researches of Cagniard la Tour and Schwann, by which it was proved that the globules of yeast are living plants which multiply indefinitely under favourable circumstances; since then it has been established, by the researches of Pasteur and others, that the ordinary processes of fermentation are so many instances of a biological reaction manifesting itself as the result of a special force residing in organisms; or, in other words, fermentation is essentially 'a correlative phenomenon of a vital act, beginning and ending with it.'*

Indeed, a ferment, such as yeast, behaves towards

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* See Schützenberger's work on Fermentation, p. 39. London: H. S. King and Co.

a chemical substance, such as sugar, just in the same kind of way that a parasite behaves towards the body on which it preys. The two phenomena are correlative and parallel.

As yeast splits up sugar (or rather, as a matter of fact, seems to yield a product which immediately does the chemical work) and lives upon it, reproducing itself, so, also, certain forms of germ life behave towards albuminous compounds as previously explained. The one phenomenon is called fermentation, the other is known as putrefaction.*

The microbes which induce putrefaction are undoubtedly ubiquitous and this is a fact which it will be important to bear in mind hereafter. All the water and air we drink and breathe, ordinarily swarm with germs of three natural groups of the micro-organisms,† viz., the mould fungi, the spreading or yeast fungi and the bacteria. These groups comprise a great variety of septic and alcoholic ferment-organisms and monads, and form part of the organic matter of the air, which amounts, according to Angus Smith, to one grain in 200,000 cubic inches in the case of pure country air, and one grain in 8,000 to 10,000 cubic inches of less pure town air.

To understand the infinitesimal size of these organisms, it may be mentioned that Naegeli has calculated each to weigh only the thirty thousand millionth of a milligram! 'Consequently,' writes

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* See the Author's paper, *Journ. Chem. Soc.*, January, 1880.

† Stated by Dr. Drysdale, partly on the authority of Naegeli. See p. 24 of his essay.

Dr. Drysdale, 'all animals and vegetables on the face of the earth are continually receiving abundance of fungus-germs in the water essential to their existence. Thus, in the air we breathe, in all that we eat and drink, and touch, and lie on, we are continually exposed to the reception of germs. Accordingly, bacteria and various fungi and germs have been detected on all parts of the surface, and of the mucous passages open to the air, and in the organs communicating with the mucous membrane. They are found in myriads on the tongue and in the tartar of the teeth, in the nose and throat, and all through the alimentary canal, into which countless myriads are continually poured with our food and drink. Even developed bacteria have been found in the liver and spleen and in the blood of healthy animals in certain cases; but the germs or spores are diffused through the interstices of the tissues, where, under favourable circumstances, they may come to maturity, as bacteria are sometimes found in abscesses shut off from the air. They are found also in the perspiration of the axilla, the face, and other parts; also in the fluid of blisters raised artificially. Nay, even they are found in seeds or ova; the pink mould has been found in the middle of a nut, and the *Dactylium soyerium* in an unbroken egg. The cells of plants produce fungi, which fructify within them. In short, we may take it as established, that the whole of the higher organisms are interpenetrated perpetually with the germs of the lower fungi, and these may even develop in small numbers without much disturbance of health.'

According to Klebs,* members of the three groups of hyphomyceta, algæ and schizomycetæ, occur in the animal and human organisms in infectious diseases. The first of these groups requires an abundant supply of oxygen and as they run their course chiefly on the surface of the body, they are not deemed to be of the greatest importance. The group includes the forms *achorion*, *trichophyton*, *oïdium*, *aspergillus*, and are considered to be the causes of favus, ringworm, thrush and possibly madura-foot and actinomycosis.

Of the algæ, only one, viz., *leptothrix*, is seriously regarded as a producer of disease. It is supposed by Klebs to give rise to deposits of carbonate of lime in the teeth and in the urinary bladder (calculi), and when the organisms attack the teeth, they are stated by Leber and Rottenstein to cause caries.

The schizomycetæ is the most important group, and it comprises two widely different series of forms, viz., *bacilli* and *cocco-bacteria*.

The bacilli consist of threads in the interior of which permanent or resting spores are found, which, when they become free, develop under the influence of oxygen into new threads. The splenic disease of cattle is caused by such organisms; so also is hog cholera (Klein), etc. Cholera and yellow fever are also supposed by some to be caused by members of this series. They are longer in proportion to their thickness than

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* 'On the Relations of Minute Organisms to Certain Specific Diseases,' *Brit. Med. Journ.*, August 13, 1881. See also 'Micro-Organisms and Disease,' by Dr. E. Klein, and an account of the Biological Laboratory at Health Exhibition in *Brit. Med. Journ.*, August and September, 1884.

bacteria; sometimes their ends are rounded, and at other times square: some have a cilium and have rapid motions, while others have not, whilst they all multiply by fission.

The second series of the same group consist of *micro-cocci* (oval or spherical bacteria). When multiplying, they become dumb-bell-shaped, and then divide transversely. They often break up by division into chains, and lead again to the production of resting masses of cocci. This series is further subdivided by Klebs into *microsporina* and the *monadina*, in the former of which the organisms are collected into spherical lumps and in the latter into layers. The one class is developed in artificial cultivations at the bottom of the fluid and requires a medium poor in oxygen, while the other genera require much oxygen and therefore develop on the surface. To the *microsporina* Klebs attributes the septic processes and diphtheria, whilst the *monadina* are believed by some to produce inflammatory processes, such as rheumatic affections of the heart, kidney and liver affections, and, in general, the inflammatory processes which do not lead to suppuration, but to the formation of connective tissue, also acute exanthemata (including variola-vaccina, scarlatina, and measles), and infective tumours (including tuberculosis, syphilis, and glanders).

Cohn gives a different classification, which has been adopted by Klein; it is as follows: (1) bacteria proper; (2) micro-cocci; (3) bacilli; (4) spirilla.

Bacteria, generally, are minute organisms which multiply by fission (division), and they are composed of protoplasm invested with a delicate membrane. It is this membrane which enables them to resist, to some extent, the action of caustic chemicals. Bacteria while alive are generally very active, their movements being produced by means of delicate thread-like processes termed *cilia* or *flagella*. Bacteria proper are oval or slightly elongated rods, having round ends; they elongate before fission, and as they separate they develop the *cilia*. Their movements cease under certain circumstances and a resting stage is attained during which the individuals become embedded in a kind of gelatinous matrix.

Of the *micro-cocci* and *bacilli* we have already given descriptions.

Spirilla are corkscrew-shaped bacteria, varying very much in size; the largest measuring about 0·03 millimetre in length, with a long flagellum at each end. They are often found in putrid organic infusions. One well-known spirillum produces a rose colour which is in many cases visible to the naked eye and other bacteria often produce pigments in the media of their development.

Pasteur, as mentioned elsewhere, divides bacteria broadly into *ærobes*, which require free access of oxygen, and *anærobes*, which grow without free oxygen. They all require food containing carbon and nitrogen and certain inorganic salts. Most bacteria are destroyed by freezing and by drying, but the spores of *bacilli* constitute an exception: they survive exposure to − 15° C.

Micro-cocci are destroyed at a temperature of 60° C., bacilli at 100° C., and all spores are killed by a temperature of 120° C. to 140° C., when sufficiently sustained. Many chemical substances are inhibitive to their growth.

These micro-organisms present a remarkable power of endurance when compared with that of human beings and animals in general, but it must not be forgotten that their type of life is altogether of a different order. Thus, Miquel has cultivated a bacterium which lives and thrives in a medium charged with sulphuretted hydrogen and it has been well established that growth or multiplication by scissiparity, or spore-production, can take place up to 55° C. (according to Cohn), or 74° C. (according to Van Tieghem).*

Already, in an earlier chapter, mention has been made of the experiments made by the late Mr. F. Hatton for Dr. E. Frankland, who concluded that bacteria can be cultivated in an atmosphere of either carbonic oxide, cyanogen, sulphurous anhydride, nitrogen, nitrous oxide, carbonic anhydride, or coal-gas. Mr. Hatton observed that in an atmosphere of air the organisms present in a meat-solution absorbed oxygen and eliminated carbonic anhydride. An atmosphere of hydrogen was not affected and did not apparently affect the bacteria. Cyanogen seemed fatal to the bacteria when in solution in that form, but its decomposition into ammonium salts and azulmic

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* See paper by F. J. Faraday, F.L.S., *Chem. News*, vol. l., pp. 71-74, 90-93.

acid was assisted by their presence. Sulphurous anhydride, even when present in the meat solution to saturation, was apparently without influence on the bacteria. Salicylic acid, strychnine, morphine, narcotine, and brucine, Mr. Hatton found to be 'without any effect upon bacteria, even when quite large quantities are put into the solution containing the germs.' On the other hand, it was noted that phenol, spongy iron, alcohol, and permanganate of potassium destroyed bacteria with great rapidity.* With regard to these experiments, it is to be observed that some of the substances employed are insoluble in meat solutions, so that unless it can be proved that bacteria breathe as do human beings, it cannot be supposed that a mere envelope of gas prejudices their existence.

Further, it must be remembered that the chief function of micro-organisms, so far as has been ascertained, is the destruction by oxidation of organic refuse at large. To accomplish this destruction, oxygen is necessary and if the bacteria cannot get it in a more ready manner, they are often able to decompose comparatively stable substances and rob them of their constituent oxygen. It would, indeed, appear, from the description and results of Mr. Hatton's experiments, that he actually experienced this circumstance. Thus, in an atmosphere of carbonic oxide, the bacteria unmistakably decomposed it, or caused its decomposition, utilizing its oxygen for purposes resulting in the production of carbon dioxide; a similar process would

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* *Journ. Chem. Soc. Trans.*, 1881, p. 247.

appear to have taken place in an atmosphere of nitrous oxide.

Mr. W. M. Hamlet also conducted an investigation about the same time and it will be interesting to direct attention to some of his results.* He used various solutions for cultivating the bacteria—viz., Pasteur's fluid with sugar, beef-tea, hay-infusion, urine, brewers' wort and extract of meat, employing flasks similar to those used and described by Pasteur. Mr. Hamlet confirmed the results obtained by Mr. Hatton in respect of the behaviour of oxygen towards bacteria, showing that they make use of it to break up dissolved organic matter into ultimate products including carbon dioxide. This is strictly in accordance with the known history of putrefaction as worked out by Pasteur. After describing his experiments, he writes: 'These results show that amounts of chloroform, phenol and creosote, varying from $\frac{1}{4}$ to 3 per cent., do not destroy bacteria, although their functional activity is decidedly arrested while in contact with these reagents.' They are subdued in activity, but not altogether deprived of their vitality, which they regain when restored to more congenial surroundings. He continues: 'Upon both classes of bacteria, oxygen has a most important action. To the anærobian, oxidation is rapid and fatal as a poison to the higher animals, while the ærobian, less easily oxidized, are resolved by complete oxidation into nitrogen, carbon dioxide, and water.'

'We may conclude, therefore, that those bodies

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* *Journ. Chem. Soc. Trans.*, 1881, p. 326.

which destroy bacteria are those capable of exerting an immediate and powerfully oxidizing action, and it seems, after all, but stating a truism to say that (extremes of temperature, of course, excepted) it is active oxygen which must be regarded as the greatest known enemy to bacterial life, whether from the action of chlorine, nitric oxide, ozone, or peroxide of hydrogen. It also follows that these bodies are the best disinfectants.'

It may be taken for granted that many micro-organisms exhibit a wonderful power of endurance. Some of them may be strongly heated and nearly frozen or dried, and the matter containing them pulverized and still they live; they may be exposed to various gases, or cast into certain chemical solutions, and yet they are not killed. It is, however, far more important to ascertain under what conditions they can be influenced or are killed. They are all destroyed by a sufficiently high temperature; they can be killed by a process of starvation adapted to the peculiarities of their life-history, and many chemical reagents either arrest or divert their functional activity, or kill them outright.

It is to the action of such micro-organisms that the germ theory attributes all the contagious diseases to which man is liable.

It will be seen that, to a certain extent, the ubiquity of germs is a very telling argument against this theory when applied in its widest sense, and it may be safely said that its upholders, in their zealous search for germs, and hoping to find them associated with infective inflammations and contagious fevers only, have indeed found them pretty well everywhere —often to their discomfiture. If it be true that germ life is *per se* contagium vivum, then it can no longer surprise us that infectious disease is of common occurrence. On the other hand, it devolves upon the germ theorists to explain the escape of any one individual from such an all-pervading contagium.

In spite of all that has been said and written on the side of the germ theory, its very advocates cannot but admit that, so far as small-pox, and most of the principal contagious fevers are concerned, 'their connection with pathogenic organisms is, as yet, a matter of pure inference' (*Roberts*).* Nay, more, it is scarcely a matter of inference; it is one of mere hypothesis. It must be obvious to all that, if the true contagious fevers are attributable to specific germs, then small-pox, scarlatina, and typhus should originate spontaneously, instead of which they seem to be entirely dependent upon previous cases. This, at first sight, would appear to be an insurmountable difficulty, but the theorists have invented a way out of it.

It is true that the constant presence of particular germs may be microscopically demonstrated in the case of certain diseases, but it is also true that the same observation may often be made in cases where there is no disease. For instance, Dr. T. R. Lewis, of the Army Medical Department, found† that the comma-

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* 'Reports on the Life-History of Contagion.' By Dr. Braidwood and Mr. Vacher. Also Dr. Roberts' address, *Brit. Med. Journ.*, 1877.

† *Brit. Med. Journ.*, September 20, 1884.

shaped bacillus, identical in size, form and reaction with dyes, with that described by Koch as the specific cause of cholera, is present in the secretions of the mouth and fauces of perfectly healthy persons: what is more, Klein does not believe in Koch's cholera *bacillus*, and is stated to have swallowed the *bacillus* and to have experienced no ill result.

The germ theorists evade such difficulties by crediting certain of these low forms of life—not distinguishable by appearance or ascertained life-history from others known to be harmless—with pathogenic powers. That is to say, they view them as physiologically distinct without sufficient warrant for so doing. Thus, it is urged against the observations of Dr. Lewis that the mode of growth of the comma-shaped bacillus in gelatinized meat infusion, should be relied upon as affording a means of distinction between the innocent germs and the pathogenic organisms of Koch; but it seems to me rather to rest with Koch to prove that this suggested distinction has a real existence, although, failing that, it might have been hoped that Dr. Lewis would himself make this proposed test of identity a matter of experimental observation.

Against the germ theory, pure and simple, it may be further urged that it is almost, if not quite, practically impossible to perform an inoculation experiment in which, with absolute certainty, only one specific micro-organism is employed and that in a state *free from any secretion or product* which may possibly constitute the virus.

It must be admitted, on the other hand, that there are several diseases which, it is now widely and confidently asserted (and not without considerable reason) are caused, directly or indirectly, by micro-organisms. To these a little attention must be devoted before we proceed to study another doctrine, which, in some respects at least, is of a more acceptable nature.

Dr. Obermeier, of Berlin, was the first to observe spiral micro organisms in the blood of patients suffering from relapsing fever, since which time the observation has been often repeated. This disease is not contagious in the ordinary sense of that word, but it may be communicated by inoculation with the blood of a patient, provided the blood be taken during the paroxysmal periods when spirilla are present; they are said to be absent at the crises—a remarkable fact, in itself, and affording, it seems to me, good reason for doubt as to the true cause of the disease. From this it is concluded that the spirilla constitute the infectant. It is admitted that ocular evidence of the germ in question is all but absent, and all attempts to cultivate the spirilla out of the body have failed. Whether, therefore, the disease is, after all, dependent upon other circumstances or communicated by some other constituent of the blood, is not absolutely certain.

In 1855 Polender discovered minute staff-shaped bacteria in the blood in cases of splenic fever, and it has been ascertained that they also exist in the spleen, the lymphatic glands, etc., etc. Cohn and Koch having devoted particular attention to this subject, they have concluded that *bacillus anthracis* is the true virus of the disease—a view which is now pretty universally held by believers in the germ theory.

Here, again, the contagium is communicated by actual contact of the blood or other exudations of a diseased subject, but it is not communicated by placing animals in the closest proximity to the diseased ones; in short, there is no infection through the air. It is also to be observed that the infective power of the blood disappears on the appearance of putrefaction. It is not necessary to go through the life-history of this microbe; it will suffice to state that Koch has proved beyond cavil that, in suitable nutriment, spores are formed, and these reproduce the rod-bacilli, certain cultivations of which are then competent to produce splenic fever in living animals. Whether, however, this result is actually brought about by the germs in question, or by anything accompanying or produced by them, has not even yet been made quite clear. The test was a somewhat crucial one; but, as admitted by more than one well-known pathologist, there exists some reason to doubt whether Koch obtained the bacillus quite free from other possibly poisonous matter.* The reason is the greater since Professor Cohn could not distinguish *bacillus anthracis* from *bacillus subtilis* (of the butyric fermentation) in a morphological sense. Under the microscope they are indistinguishable.

More recently Klein, by his investigation† of infec-

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* See Dr. Drysdale's Essay, p. 16. Also my 'Animal Chemistry' (Longmans and Co.), p. 438.

† Seventh Annual Report of the Local Government Board (1877-78).

tious pneumo-enteritis in the pig (pig-typhoid, so called), came to the conclusion that this disease is caused by a microphyte admitting of artificial cultivation outside the body, and which, when so cultivated, even to the eighth generation, is capable of producing the original disease in a healthy pig. No one can question the extreme care and skill with which these experiments were conducted; but at the same time there still exists the doubt as to whether the disease is really caused by the germ itself (or some toxic substance accompanying it), or is owing to some product to which either it, or some secretion from it, gives rise in the body of the pig, or whether the whole phenomena observed are merely imitative of the natural disease.

To illustrate the full intent of this argument, it will be convenient to recall the facts concerned in septicæmia. In that disease the poison has been proved not to consist of germs, but of a non-living substance elaborated by micro-organisms in a suitable medium, and both splenic fever and pneumo-enteritis of the pig are, in all probability, similarly produced.

The position may be summed up in a few words.

If it be admitted that splenic fever and so-called pig-typhoid are directly caused by microphytes *per se*, then I contend that such diseases must be taken out of the class of ordinary contagious diseases, and be henceforth viewed as parasitic diseases, being placed side by side with scabies, fungus foot, and the horrible disease caused by the *Trichina spiralis* when introduced into the living body.

It has been mentioned already that Cohn failed to distinguish *bacillus anthracis* from *bacillus subtilis*. Büchner went further than this: he thought that he had established their convertibility, but both Klein and Koch have published an account of experiments which, in their opinion, upset this idea. I refer to this, in order to call attention to the hypothesis of Von Nägeli as to the convertibility of the different species of micro-organisms generally. This hypothesis did not receive the support of Pasteur, who believed that each special process of fermentation or disease has its own special originating micro-organism. While, however, he did not admit their polymorphous character, he himself called attention to the means of attenuating their activity to such an extent that it might almost be believed that convertibility does take place. He stated* that if the most minute drop of blood be taken from a fowl about to die from chicken cholera, and placed in some clear *bouillon de poule* previously sterilized at a temperature of 115° C., and kept under conditions in which neither the outer air nor the vessels employed can introduce exterior germs, at a temperature of 25° to 35° C., the inoculated liquid grows turbid and full of tiny micro-organisms. From this cultivated solution successive solutions can be inoculated to the hundredth or thousandth generation, and if from the last of the series the most minute portion be inoculated under the skin of a previously healthy fowl,

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* 'Address on Vaccination in relation to Chicken Cholera and Splenic Fever.' By M. Pasteur. *Brit. Med. Journ.*, August 13, 1881.

the bird will die as surely as though it had been inoculated with the blood taken direct from the fowl which furnished the original source of the poison, and with the same symptoms.

On the other hand, if a considerable interval of time, say a fortnight, a month, three months, or ten months, be observed between the artificial cultivations of the virus, then the virulence of each succeeding product is lessened, notwithstanding the abounding presence of the tiny micro-organisms (shaped like the figure 8), until a product is obtained which when inoculated into a healthy fowl, will make it ill, but will not kill it. 'When the fowls have been rendered sufficiently ill by the attenuated virus, which the vital resistance has arrested in its development, they will, when inoculated with virulent virus, suffer no evil effects, or only effects of a passing character.' Here, Pasteur says, we evidently touch the principle of vaccination, and he endeavours to show that it is by the agency of atmospheric oxygen that the attenuation of the virus is brought about, for in the absence of oxygen the virulence of successively cultivated solutions is not appreciably impaired.

Others have since shown that a similar attenuation can be brought about much more quickly by mixing the virus with peroxide of hydrogen. What, then, is the action of the oxygen? Can it be supposed to alter the very nature of the germs themselves? or does it oxidize some virulent chemical secretion or poison which the germs intermediately elaborate or produce? Unless there be an actual process of evolution by which the germ of chicken cholera is morphologically converted into an innocuous form by the agency of oxygen—a supposition which meets with no favour from the highest authorities—the attenuation, it seems to me, must be brought about by a chemical change between oxygen and the real poison, which in that case must be regarded as a chemical substance resulting from the life-function of the germ under suitable conditions, just as sepsin is elaborated in the process of putrefaction. (See p. 245).

The accuracy of this view is supported by the fact that there is no fundamental distinction between the effects of many well-known chemical poisons, such as prussic acid, strychnine, and certain other alkaloids, and the symptoms of diseases of the class of chicken cholera, except, perhaps, the greater intensity of the poisons that are often associated with micro-organic life. I am confirmed in this view for another reason, which I have set forth in a short critical note of Pasteur's work on this subject.* The interpretation placed by that eminent investigator upon his own observations, necessitates the assumption of the presence in the human body of a number of distinct substances, each forming the proper and distinctive food of a particular parasite, and the further assumption that vaccination in some undetermined way gets rid of such substances, or converts them into products not fit to serve as food. In the inflicted process of vaccination with an attenuated virus, the body becomes ill, but does not die. It does not die because, if Pasteur be correct,

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* *Chem. News*, vol. lxiii., p. 28.

the parasites do not sufficiently multiply. Why do they not so multiply? It cannot be on account of the insufficiency of the pabulum, for when death follows inoculation of an attenuated virus, it results, so Pasteur says, from the very profusion of the growth of the parasite. The pabulum, which is sufficient to support a given number of parasites, is of necessity able to support a smaller number thereof!

Moreover, there is an utter disregard of chemical and quantitative evidence in these various assumptions, for although we are tolerably familiar with the very considerable decompositions effected by parasites, as, for example, in the processes of putrefaction and alcoholic fermentation, it can scarcely be supposed that even, say in three successive inoculations, the pabulum afforded by the body of a fowl to the virus of chicken cholera can be entirely used up; if it be, then its amount must be extremely limited, and its nature is a mystery.

For my part, I have always thought and taught, and still believe, that this is an entirely erroneous line of theory, and if we are to believe in the existence of diseases initiated by germs (and I fail to see how this can be doubted), we must, at least, seek for the real poisons that cause death in the secretions of the parasites or in the chemical products to which they can give rise in suitable media. It is easy to understand how oxygen and other chemical substances and conditions may change purely chemical products, but such changes cannot be conceived as occurring in the parasites themselves. It is only a difference of form, as Klebs expresses it, that corresponds to a difference of function, and if we outstep this boundary we must assume the possibility of the transformation of species, an assumption which is, so far, utterly unwarranted.

As bearing upon this view of bacteria and their connection with disease, it is interesting to refer to some recent experiments made by Dr. Klein, which were conducted on behalf of the Fishmongers' Company and from which it appeared that oysters contaminated with so-called specific infective *bacilli* possess the property of ridding themselves of such micro-organisms within a short period when relaid in clean waters. Other shell-fish were found to cleanse themselves similarly, but more slowly. It seems to me that these observations admit of several interpretations. The cleansing may be purely mechanical—that is to say, the *bacilli* may be removed or carried away by the fresh water, or at least be largely diluted. The doubt also arises as to whether the shell-fish did really rid themselves of the *bacilli* branded as specifically infective, or were these otherwise harmless micro-organisms merely purified from poisonous chemical products previously associated with them by the fresh clean waters? The point is a pertinent one, and should be cleared up by further investigation.

Nägeli contends that the contagious organisms are derived from the miasmatic and these again from the putrefactive, the latter having an unlimited variability of form and action. Much the same view has been advocated by Dr. Hueppe, who argues that all the so-called specific bacteria owe their origin to putrefactive bacteria on the Darwinian principle of modification by descent. As I have already stated, investigation has failed, so far, to produce any acceptable proof of such contentions. It is far more likely that a number of quite different organisms are capable of producing the same disease by production of the same or similar chemical products, each multiplying under suitable, though, perhaps, different circumstances; that is to say, in appropriate but not necessarily the same media. Or, instead of the chemical products being absolutely identical, it is conceivable that within certain limits they may vary both as to amount and exact constitution, the consequence being that, as observed in medical practice, cases of infective fevers present equally variable features of intensity and symptoms, even when diagnosed as being identical in essence.

With further respect to this subject of possible mutability of micro-organisms, it may be ad de that it is difficult enough and even impossible in many cases, for the most expert bacteriologists to tell with what micro-organisms they are working. As a rule they are identified—to the limited extent that is possible—by their shape or form, but it has been quite recently pointed out by two workers in this particular direction that they sometimes change their form under one's very eyes. For example, in the *British Medical Journal* of July 2, 1904, G. W. Ainley Walker and W. Murray have described such changes which they have observed in respect of a normal short bacillus into a form which presents itself 'almost entirely or entirely' as long filaments or threads, which may be twenty or more times the length of the ordinary bacillus and often show no sign of segmentation. They worked with different strains of the *bacillus typhosus*, and obtained similar results with the *bacillus coli* and the *cholera vibrio*. Be it said, these wonderful changes are all brought about by introducing small percentages of various dyes! What is to be said of such observations? The tiger can't get rid of his stripes, but these little beasts, which are to be recognized under the microscope only by their forms and culture, can apparently change themselves out of identification! They are all infinitesimally small and very much alike, so much so, that under the microscope some of the most virulent cannot be diagnosed from some of the most harmless varieties.

Why should we not be content with the chemical theory, which rests only upon well-ascertained facts?

The fermentation of sugar into alcohol is carried on by the agency of yeast cells—that is to say, by the life-function of a living organism, and one of the chief products of the chemical change thus induced is alcohol,

$$\underset{\text{(Cane-sugar.)}}{C_{12}H_{22}O_{11}} + \underset{\text{(Water.)}}{H_2O} = \underset{\text{(Alcohol.)}}{4C_2H_6O} + \underset{\text{(Carbon dioxide.)}}{4CO_2}.$$

The fermentation may be carried on until the amount of alcohol thus obtained in solution is inhibitive to the functions of the yeast, or even destructive of the cells themselves, notwithstanding that strychnine has no effect on the properties of yeast. Thus, the production of alcohol is precisely parallel to the formation of sepsin and other poisonous products by putrefaction: these poisons are fully capable, when introduced in sufficient quantity into the bodies of animals, of causing death. Alcohol itself, in excess, produces poisonous effects and that it is not more actively poisonous is a mere chemical accident, no more to be wondered at than the fact that prussic acid is more poisonous than carbolic acid.

By the introduction of another ferment into the alcoholic product, in presence also of air, the alcohol becomes oxidized into acetic acid,

$$C_2H_6O + O_2 = C_2H_4O_2 + H_2O,$$

until it entirely disappears. In like manner, it is easy to understand how other poisonous products of fermentative processes can be destroyed or converted into innocuous ones by subsequent acts of fermentation or purely chemical changes. These considerations afford a direct explanation of vaccination, and a solution to the process of attenuation with which Pasteur and others have acquainted us.

Another matter which requires attention in connection with this subject is of the very greatest importance, and concerns the power of the micro-organisms, or ferments, to produce products *varying with the media* in which they are cultivated. Pasteur has shown that the property of exciting alcoholic fermentation is not confined to the cells of yeast, *but extends to the elementary organs of plants in general.* In brief, the mode of life of micro-organisms enables them to live under very various conditions and in many different media : corresponding with the difference in chemical composition of the pabulum, there must be corresponding differences in the products of their life-function, so that sometimes poisonous products may result, and, at others, innocuous products, and according as the one or the other is introduced into the human body, so illness or death may be the consequence, or health may not be impaired.

It must be borne in mind that any one medium does not suit the wants of all kinds of micro-organisms; in other words, while many classes can live upon and develop in one particular cultivating fluid or solid, others cannot. Some require mineral matter, not only of a special kind, but also of a special quantity ; some, again, like an alkaline medium and others an acid condition ; some require oxygen, and others are killed by oxygen. Yeast likes lime, nitrifying organisms like gypsum, and so forth. It will be shown in detail hereafter that, wide as is the variety of substances and conditions in and under which various micro-organisms live, so the nature and properties of the chemical products which are thus elaborated are equally numerous and diverse.

Here attention may be usefully called to the precise manner in which some processes of fermentation are induced. It is thought that acts of fermentation do not represent the immediate result of the presence of micro-organisms, but are rather the expression of chemical changes brought about by a secretion of the micro-organisms which is elaborated in the act of life after some such manner as saliva is secreted by man.

These products are collectively termed 'zymases,' or soluble ferments, and are all derived directly from living organisms: they cause the decompositions known as fermentations by purely chemical means. It is in this way that diastase (from malt, vetches, etc.), maltin (malt), emulsin (from sweet and bitter almonds), ptyalin (saliva), pepsin (gastric juice), give rise to the peculiar chemical changes that are so well known in connection with their several agencies. Thus, ptyalin converts the starch of food into sugar, while emulsin converts amygdaline into glucose, oil of bitter almonds and prussic acid. The soluble ferments are all uncrystallized albuminoid derivatives elaborated by organisms, coagulable by heat and precipitable by alcohol. Taken collectively, their chemical function is that of hydration or hydrolysis; that is to say, they influence substances just in the same way that vibriones (or a secretion of vibriones) act upon albuminous principles: they, in other words, split up chemical substances by the fixation of the chemical elements of water.

If, now, it be conceded that micro-organisms cause disease in man by the poisonous action of their secretions or the chemical products derived directly or indirectly from their life-actions, then, since these products must vary enormously according to the nature of the media in which they are produced and other extraneous circumstances, we may expect to find different diseases or modifications of the same disease, induced by one and the same or other micro-organisms acting under different conditions, and this fully accords with experience.

Proceeding further with the argument, it follows that the presence of particular micro-organisms in the body does not necessarily imply the existence of a specific disease, for a specific disease can only arise when the conditions surrounding the life of the micro-organisms are of a definite character and adapted to the production of particular poisonous products by their chemical action or that of their secretion. We shall see hereafter that this is literally the case.

After all, then, it is not only not impossible, but very likely, that the comma-shaped bacillus observed by Dr. Lewis in the mouths of healthy persons, is absolutely identical with the micro-organism to which Koch attributes the propagation of cholera.

There are other diseases, to obtain a proper understanding of which it will be necessary, first of all, to explain a few fundamental facts taught by physiological science.

Microscopical examination of the structures and tissues of the living body reveals the presence of a matter termed by physiologists 'protoplasm,' or 'bioplasm,' and it has been ascertained that all forms of animal and vegetable life are derived in the beginning from this substance. It is a living, moving and growing transparent matter, which exists in every part of the body, and it has the power of taking up or assimilating lifeless material as its pabulum, which it changes in such a way that its elements lose their inorganic nature, become organized and form part of the living bioplasm. In other words, bioplasm, or germinal matter, feeds upon dead nutrient matter and thereby grows, increasing its mass. As this operation proceeds, the mass of bioplasm divides and subdivides into multitudes of smaller parts, each of which gradually assumes a definite form or structure.

It is in this way that, at the birth of an animal, the different organs and parts of the fully developed body are formed; and while life lasts, every organ and part is sustained by the formation of new material by the same process. The blood conveys the nourishment, from which the bioplasm resident throughout the organism appropriates the proper elements and converts them into matter like itself, but which afterwards assumes structural form: the newly organized tissue is attached to the parent tissue, replacing that which is destroyed by the act of life; that is to say, in life the tissues are worn down or away (chiefly by oxidation), being resolved into products which are removed in the breath, sweat, urine, and fæces. Every thought and act wears out, in this manner, some part of the living body, which is repaired in the manner above set forth.

This grand fact, although long known in principle, was largely proved in detail by the researches of the late Lionel Beale.* He demonstrated the fact that bioplasm, occurring in every part of the living body, is germinal matter possessed of a power of selection of elements from the pabulum supplied to it, by which it converts dead or lifeless matter into living matter. By the specific changes which happen in bioplasm at certain

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* 'Bioplasm,' etc. By Lionel S. Beale, M.B., F.R.S. J. and A. Churchill, 1872.

stages, tissue results, and hair, skin, bone, nerve and muscle are produced.

Thus we see that every different part of the body has its own bioplasm, by the growth, division and change of which so many different types of matter and the secretions are formed. All this is certain and it is true, not only of animal, but also vegetable life.

So long as normal changes go on, the life of the animal or vegetable is normal and the products of the change in the bioplasm are physiological in nature. But if these normal changes be influenced extraneously, then other products—departures from the normal type—are formed, and these are pathological in nature.

Such ideas as these, although not so clearly perceived, have existed for ages in the minds of thinking men, and Dr. Drysdale has directed attention to the view* that, 'in Fletcher's Pathology it is laid down more particularly that the exciting cause of all contagious diseases consists of diseased secretions thrown off by animals affected with the same disease; while miasms, or malarious poisons, consist in diseased secretions thrown off by vegetables in a state of disease.' This amounts in substance to what has just been stated regarding the normal and abnormal changes of bioplasm and furnishes us with a theory of contagious disease at once simple, natural and yet not at variance with the so-called and modified germ theory previously described.

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* See p. 33 of his afore-cited Essay.

Mucus and saliva, like all other substances formed in the body, are derived from bioplasm, and so also is the poison secreted by rattlesnakes; yet the latter substance is terribly poisonous to man. It is not, however, by such obvious outside influences alone that the normal secretions of the body are influenced. They are liable to be perverted or diseased by a great number of causes, some of which may be even of a mental origin and thus the body itself becomes irritated and diseased. It is, then, surely natural to believe that, if this can take place in the body of one individual, the vitiated secretions which are thrown off from the body are also competent to graft themselves upon or in the bodies of others and similarly influence them.

To perceive all this clearly, it must be borne in mind that just as nerve and muscle grow from bioplasm, so also are the secretions similarly derived ; indeed, all living or growing matter necessarily depends upon bioplasm ; hence, just as mucus, when examined under the microscope, reveals the presence of bioplasts (the particles of bioplasm), so also do diseased secretions similarly exhibit corresponding particles. If, now, such vitiated thrown-off particles come into contact with another person, they have the power, by virtue of the bioplasm which is contained in them, of grafting themselves in or upon the body, and thus disease is communicated. This is the theory of Dr. Lionel Beale.*

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* See Beale's work on 'Disease Germs: and on the Treatment of Diseases caused by them.' Also Dr. Ross's work on the 'Graft Theory of Disease.'

Now, as bioplasm, whether normal or diseased, may also be called germinal matter (since it is literally living matter), it may be allowable to speak of disease germs; but if this be done, it should also be pointed out that by this expression it is not intended to imply parasitic organisms of more or less definite morphological characters. Such organisms are not comparable with bioplasm, for they themselves grow and develop by means of their own bioplasm, and hence they are only comparable in this sense with other organisms possessing structure in common with all animals, including man. Bioplasm has no structure.

Since, however, the public at large have been misguided in the use of the word 'germs,' it is better to describe this as the 'graft or germinal theory of disease.'

In the face of what has just been described, it is particularly interesting to turn back to the views maintained by Liebig against those other scientific men of his day who advocated the parasitic theory. Liebig admitted the existence of vital force in a primary sense, and he maintained that (which to-day cannot be disputed) the life of an organism follows, in the main, a predeterminated course which results in a definite form and composition of the parts. While this process continues it is normal, and the result is health. If opposed by extraneous influences, the vital power of the organism resists them, or succumbs to them, according as to which is the more powerful process. Should the foreign power prevail, then the normal performance of function is interfered with and the results are pathological.

It is seen that Liebig's teaching also establishes the individual power to resist disease, some persons being more susceptible than others, thus succumbing more easily to its attacks. This individuality depends upon a great variety of conditions affecting personal history and surroundings.

The specific contagia of the fevers and some other contagious diseases may possibly, then, be degraded forms of bioplasm which exhibit great powers of resistance (owing to their vital nature); they may be preserved in the moist or partially dry state, within certain limits, and may be carried hither and thither by air or in water.

Without overstraining the analogy between ordinary infective processes and the infective process of a cancerous growth, Dr. Creighton's investigations* of this last-named disease are of extreme interest, if viewed side by side with the germinal theory.

Creighton demonstrated that cancerous diseases are characterized by the chronic self-propagative nature which they exhibit. When the elements of the originally diseased parts are carried by lymph or blood-streams to other parts, these latter are impregnated and the tumour grows out of the original textural type. This result is not known to be due to any specific organisms resident in the parent tumour, but rather to a ferment-like power of the transported

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* Reports of the Medical Officer of the Privy Council. New Series, No. 3, 1874, and No. 8, 1876.

elements which induces previously healthy parts to grow after the manner of the infectant.

These observations are vastly important, because it seems that in such studies the actual process of infection can not only be watched, but followed far better than in processes of inoculation with cultures of micro-organisms floating in liquids of indefinite chemical composition. So far as at present determined, the process strictly accords with what might be expected to take place, assuming that the secondary infection is due to the influence of degraded bioplasts derived from the primary growth.

Enough has been said to show the grounds upon which the graft theory of disease is founded, and it can be well understood that, just as one kind of plant or tree may be grafted on to another, by virtue of the living matter contained in the graft; so also graft bioplasts may exist that are capable of attaching themselves to, and growing upon, the previously healthy body, thereby producing a departure from the normal life-history, or, in other words, instituting disease.

The phenomena of infective processes can thus be well explained, and, granted that parasitic germs can and do produce disease also, it is practically certain that this is owing to the products to which they give rise directly or indirectly.

Further information of an extensive and comprehensive nature is wanted, and until more facts are ascertained by strictly conducted and accurate investigations and observations, we shall not make any further material advance in our knowledge of the nature of the various contagious diseases.

Writing of those diseases which now never arise, it is supposed, except from infection, Dr. Drysdale says, 'their origin is hidden in the night of time;' and 'although we may circumscribe the area of their operation, yet we can never hope that good food, virtue, drainage, and ventilation will extinguish them altogether, as long as man is a social animal.' On the other hand, I think they are hidden in mere physiological and chemical consideration. Again, writing of another class of infectious diseases, such as the catarrh and erysipelas group, he says that as long as these 'arise from the operation of mere common non-specific causes, if by any chance they were swept clean out of the land, they would infallibly reappear, so long as poverty, dirt, overcrowding, famine, war, vice, etc., afflict the human race.'

To sum up, it has been shown that there are:

1. Diseases which are due directly or indirectly to parasites and micro-organisms.

2. Diseases which depend, perhaps, upon germinal matter (degraded forms of bioplasm) or diseased living matter of an animal origin.

3. Diseases which are undoubtedly due to mere chemical products, elaborated by living processes.

Further, it is seen that all these diseases originate from matters of an animal or vegetable origin which may be directly derived from organisms by certain processes of change induced by degraded living bioplasm or by microphytes (as in putrefaction).

Now, having reviewed the various theories of disease and the facts upon which they are based, to what conclusion are we impelled as regards the practical prevention of epidemics? The only conclusion points to the necessity of observing cleanliness of the body as of paramount importance with the health of the mind and of securing pure air, water and food as also absolutely essential to sanitation.

While, however, the hope of ever extinguishing the contagious diseases is built upon a poor foundation, it must still be borne in mind that there exists a terribly large amount of actually preventable disease.

To use the words of the late Professor Corfield:* 'People who are living in the midst of general insanitary conditions are in a worse plight than people living in the crater of an extinct volcano; for not only may any one of the severest epidemic diseases break out among them at any time, but they are continually sacrificing unnecessary victims to the demon filth.'

It is beyond doubt that, were the evacuations of typhoid-fever patients invariably destroyed or properly treated in good time, there would be an end to, at least, a vast majority of the 100,000 cases that occur every year. Then, again, all the fever that owes its origin to well-pollution by drainage from inhabited buildings, as also the farmyard and its abominable heaps, is likewise almost wholly preventable. Further, all diseases due to the putrefaction and decay of animal and vegetable matters are mere expressions of insanitary conditions and could be entirely avoided; while as

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* Address to the Sanitary Congress at Croydon, 1879.

regards such diseases as small-pox, scarlet fever and the other members of the more strictly contagious diseases, it is in human power to prevent also the majority of cases by a judicious circumscription of the area of disease, the application of strictly scientific methods of isolation and by securing purity of the surroundings.

With respect to the distribution of disease, it is not possible to enter into any detailed considerations here, but it may be laid down as a general proposition, fairly well established by Mr. Haviland, that some diseases have a sort of geography.* He finds that certain districts are store-beds of particular infections and thinks he is able to trace a connection between such states and local conditions. Thus Cheshire and Lancashire show the greatest death-rate of all the counties in England and Wales from scarlet fever : 'in them scarlet fever seems ever to be stored, ready at a moment's notice to be carried far and near.' Then, again, the Thames runs through a vast cancer-field, and there does not exist an important river in England or Wales, subject to seasonal floodings, that does not flow through high mortality districts.

These and similar facts brought forward by Mr. Haviland demonstrate that places exist where the local conditions are such as either originate or favour certain specific diseases. These conditions are no doubt very multifarious and partly concern climatic

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* See a paper by Alfred Haviland, M.R.C.S., *Journal of Society of Arts*, vol. xxvii., p. 157 ; also his work on 'The Geography of Heart Disease, Cancer, and Phthisis.' Smith, Elder, and Co.

influences, geological particulars, the character of the water-supply and so forth.

By way of instance, reference may be made to the climate and disease characteristic of Liberia, which is as bad as that of any other part of the African West Coast. According to the report of Captain C. Braithwaite Wallis (H.M. Consul at Monrovia), there is practically no drainage and little attempt at sanitation in the Americo-Liberian settlements, and at the beginning and end of the rain seasons malarial fever of a severe type is prevalent. A chief source of this disease is by the bite of the infected anopheles. Stagnant pools abound and form the breeding-ground of the anopheles mosquito, which, so soon as their larvæ are hatched out, fly to the nearest huts and houses, hiding in dark nooks and corners until dusk, when they come forth to feed upon the blood of the inhabitants. As the blood of nearly every native child has been found to contain malarial parasites, it can be well understood how readily the disease is spread—by the mosquito sucking such blood and transmitting the sporozoits to previously healthy people by biting and injecting the microbes into the blood by means of its proboscis. Careful investigation has shown that anopheles caught in native villages invariably contain a large percentage of infected specimens. The geographical distribution of malaria in Liberia is general, owing to these anopheles existing practically throughout the entire territories of the republic.

In the following pages it will be my aim to ascertain more particularly the exact chemical changes that can be initiated by certain classes of micro-organisms, seeking at the same time to utilize the facts thus elicited, in explaining the production of infectious diseases through their agency. Based upon the same considerations, an endeavour will be made to ascertain how far antiseptics and disinfectants can be used to assist in the accomplishment of such a desirable end as the prevention of epidemics. Taking the classification of infectious diseases given on a preceding page (228), it is seen that, practically, there is the choice of the following classes of substances for employment in this way:

1. Substances which may be used either to locally destroy, or effectually interfere with, the life of parasites and micro-organisms so as to prevent the production of the toxic products which cause disease.

2. Substances which chemically change and thus destroy toxic substances or matter which are produced by micro-organisms.

3. Substances which destroy germinal matter, or effectually interfere with the grafting process.

4. Substances which may be used locally to secure an efficient sanitary state and thus prevent the spread of infection.

CHAPTER VIII.

ORIGIN OF LIFE AND SPONTANEOUS GENERATION—BACTERIOLOGICAL STUDIES — PHAGOCYTOSIS—IMMUNITY—DISEASE AND ITS CHEMISTRY—CHEMISTRY OF BACTERIAL LIFE.

THE origin of life has given rise from time to time to all sorts of theories and speculations, one of the latest contributions to the subject coming from Mr. J. Butler Burke, a young Cambridge physicist. He had been making some experiments concerning phosphorescence, using in connection therewith certain organic substances and a salt of radium. When testing glycerine and gelatin, the radium was introduced into a tube containing the substance, which was then frozen by means of liquid air, with the result that crystals were produced in each instance. Having ascertained that crystals were also produced when the radium was omitted, he proceeded to test sterilized bouillon and found that certain specks or particles were produced which were not crystals on the one hand, nor like bacteria on the other hand. As they increased in size and subsequently divided, or appeared at least to do so, Mr. Burke conjectured that his so-called radiobes were living matter—a view, however, which has not met with much favour at the hands of scientists. Personally, I see nothing remarkable in the experiments, the results of which may very well be compared with the effects produced in solutions of gelatin or albumin by means of many precipitating agents or a heated wire.

Radium is known to continually give off heat, and it may very well be that its salts give off energy in the form of chemical action which would produce the results observed by Mr. Burke. Immerse a heated wire or glass rod in a solution of gelatin or albumin and coagulation occurs in immediate proximity to the heated wire or rod, and the particles, specks, or radiobes thus formed will continue to grow—that is to say, they increase in size—and later on apparently subdivide just in the manner observed by Mr. Burke. In all probability certain active rays would produce corresponding effects without the direct introduction of a material article such as a heated wire or glass rod, for coagulation of such solutions is well known to result from the external application of heat alone. Moreover, Mr. Burke's experiments did not extend to any satisfactory investigation concerning the vital or non-vital nature of his radiobes, and they cannot, therefore, be regarded as having any real bearing upon the speculation that life can be produced *ab initio*.

This latter view is not held in favour by the general body of scientists; but there are some who undoubtedly accept it, and notably Dr. H. Charlton Bastian, F.R.S., who believes that the lowest forms of living matter with which the world teems are being continuously produced by evolution from organic matter or so-called dead materials.

Dr. Bastian has professed this view for upwards of thirty years; but many years ago experiments made by Pasteur, Tyndall and others then satisfied chemists and bacteriologists that there was no spontaneous generation of living matter in media which had been effectually sterilized and in respect of which sufficient care was taken to exclude the introduction of living spores or germs. Dr. Bastian, however, remains unconvinced and contends that he has demonstrated over and over again under the most rigid conditions that living organisms or cells can be evolved under certain circumstances from fluids which have been subjected, for instance, to a temperature of 130° C. for a prolonged period.*

It would be only generous and just if some bacteriologists of high standing would repeat Dr. Bastian's more recent experiments, with the view of confirming or disproving his contention; for it must not be forgotten that nearly, or quite, thirty years have elapsed since the former test of his previous work was made, and a statement of this kind ought to be once for all substantiated or disproved, having regard to the high importance of the subject.

If I may be allowed to express a personal opinion, I should say that in all probability Dr. Bastian is in error. If it were proved that living matter is spontaneously generated from dead organic substances of

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* 'The Evolution of Life,' by H. Charlton Bastian, M.D., F.R.S. Methuen and Co.

animal or vegetable origin, all current views respecting diseases of infectious and contagious character would be profoundly affected and the subjects of disinfection and the prevention and treatment of such diseases would have to be reviewed anew.

In an address on the subject of Bacteriological Research made by Dr. R. Koch in 1890,* he said: 'It must now be regarded as completely proved that bacteria, like the higher vegetable organisms, form constant species, though the limits of these are sometimes difficult to define.' He also pointed out that a species of bacteria, under unfavourable conditions of nourishment, may present stunted forms; some of its properties, such as the formation of colouring matter, may also permanently disappear; these fluctuations, however, are only observed within certain limits, and hence it is not necessary to admit transformation into new or other known species.

Whether or not transformation of species is effected does not appear to me, however, to be the most important consideration. It is the change of character that is of far greater importance, and the question naturally arises whether this change is ever so great that bacteria, which at one time, it may be assumed, are undoubtedly capable of producing an infectious disease in the animal body, are at other times incapable of producing such a result. Koch would probably answer this question in the negative, but such an answer by no means satisfactorily disposes of the matter. On

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* Address delivered before the International Medical Congress at Berlin. See *Brit. Med. Journ.*, August 16, 1890, pp. 380-383.

the other hand, there is distinct evidence to the other view. According to Klein, for example, the *bacillus anthracis,* after passing through white mice, loses the property of infecting sheep and cattle with anthrax. Surely, if this fact has any meaning at all, it must be taken as evidence that cases of infection of anthrax do not merely depend upon the introduction into the animal body of this particular *bacillus,* but are also dependent, in some degree at least, upon other factors which have not yet been ascertained. This is a very important matter and the more so, perhaps, because it breaks down one of the conditions which Koch has stipulated as essential in identifying the precise relationship of pathogenic bacteria to disease : for, as one of those conditions, it is necessary that a pure culture of *bacillus anthracis* should invariably produce the disease when introduced into the living body.

In the same address Koch called attention to the fact that all bacteria can grow only under moist conditions—that is to say, in the presence of water or other suitable fluids—and that they cannot of their own accord pass from wet surfaces into the air. It therefore follows that pathogenic bacteria can be taken up by the air only in the form of dust, and this limits them, speaking generally, to such as can retain their vitality in a dry state. Bacteria cannot multiply in the air, as was formerly held to be the case.

Koch made some interesting experiments with reference to so-called pure cultures of tubercle *bacilli,* and found that a number of substances are capable by their presence of hindering the growth of the *bacilli,* cyanide of gold being most efficacious of the substances then tested in this respect; thus, a solution of 1 in 2,000,000 parts was found to check their growth. All these substances, however, remain absolutely without effect if tried on tuberculous animals. This failure did not discourage him in prosecuting his search, which was made with the view of discovering a growth-hindering remedy, and in his communication, now under notice, he stated that he had hit upon a substance which had the power of preventing the growth of tuberculosis *bacilli*, not only in a test-tube, but also in the body of an animal.

Guinea-pigs are, as is well known, very susceptible to tuberculosis; but if they are exposed to the influence of the substance referred to by Koch, they ceased, it was said, to react to the inoculation of tuberculous virus and that even in respect of guinea-pigs suffering from general tuberculosis to a high degree, the morbid process could be brought completely to a standstill without the body being in any way injuriously affected.* From the results of this investigation, Koch drew the conclusion that it is possible to render pathogenic bacteria in the living body harmless without injury to the latter; but this particular conclusion was not open to doubt after the earlier observations made by Klein with reference to the *bacillus anthracis,* as previously described.

As to the relations of micro-organisms to infectious diseases generally, Koch argues that if it can be proved, first, that the parasite is met with in each

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* Since then Koch's remedy for tuberculosis has proved a failure.

individual case of the particular disease and under conditions which correspond to the pathological changes and the clinical course of the disease; secondly, that in no other disease is it found as an accidental non-pathogenic guest; and, thirdly, that, if completely isolated from the body and cultivated in pure cultures with sufficient frequency, it can reproduce the disease, then it can no longer be considered an accidental accompaniment of the disease; but in that case no other relation between the parasite and the disease can be admitted than that the parasite is the cause of the disease. It is now, however, known that a particular bacillus does not necessarily produce disease when present in an animal body; other conditions must also prevail before the disease can be produced. This is a serious difficulty, and the morphological characters of bacteria are insufficiently distinct for Koch's second condition to be tested in any strict sense.

At one time it was represented that a particular disease must consequently and necessarily ensue upon the introduction into the body of a particular germ; and while, of course, the experiments of Klein with reference to the *bacillus anthracis* above referred to do not, perhaps, suffice to entirely upset the doctrine of specificity, they constitute a very great obstacle in the way of its absolute acceptance. If, on the other hand, the so-called specific diseases result directly from the production of poisons within the living body by the agency of bacteria, it almost necessarily follows that the same, or equally virulent poisons, may be produced by a great variety of bacteria ; further, that they are capable of producing different poisons according to the media and conditions in and under which they are developed, varying, of course, with the substances which they encounter. Such a revelation, if thoroughly established, would, after all, be only on a par with the fact that many different micro-organisms, when developed in chemical media, give rise to some extent to the production of one particular product, as well as to a variety of others.

I wish to make it clear that, so far as bacteria are the causative agents of disease, they are only indirectly so, and that the effects witnessed in cases of disease are in reality due to the chemical products which the bacteria originate. Further, that inasmuch as the action from which these products result is chemical in character, their nature must of necessity vary according to the substances from which they are produced, and with many other factors which may assist or retard or modify the chemical processes which are involved.

Koch admits that, in respect of a great number of infectious diseases, bacteriological research has left workers entirely in the lurch. 'This is the case,' he says, 'most conspicuously with the entire group of infectious exanthemata, such as measles, scarlet fever, small-pox, and exanthematic typhus. For in not one of these have we succeeded in discovering even the least clue as to the nature of the agents which produce it. Even vaccinia, which is always at our disposal and can so easily be made the object of experiments on animals, has obstinately resisted all endeavours to discover the real agent which produces it. The same thing holds good with regard to rabies.'

'Again,' he continues, 'we know nothing as to the generating factors of influenza, whooping-cough, trachoma, yellow fever, cattle plague, pleuro-pneumonia, and many other undoubtedly infectious diseases.' As a way out of this dilemma, Koch is inclined to think that in these diseases the causal agents belong to quite another group of micro-organisms and not to the class of bacteria at all.

Even in respect of those diseases as to which bacteriologists are agreed respecting the original causes, Koch has felt it incumbent to accentuate the difficulties attached to the identification of the specific bacteria, and has gone so far as to admit, for example, that even a very skilful bacteriologist cannot with absolute certainty distinguish other *bacilli* from the real typhoid *bacilli*, which they very closely resemble.

His own work has furnished evidence tending to show that the *bacillus* which produces tuberculosis in fowls is not identical with that which produces the disease of the same name in man and other animals, although they very nearly resemble each other both in appearance and properties. In the same address, Koch stated that there is now a unanimity of opinion respecting the *bacillus* which is regarded by him as the causal agent of cholera, but, as a matter of fact, there is not, and certainly it is well known that Klein, one of the most advanced bacteriologists in this country, did not endorse that view.

In connection with the diseases which are supposed to be caused by bacteria, much attention has been paid during the last few years to the subject of so-called phagocytosis, a doctrine which is particularly connected with the name of Metschnikoff. He investigated the amœboid movements of certain cells and found that they possess the power of ingesting other cells and bacteria, as also of digesting or absorbing same by means of contained or produced ferments. He states that when a virulent virus is introduced into the body of an animal, and if the animal proves to be non-resistant, no such phenomena of phagocytosis can be observed and the microbes remain free to do their evil work. From such observations he concludes that the phagocytes are specially charged with the defence of the human organism and enter into conflict with the parasites which are known to affect mankind.

One of Metschnikoff's most striking experiments on the absorption of *bacilli* by phagocytes or leucocytes was as follows: he introduced under the skin of a frog a membranous tube (made of the lining of a common large grass which grows on the banks of rivers) containing the spores of anthrax *bacillus*, with the result that very soon the little tube was filled with lymph which was found not to contain any leucocytes, the membrane being impermeable to them. A similar experiment was made with another tube, the ends of which were left open, so that leucocytes could enter. In a day or two both tubes were examined. The contents of the closed tube swarmed with *bacilli*, but in the open tube, the spores had been so effectually disposed of by the leucocytes that the contents could be inoculated into susceptible animals without effect. In a review* of the subject by the late Professor J. Burdon Sanderson, attention was called to the consideration that incorporated or englobed *bacilli* are not necessarily defunct. He also expressed the opinion that Metschnikoff's theory had been received, on the whole, with little favour by pathologists, and that many of the facts to which Metschnikoff directed attention had been known for more than forty years, the interpretation alone being for the most part new. In conclusion he added : 'Let us avoid attaching any other meaning to the unquestionable fact of phagocytosis, excepting, first, that the emigration of leucocytes is an essential part of the process of inflammation and that there is an antagonism between this process and the process of general infection.'

An excellent paper on the subject of phagocytosis has been published by Dr. Harold C. Ernst,† and much of the following information has been taken from that source.

The so-called phagocytes do not consist solely of the leucocytes (the white blood-corpuscles); some, at least, are produced from the fixed cells of the surrounding tissue. Beyond the power of englobing bacteria which is exhibited by leucocytes, it is said that a further exceedingly important property has been established—viz., so-called 'chemiotaxis,' which

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* The Croonian Lectures on the Progress of Discovery relating to the Origin and Nature of Infectious Diseases. See *Brit. Med. Journ.*, November 14, 1891, p. 1033.

† See *Pharm. Journ.*, October 14 and 21, and November 11, 1893.

may be described as the property that movable cells have of responding to irritation of any kind, either chemical (as in the case of simple chemical irritants), or vital (as in the case of invading bacteria). This response is of an active kind and is manifested by actual movement towards or away from the irritant material, as must be familiar to everyone who has seen a swelling in any of the vital tissues resulting from any sort of irritation.

One of the great opponents of Metschnikoff's theory is Christmas-Dirckinck Holmfeld, who has paid great attention to the changes which take place at the seat of inoculation and who employed rabbits, mice, and rats with anthrax *bacilli* by way of materials. It should be stated that rabbits and mice are very susceptible, while rats are comparatively insusceptible to inoculations of the *bacilli* of anthrax. He found in respect of *bacilli* of full virulence, in the case of mice and rabbits there was little reaction at the seat of inoculation, and suppuration never occurred ; the bacteria quickly found their way through the organisms and the animals died. With slightly susceptible animals (rats) a perceptible suppurative reaction was produced in the tissues and the pus formation was in proportion to the greater or less susceptibility of the animals experimented upon ; the less the susceptibility, the greater was the amount of pus formation. The same thing is true of many infectious diseases ; the more virulent and more suddenly fatal the disease, the less is the pus formation.

Holmfeld considers that the means by which the bacteria are rendered harmless is more in the nature of a chemico-biological action than absorption by phagocytes, and he maintains that most of Metschnikoff's work having been carried out on cold-blooded animals, the results do not hold good for warm-blooded animals.

Baumgarten (another opponent of Metschnikoff) states that the results of experiments carried out in his laboratory were widely different from those of Metschnikoff, while Bitter, who published a long review of all the work done on this subject up to that time (*Zeit. f. Hyg.*, Bd. IV., S. 378), drew the conclusion that Metschnikoff's work and that of his supporters does not afford absolute proof that phagocytes take up and destroy disease-producing bacteria.

Now, so-called immunity—that is, the power possessed by the animal body of resisting infection or disease, whether of bacterial or chemical action—is conjectured to arise either in consequence of the power of leucocytes and other cells to englobe and destroy virulent microbes, or to the absorption of the virus by the cells.

Numerous facts have been alleged showing, as above mentioned, that microbes which may be contained within the phagocytes are not necessarily degenerated or dead. Lister directed attention* to some experiments in which it was observed that in lymph taken from the body of a pigeon or rabbit which had been inoculated with virulent bacteria, numerous *bacilli* were imprisoned by the leucocytes, and they were also seen to grow and eventually make their escape.

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* See *Brit. Med. Journ.*, August 15, 1891.

Again, even in refractory animals, the microbes have been found to increase when kept out of the reach of the leucocytes; thus, if a rabbit were inoculated in the anterior chamber of the eye where there were no such cells, the bacteria would be observed to grow freely, and their development was only checked when the leucocytes had, after a time, migrated in large numbers and proceeded to englobe the microbes.

The way in which inoculation with an attenuated virus is supposed to produce immunity is as follows: If the animal has not been inoculated, the products of the microbes (of the particular disease) repel the leucocytes, whereas if the animal has been inoculated, the phagocytes which have already become habituated to the products of the microbes are attracted to the point of inoculation.

M. Gamaleia and M. Pfeiffer have, however, shown that animals completely inoculated against infection are just as susceptible to toxic doses of sterilized cultures as animals not inoculated at all.

Hankin has made some important contributions* to the subject of immunity as produced by injection of the soluble products of the life of microbes; that is to say, by chemical means as distinguished from vaccinal means. All attempts to produce immunity by means of the poisonous alkaloids called ptomaines have failed, and Hankin suspected that not ptomaines, but poisons of an entirely different stamp—so-called albumoses—are concerned in the production of chemical

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* See *Brit. Med. Journ.*, July 12, 1890, and *Medical Press and Circular*, August 26, 1891.

immunity. This consideration led him to make experiments with a view of isolating the albumose of anthrax cultures, and having been successful in that endeavour, he has, by means of the product been able to produce immunity not only in rabbits, but even in mice. In one of his papers he calls attention to the work of many scientists—chiefly German—who have shown that the cell-free blood is sometimes capable of destroying bacteria; thus, Bouchard has shown that the blood-serum of an ordinary rabbit will serve as a culture medium for the *bacillus pyocyaneus;* if, however, a rabbit be made immune against the disease which is produced by this *bacillus*, its blood-serum will be found to have acquired the power of attenuation and even of destroying the microbe in question. Similar results, it is said, have been obtained with the microbes found in association with cholera, anthrax and other diseases.

In other diseases, such as tetanus and diphtheria, the microbes do not spread through the body as is the case with anthrax, but, on the contrary, remain at the immediate seat of inoculation, where they elaborate their deadly poisons which produce such disastrous effects. Behring and Kitasato found that the serum of a rabbit immune from diphtheria exerts no bactericidal action upon the diphtheria *bacillus;* it possesses, however, the remarkable power of destroying the poison which is produced by that microbe, and it has thus been found possible to cure both diphtheria and tetanus in mice and guinea-pigs; indeed, Behring is said to have cured mice of tetanus in which the disease had so far progressed that several of the limbs were in a condition of spasm.

The question naturally arises as to what is the nature of the substance or substances on which this bactericidal action of blood serum depends? As stated above, Hankin was led from theoretical considerations to suspect that it was a particular ferment-like proteid, known as cell-globulin B. He proceeded to search for the necessary proof by a study of the defensive proteid of the rat. This animal is known to be highly resistant to anthrax, and he soon found that the serum of this animal (which is peculiarly alkaline) contained a proteid body possessing a well-marked alkaline reaction and a power of destroying anthrax *bacilli*. When injected into mice along with fully virulent anthrax spores, it prevented the development of the disease. Again, rats fed on bread instead of meat were observed to become susceptible to anthrax, while at the same time the amount of the above-mentioned defensive proteid became very much diminished.

These defensive proteids appear to be albuminous bodies of a ferment-like character, and Hankin thinks that the discovery of them is not necessarily to be regarded as a serious blow to the phagocytic theory, for he conceives it possible that they are the weapons used by phagocytes in their conflict with microbes, and that only after the death of the cells do these substances find their way into the blood-serum.

It is now considered to be well proved that immunity from various diseases can be produced by the injection of the soluble products of the life of the microbes which lead to their production. All the poisons that are supposed to possess the property of suppressing the bactericidal power of the body are albumoses, or at least connected with them. The juice of the papain-tree, according to Rossbach, contains a poisonous albumose which, when injected into the blood in sufficient quantity, causes a sort of *septicæmia.* After the death of an animal caused in this way, the blood is found to be teeming with bacteria, none of which, it is said (or rather, assumed), are pathogenic in character, but are decay-producing microbes, which. owing to the action of the papain, are enabled to wander from the intestine into the blood and tissues. Further substances of this class will be referred to in a later chapter, including the poison which is contained in jequirity seeds and the albumose of snake-poison.

In the same way that Hankin succeeded in isolating the so-called albumose of anthrax, Roux and Yersin have, they believe, isolated the corresponding poison of diphtheria, and they described it also as a proteid body soluble in water, giving all the reactions of albumoses.

Some years since, Dr. Sidney Martin communicated to the Royal Society* a paper in which it was stated that he had separated from anthrax cultures a poisonous alkaloid and two poisonous albumoses, and that, with both the alkaloid and the albumoses, he had succeeded in reproducing all the symptoms of anthrax.

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* Proc. Royal Soc., 1890.

Hankin also isolated a globulin from lymphatic glands which was said to have the power of killing anthrax *bacilli*. He concludes one of his papers* with the following remarks :

'The fact that I have succeeded in obtaining immunity with the anthrax albumoses is a proof that these bodies form one of the factors in the conflict between the organism and the microbe. If ever it could be shown that cell-globulin has, or tends to have, a similar action in the living body to that which it has in a test-tube, the question would arise as to whether the anthrax *bacillus* defends itself from the cell-globulin by means of its albumoses. For this possibility of an albumose destroying a ferment an interesting parallel can be found. Mr. Dickinson, of Caius College, Cambridge, has recently proved that the active principle of leech extract is an albumose; and just as the leech albumose destroys fibrin ferment, so is it possible that anthrax albumose destroys the ferment-like cell-globulin. Whether or not this is the case I hope to be able shortly to decide, so far as this can be done by a test-tube experiment.'

The two varieties of so-called antisera are named anti-toxic and anti-microbic.

'The serum of an animal actively immunized against a toxin of a particular organism, if inoculated along with some similar toxin into non-immunized animals, will have the power of neutralizing that toxin so that

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* Report to the Scientific Grant Committee of the Brit. Med. Assoc. (*Brit. Med. Journ.*, July 12, 1890, pp. 65-68).

the second animal will not show ill-effects. This is anti-toxic serum.

'Similarly, if the serum of an animal actively immune to a particular microbe (not its toxic) be inoculated into an animal, it will confer upon that animal the power of resistance to an invasion of that particular organism. This is anti-microbic serum. . . . 'The power of the toxin is generally expressed in the terms of M.L.D.—*i.e.*, "minimum lethal dose"—and is the number of cubic centimetres required to kill a guinea-pig of 250 grammes weight in four days.'*

It would be quite impossible in the space at my disposal to give anything like a complete summary of the work that has been done in connection with the subject of immunity, nor is it necessary for the plan of this work. The only object in view in making such references has been to show the main relations existing between micro-organisms, together with their chemical educts and products and infectious or contagious diseases.

These observations, then, must be left to carry their own inferences, but by way of summary it is evident, from the results of an immense amount of investigation—

1. That micro-organisms when cultivated in the laboratory, or successfully inoculated in living bodies, give rise to the formation of chemical (often poisonous) products, all of which exhibit definite

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* Extracts from a paper by F. C. Lewis on 'Natural and Conferred Resistance to Disease in the Human Body,' read before the North-West Centre of the Sanitary Inspectors' Association at Liverpool, October 18, 1904. See *Sanitary Journal*, pp. 115-120.

characteristic (pathological) effects and that these necessarily vary with the culture medium and the animal.

2. The chemical principles of the blood and tissues of animals exhibit more or less bactericidal properties and are capable of effecting chemical changes in the composition of the products which result from the cultivation of micro-organisms, while they are also themselves susceptible of chemical changes as the result of being placed in contact with the said products. It therefore follows that the whole result of inoculating or infecting an animal with micro-organisms or their culture-products is, to a large extent, strictly chemical in character and that it necessarily varies with the composition of the substances thus introduced.

3. That until we know immensely more than is at present known respecting the chemistry of the living body and of the substances that are produced incidentally in the culture of micro-organisms, both in the laboratory and in the living body, as also of their physiological and pathological effects, it is really preposterous to write dogmatically or with any assumption of certainty respecting the precise relations of bacteria and disease.

4. Although, then, the germ theory of disease is now widely held to be generally true and notwithstanding that many micro-organisms have been isolated and cultivated, little is yet known as to the precise method by means of which they set up disease. We have an inkling of the truth, but not much more than that.

As regards the general and chemical properties of the so-called albumoses, they are bodies which are soluble in water and have been in several instances prepared from cultures by filtration through the Chamberland-Pasteur filter, which, in common with the Berkefeld filter, suffices to remove all solid particles and micro-organisms. The albumoses can be precipitated from their concentrated aqueous solutions by means of absolute alcohol. Roux and Yersin found that the diphtheritic albumose is destroyed at 100° C. and that its virulence is weakened even by long-continued exposure to 58° C. (doubtless owing to partial decomposition). The same substance as prepared by Brïeger and C. Frankel after repeated purification, was snow-white in colour, and when in aqueous solution it was found to be precipitated therefrom by strong mineral acids, ferrocyanide of potassium and acetic acid. It also gave the biuret reaction, the red coloration with Millon's reagent and the xantho-proteic reaction. It was found to be extremely poisonous, and when injected into animals produced the same symptoms as the culture. It was accompanied in the original filtrate by a second non-poisonous albumose.

The albumose which was described by Martin was prepared by the cultivation of the anthrax *bacillus* in alkali-albumin and was similarly purified by filtration, the filtrate being found free from micro-organic life. He observed that in aqueous solution the albumose was strongly alkaline in reaction.

In connection with this subject, it should be mentioned that before Hankin obtained the albumose of anthrax, Nuttall had in 1888 observed the bactericidal character of fresh blood or blood-serum, an observation which was confirmed by Buchner and Nissen shortly afterwards. Emmerich and Mastbaum also found that the microbes associated with pig-typhoid are killed by the blood-serum of immunized rabbits, and they successfully employed such serum to cure the disease in other susceptible animals.

Ogata has, by methods similar to those used by Hankin, extracted a bacteria-killing substance from the blood-serum of various animals, whilst Tizzoni and Cattani have arrived at the conclusion that the 'anti-toxic' substance which is contained in the serum of a dog that has been rendered immune to tetanus, is a proteid ferment-like body.

Note may here be taken of the fact, as demonstrated by some experiments of Klein,* that under certain circumstances one *bacillus* may protect the body against the evil effects of others—doubtless by the production of a bactericidal substance. For example, 'guinea-pigs which had survived a first intraperitoneal injection of the living or sterilized vibrio of Finkler, of the *bacillus coli*, or the *bacillus prodigiosus* respectively, were found refractory against the peritoneal injection of otherwise fatal doses of the living cholera *bacilli* of ordinary culture, as well as of the "virus fort" of Haffkine.'

Incidentally, these observations of Klein upset certain conclusions of Haffkine regarding the specific action of the cholera *bacillus* and are remarkable as

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* *Lancet*, March 25, 1893, p. 653.

affording some evidence that these different bacteria produced, apparently, the same or nearly allied poisons, for they all acted alike, giving rise to the same disease in these experiments. The peritoneal introduction of agar-culture of (1) the vibrio of Finkler, (2) *bacillus coli*, (3) *bacillus* of typhoid fever, (4) *proteus vulgaris* and (5) *bacillus prodigiosus* (whether sterilized or not), all produced, Klein states, the same disease—viz., intense acute peritonitis—and when the injection was made subcutaneously, there was produced the same local soft œdematous tumour, gradually becoming smaller and firmer and occasionally leading to localized necrosis and ulceration of the skin.

As the production of a number of diseases has been shown to be intimately associated with the chemical processes which are induced by micro-organisms in various media, it will be of interest to refer to some further facts that have been ascertained concerning the chemistry of micro-organic life.

S. Arloing has ascertained* that *micrococcus septicus puerperalis* of recent cultivations, and also the anaerobic virus of *gangrenous septicæmia*, set up fermentations in solutions of glucose, dextrin and inulin. Hydrogen and carbonic anhydride are evolved in varying proportions; the solutions become acid and are found to contain glucose, while the deposits which are formed during the fermentations are capable of inducing similar chemical changes in fresh solutions.

The recently dried virus from *septicæmia* and

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* *Journ. Chem. Soc. Abstracts*, 1886, p. 170.

anthrax give similar results, unless its activity be previously lessened by the action of heat or prolonged dryness.

Adrian J. Brown has studied the chemical action of pure cultivations of *bacterium aceti*.* He shows that this organism, which is strictly aerobic, oxidizes ethylic alcohol to acetic acid and that the acetic acid so formed is subsequently destroyed by the ferment. It also oxidizes normal propylic alcohol into propionic acid, while it is without action upon methylic alcohol, isoprimary butylic alcohol and amylic alcohol. It converts dextrose into gluconic acid and similarly influences milk, sugar and starch. Mannitol is completely acted upon by the *bacterium aceti*, the main product being lævulose.

All these changes may be described, in common with some which I personally and previously investigated,† as brought about by the fixation of either water alone, or of water and oxygen, into the molecules of the substances acted upon, thus producing new products by the processes of hydrolysis, or hydrolysis and oxidation. The same general explanation applies to all chemical actions which micro-organisms are capable of initiating, not merely in laboratory experiments, but also, probably, when acting pathologically in the human body.

In a later paper‡ Brown has continued his study of *bacterium aceti* and shows that by its action the

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* *Journ. Chem. Soc. Trans.*, 1886, p. 172.

† See Section on Chemical History of Some Micro-organisms in Chapter XIV., Part II.

‡ *Journ. Chem. Soc. Trans.*, 1887.

dihydric alcohol, 'glycol,' is oxidized into glycollic acid only, and that this change is favoured by the presence of calcic carbonate which neutralizes the acid so soon as it is formed.

The trihydric alcohol, 'glycerol,' is completely decomposed into carbonic anhydride and water, and appears to favour the growth of *bacterium aceti* exceedingly.

Thus it is clearly established that micro-organisms exercise a selective influence on substances with which they come into contact and can initiate a variety of chemical changes by hydrolysis and oxidation; in consequence, the products must vary with the nature of the pabulum or medium in which they are cultivated.

If the *bacterium aceti* be introduced into a part of the human body and glycerol be found present, then, in the ordinary course of things, the glycerol will be decomposed. If, however, an antiseptic be first admixed with the *bacterium aceti*, the chemical change will probably not take place and the micro-organism itself will be absorbed by the cells of the human body. Similarly, there appears to be some substance present in the human body which is decomposed by the *bacillus anthracis* and as one of the products is poisonous, the process is apt to lead to disease and death. If, however, an antiseptic, such as 'Sanitas fluid,' were first admixed with the bacterium-culture, then (apart from its germicidal action) in all probability it would be found that the *bacterium* is prohibited from setting up the change in question and that it would be absorbed or destroyed by the cells of the human body before it could do any harm.

Since all the changes which can be initiated by micro-organisms can be classified as acts of hydrolysis or of oxidation, and since I have shown that 'Sanitas fluid,' when present in sufficient quantity, prohibits *every such change* (so far as examined) from taking place, it follows of necessity that it is equally capable of preventing pathogenic micro-organisms from initiating disease (see Chapter XIV.).

In another contribution, Mr. Adrian J. Brown has demonstrated the fact that a pure cultivation of so-called 'vinegar plant,' or 'mother' (which is to be regarded as a distinct organism from *bacterium aceti*), gives all the reactions of cellulose like that which is obtained from cotton-wool, but which *bacterium aceti* does not show. The cellulose thus formed is converted by strong sulphuric acid into dextro-rotary sugar, and in this respect it resembles ordinary cellulose. The fermentative properties, however, of this growth are identical with those of *bacterium aceti*.

Further experiments showed that the vinegar plant converts dextrose, mannitol and lævulose all into cellulose and gluconic acid, but that cane-sugar, starch, and ethylic alcohol do not yield cellulose. Brown has named this cellulose-producing organism *bacteria xylinum*.

The fermentation of calcium glycerate by *bacillus ethaceticus* has been investigated by P. F. Frankland and W. Frew.* The products obtained in this fer-

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* *Journ. Chem. Soc. Trans.*, 1891, p. 81.

mentation were principally ethylic alcohol and acetic acid, together with smaller proportions of formic and succinic acids. In the case of each completed fermentation there was also found a quantity of a fixed acid amounting to about one-half of the glyceric acid employed; this acid turned out to be one of the two optically active glyceric acids, of which, according to Van t' Hoff's hypothesis, ordinary inactive glyceric acid is composed.

It has been shown by P. F. Frankland, A. Stanley and W. Frew, in an investigation* of the fermentation induced by the pneumococcus of Friedländer, that this organism is capable of producing fermentative changes in glucose and cane-sugar, as previously stated by Brieger. They also found that it ferments maltose, milk-sugar, raffinose, dextrin and mannitol, but that, like *bacillus ethaceticus*, it does not attack dulcitol. The authors made a special study of the fermentations of glucose and mannitol, the products in each case being ethylic alcohol, acetic acid (generally accompanied by a little formic acid and a trace of succinic acid), carbon dioxide and hydrogen; both the glucose and the mannitol were only partially fermented, the decomposition of the glucose, especially, being incomplete.

In a study of the fermentation of arabinose by *bacillus ethaceticus*, P. F. Frankland and J. McGregor† found that the products are qualitatively the same as in the fermentation of glycerol by the same organism, *i.e.*, ethylic alcohol, acetic acid, carbonic anhydride,

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* *Journ. Chem. Soc. Trans.*, 1891, p. 253.

† *Ibid.*, 1892, p. 737.

hydrogen, traces of succinic acid and another unidentified volatile acid. They also made a quantitative determination of the products of the change, from which they concluded that in the fermentation of arabinose by *bacillus ethaceticus* the proportion of acetic acid to alcohol is greater than in that of dextrose and still greater than in that of mannitol and glycerol, but less than in that of glyceric acid.

Warrington has pointed out that it is well known all ordinary soils contain organisms possessing a vigorous power of oxidation—of bringing about, that is to say, a combination between the oxygen of the air and various organic and inorganic bodies.

The organisms producing nitric acid have been made the subject of study by many chemists, and after much labour and many disappointments they have been satisfactorily isolated.

It is now known that the production of nitrates in the earth is accomplished by two organisms. By one, ammonium carbonate is oxidized and the nitrogen converted into a nitrite; by the second organism, nitrites are converted into nitrates (see p. 51).

These organisms grow and exercise their functions in dilute solutions of appropriate composition; it is, therefore, possible to study the exact mode of their chemical nutrition. Like all other living organisms, they require the presence of certain inorganic salts, *i.e.*, phosphates and sulphates of calcium, potassium and magnesium. The nitrogenous food is amply furnished either by ammonia, or by a nitrite which may be intentionally added to their culture solutions.

We now come to inquire respecting the source of carbon for these organisms, and we are confronted by the startling novelty that it is unnecessary to supply these organisms with any carbonaceous food save carbonates, bicarbonates being preferred. The fact of the conversion of carbonates into organic cell substance has been conclusively proved in the case of the nitrous organism, and it is assumed to be true also of the nitric organism as this also does not require the addition of organic carbon to its nutritive solution.

It is, of course, well known that green plants when exposed to sunlight are capable of forming organic bodies from the carbonic anhydride of the atmosphere; but in the case of nitrifying organisms we have colourless cells growing in the dark, capable of decomposing that compound. Now, the decomposition of carbon dioxide requires a certain amount of energy, which in the case of plants and trees is supplied by the sun, but in the case of nitrifying organisms must have some other source. This is explained as follows: this nitrifying organism attacks carbonic anhydride in its combination with ammonia, *i.e.*, ammonium carbonate, and the formation of an organic compound proceeds at the same time as the oxidation of ammonia, the result of the whole reaction being a liberation of heat, or, in other words, a surplus of energy.

Another micro-organism which occurs in soil and which has been studied by Winogradsky, appears to possess the remarkable power of assimilating free nitrogen from the atmosphere.

In order to study this bacillus, some of it was grown in a solution of sugar containing the necessary non-nitrogenous salts. Under these circumstances a vigorous growth of the bacillus takes place, the sugar undergoes butyric fermentation and nitrogen is assimilated from the air. In one experiment, using 7 grammes of sugar, 14 grammes of nitrogen were assimilated.

That a vegetable organism should be able to acquire from the air the whole of the nitrogen which it needs is certainly very remarkable and is an extraordinary fact both to the physiologist and the chemist.

CHAPTER IX.

THE SCIENTIFIC BASIS OF DISINFECTION — PRACTICAL DISINFECTION—ANTISEPTICS AND ANTISEPTIC SURGERY —DISINFECTANTS AND THEIR STANDARDIZATION.

The scientific use of chemical substances for the purpose of preventing and arresting the spread of infectious diseases is necessarily governed and controlled by what is known respecting the causes of these diseases.

In the two preceding chapters it has been shown that, undoubtedly, certain diseases are indirectly caused by living micro-organisms. Respecting, however, the more important contagious diseases, including small-pox, scarlet fever, measles, typhus fever, syphilis, etc., nothing precise has been forthcoming, and in considering the means to be employed for their prevention, we have to depend upon more general considerations and experience.

For the sake of argument, let it be conceded that all infectious diseases are originated either directly or indirectly by micro-organisms which prey upon the human body: how, then, are we to prevent their spread? Fantastical definitions of the terms 'antiseptic,' 'disinfectant,' 'germicide,' and so on, merit no consideration: we have simply to deal with the prevention of diseases which we have assumed to have a common originating cause in micro-organisms* (germs).

This being assumed, the next point to consider is, how these micro-organisms produce disease and death, and in answer to this question, scientific investigation of a practical kind has not, so far (as we have shown), provided an unequivocal reply.

In investigating the exact relationships of micro-organisms and disease, with the object of proving that a particular infectious disease is due to a particular micro-organism, Koch and Klein have pointed out† that the following conditions must be observed:

1. It is absolutely necessary that the micro-organism be found present either in the blood or the diseased tissues.

2. It must be possible to take the micro-organism from its nidus and cultivate it artificially in some suitable medium to successive generations, care being taken to exclude the introduction of all other micro-organisms. The object of this proceeding is to free the particular micro-organism from every kind of extraneous matter derived from the animal body which furnished the microbe originally.

3. It must be shown that the cultivated microbe

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* Consult the pamphlet by Dr. Charles Cameron, M.P., on 'Microbes in Fermentation, Putrefaction, and Disease.' Baillière, Tindall and Cox, London.

† *Die Milzbrand-Impfung.* Cassel und Berlin, 1883 (Koch). *The Practitioner*, March, 1884, p. 171 (Klein).

is capable of producing the particular disease by inoculation of the healthy body of an animal.

4. The micro-organism must be found associated with the disease in the body of the animal thus secondarily infected.

It will, however, be seen at once that it is absolutely impossible to dissociate any particular micro-organism from its own secretions and life products, for successful artificial cultivation implies the association of a suitable medium in which it lives with ease and multiplies, and the consequent production of certain chemical substances of possibly toxic character. So that, after all, such investigations can only indicate micro-organisms to be the originating cause of disease and are not adapted to the elucidation of all the contingent circumstances.

It is not even sufficient to separate the solid from the fluid parts of cultivation liquids and to prove that the sedimentary or solid parts are infective, while the fluid parts may or may not be inactive, or *vice versa*. This is proved by the experiments of Panum and Burdon Sanderson, in which it was demonstrated that in certain sterilized cultivation-mixtures it was the solid particulate parts that induced septicæmia in animals and that these particles consisted of a chemical substance (sepsin) elaborated by micro-organisms. Further, filtration through clay, or gypsum, removes sepsin from cultivation-mixtures and allows an innocuous liquid to pass through the filter, while in other cases it has been shown that the liquid filtrate thus freed from bacterial life constitutes a virulent poison. Processes, then, of sedimentation and filtration cannot be resorted to with the assurance that they remove the micro-organisms only. Any test which may be applied to such filtrates must be of an imperfect character. Rather, means must be found of sterilizing cultivation-mixtures, so that, after an assurance of the absence of living micro-organisms is obtained, tests may be made with the mixtures, to ascertain if the associated matters can induce disease in animals. The difficulty in applying such tests is to make sure that the means adopted for sterilization do not affect or alter the chemical nature of any substances that may have been elaborated by the micro-organisms in the cultivation-mixtures.

Since the fourth edition of this work was published, some such experiments have been made, and a general description of them has been given in Chapter VIII. The results have entirely justified my original and consistent contention, that we must look for the real poisons that cause disease among the chemical products of bacterial life, and amongst such substances are the albumoses.

For the purpose of testing some statements made by Sattler, Klein prepared an infusion of jequirity seeds (*Abrus precatorius*) and made a number of interesting observations therewith. Among other results, he proved that the infusion contains a very poisonous principle, which produces violent ophthalmia when inoculated into the eyeballs of healthy rabbits, and that it is a natural constituent, having no relation whatever to the peculiar *bacilli* which can be cultivated in the infusion and to the action of which Sattler had previously attributed the ophthalmia. This poisonous principle is destroyed by boiling and comports itself something like the pepsin ferment. Warden and Waddell have since isolated this substance and named it *abrin*. A similar substance exists in castor-oil seed (*ricine*). Both are intensely toxic bodies, minute fractions being fatal to many mammals when directly introduced into the circulation. They are much less active when introduced into the stomach, and Ehrlich has shown that by feeding animals with a diet into which they enter, immunity is in time conferred in respect of what would otherwise prove to be toxic doses of these poisons, although the immunity of each case does not apply to the poison of the other. There is supposed to be some chemical relationship between these toxalbumens and the albumoses which are produced by micro-organisms, and Ehrlich's experiments are held by some to throw a considerable light upon the subject of immunity from disease.

In taking into consideration the method by which micro-organisms produce disease, Klein, after pointing out* that their chemical influences on animal tissues are yet unknown, and that even in artificial cultures their chemical effects have not been ascertained, admits: 'It is quite possible that the pathogenic, like the zymogenic, organisms have this special character; that if the soil (animal body) contains a certain chemical substance, they are capable of growing

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* 'Micro-organisms and Disease,' by Dr. E. Klein, chapters xviii. and xix.

and thus capable of producing a definite zymogen or ferment.' Although he admits so much he attempts a distinction between septic, zymogenic and pathogenic organisms, by citing the fact that the former two absolutely refuse to grow in the living tissue of a living animal; they can only grow where the once living tissue has become dead through the operation of other influences. After all, this distinction is but a mere matter of accident, in my opinion, for each micro-organism, irrespective of class, requires special conditions and substances for growth. In the absence of sugar, yeast cannot produce alcohol, and in the absence of alcohol, the acetic ferment cannot, of course, produce acetic acid; so also, so-called pathogenic organisms require certain conditions for their propagation, and it is a mere chance that such conditions are presented by living tissues. In this sense, it is absolutely impossible, by any number of successive artificial cultures, to clear a pathogenic micro-organism from its adhering chemical virus, because the micro-organism cannot live except in the presence of suitable pabulum, and that condition being observed, it must give rise to new chemical products by its very life.

Thus, although we may admit that certain germs originate disease, it cannot be admitted that they themselves, by their mere presence in the living tissue, produce all the characteristic symptoms and consequences; it stands to reason that they alter the chemical composition of some substances upon which they feed by the agency of a product that they immediately produce.

Zymogenic and septic organisms cannot live in living tissue, because it is, or it contains some chemical substance, or presents some chemical circumstances inhibitory to their growth. The same substances or circumstances may constitute favourable conditions for the life of other (pathogenic) organisms. In brief, a micro-organism cannot be identical with the virus of any disease; it can only produce the virus by chemical change of a substance or substances present in the culture-medium or living body in or upon which it grows and multiplies.

Vaccination may be supposed to give protection either by introducing into the body a chemical substance, which is inhibitory to the infective process, or by the chemical alteration of parts of the body, rendering them immune to small-pox.

Klein is forced to admit* that (pathogenic) organisms act, in all probability, by the production of chemical poisons; but there he stops short, and does not apparently see that if this be so, then two further inferences must be made: in the first place, a pathogenic micro-organism can never exist apart from its products (containing probably some virus, seeing that its life-function is identified with their production); secondly, since the virus is the true infectant, three classes of chemical substances can be employed in the treatment and prevention of specific diseases: (1) substances which chemically change and destroy the virus; (2) substances (antiseptics) which, by inhibition of the growth of the micro-organisms, or by chemical

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* *Practitioner*, September and October, 1884.

changes induced in the medium, prevent the production of the virus; (3) substances (germicides) which may be proved to be fatal to particular micro-organisms and their spores, if such substances can be applied locally with effect.

Germicides, if otherwise available, cannot possibly be exclusively relied upon for the cure of diseases; for their introduction into the human body may be as fatal to the host as to the parasites, and while many of them are as poisonous as the true virus of any infectious disease, they may, for all that is known to the contrary, be without action upon the virus itself, even if the micro-organisms are killed off. As Koch has well put it,* 'it is not necessary, as has often been erroneously assumed, that the bacteria should be killed in the body: in order to make them harmless to the body it is sufficient to prevent their growth, their multiplication.' Among such substances he includes the essential oils, β-naphthylamin, paratoluidin, xylidin, many of the so-called tar dyes, such as fuchsin and methyl blue, and many compounds of mercury, silver and gold.

In every sense, then, non-poisonous disinfectants of the two classes first named are to be preferred, both for the prevention and the cure of infectious diseases.

Chemistry has, unfortunately, been too much neglected in all the recent studies bearing upon infectious and contagious diseases, and its application to them at the present time is still the most patent requirement.

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* *Brit. Med. Journ.*, August 16, 1890, p. 383.

It must be clearly understood that, so far, the exact nature of the connection between micro-organisms and infectious diseases has not been satisfactorily established even in the best studied cases, including septicæmia, relapsing fever, splenic fever, chicken cholera, glanders, swine plague, erysipelas and puerperal fever. As regards consumption, malarial fever, leprosy, gonorrhœa, and rinderpest, there is yet no final evidence indicating the causes; while in respect of small-pox, scarlet fever, typhoid fever, typhus fever, cholera, diarrhœa, diphtheria, measles, whooping-cough, chicken-pox and syphilis, the information is, if possible, still less precise in character.

That readers may not altogether confine their attention to the germ theory to the exclusion of all other theories of disease, I beg to refer them to Chapter VII., in which there is given an account of the graft or cell theory, as it is variously called, and also a study of the infective process witnessed in cancerous growths.

After all, then, we have still to depend very much upon the scientific use of the imagination in drawing up measures for the prevention and cure of infectious and contagious diseases.

It is utterly unscientific to suppose, as was once the case, that the mere presence of micro-organisms in the body causes death, although it may be conceded that disease and death are due to certain effects of their presence, as distinct from the mere mechanical lodgment of living matter in the wrong place. Irritation and local disturbances alone could arise from such mere lodgment. To ascertain their effects we must make ourselves acquainted with the chemical aspect of their life-history. We know that, in common with all living organisms, they require sustenance and reproduce their kind. These acts of life are attended with the production of excretions and secretions, and all recorded information concerning the chemistry of the living body would point to some product (being either a secretion or a product of its action on other substances) as constituting the direct cause of death to the higher organisms preyed upon by these micro-organisms.* Indeed, practical investigation has, as we have already seen, afforded what may be regarded as sufficient proof of this statement.

The fermentation of sugar (and the resulting production of alcohol) is not induced by the mere presence of yeast cells in the solution, but is the consequence of a chemical change imparted to the sugar by a secretion of the yeast cells; this secretion in its turn being a product of the life-action of the yeast cells. A similar chain of reasoning applies to the toxic albumoses that are produced by microbes. Thus, it will now be readily understood that blood-poisoning, which results from the introduction of putrilage into the system, is not brought about by micro-organisms in any direct sense, but only indirectly. In a suitable medium these organisms live and flourish and elaborate a purely chemical poison,

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* Compare 'Infectious Diseases in the Army,' by Professor Rudolph Virchow. Translated from the German by John James, M.B. London, F.R.C.S. (H. K. Lewis).

termed sepsin. This substance is a chemical product derived from the albumin upon which the micro-organisms depend for food.

Allied to sepsin (the poison found in putrid meat) are the various substances now termed albumoses, while the so-called *ptomaines* or noxious alkaloids found *post-mortem*, etc., are frequently found associated with them. As a rule, the action of these ptomaines is of a tetanizing nature, acting particularly on the nervous system.

O. Bocklisch* found that by the action of a pure culture of *vibrio proteus* upon chopped beef in water, an innoxious alkaloid termed cadaverine was produced amongst other substances; but when the microbes of putrefaction were introduced into the nutritive medium (care being taken to also introduce those bacteria which are always found present in the contents of the intestines) a toxic substance termed methyl guanidine was formed.

W. Nicati and Riltsch† found that the product of the culture of the so-called *comma bacillus*, which exercises a poisonous effect when injected into the veins of dogs, depends for its effect, not upon the micro-organisms themselves, but a poisonous compound which they produce in the cultivation fluid.

Tyrotoxicon is the name which has been given to another chemical product, having an intense poisonous character, which can be obtained from milk and cheese and articles like ice-cream which are made

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* *Berl. Ber.*, 1887. 1441.

† *Journ. Chem. Soc. Abstracts*, 1886, p. 169.

partially from milk. Victor C. Vaughan* claims to have established the identity of this tyrotoxicon with the chemical product termed diazobenzol, and has shown that it can be readily produced by inoculating normal milk with the butyric acid ferment and keeping the mixture in a closely-stoppered vessel for some eight days. It may be added that tyrotoxicon is rapidly decomposed upon exposure to the air, thus incidentally furnishing another proof of the disinfective value of the process of oxidation.

In common with other putrefactive poisons, tyrotoxicon produces nausea, vomiting, and diarrhœa.

From these statements it will be seen that the introduction into the human body of microbes results in the production of quite a large number of distinct chemical products, which are the outcome of the chemico-physiological changes which these organisms set up in the protoplasmic elements with which they come in contact.† Some of these products are poisonous, others are inert, while their interaction may result in the formation of yet further substances, all of which, acting upon the human organism, contribute to determine the symptoms of the disease or to ensure immunity from it. I contend that if these views be correct—and it seems to me no other position is tenable—then, as Koch has also pointed out (see p. 270), practical disinfection does not demand the destruction of the microbes themselves, but only

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* *Pharm. Journ.* (3), vol. xvi., p. 147, and December 10, 1887.

† For some further account of the chemical changes brought about by micro-organisms, see Chapter VIII.

the prevention of the production of the particular poisons which are excreted, secreted, or elaborated concurrently with their development under special circumstances.

To use the words of Professor Virchow, 'These secreted poisons are conceivably isolable from the micro-organisms which have hatched them; their activity is not tied to the presence of the fungus any more than the fungus itself is of a poisonous nature.'

Again, it is altogether unscientific to argue, as has been done, that a disinfectant must also be a poison. There is absolutely no foundation for such a view, and it is matter for surprise that Dr. A. Wynter Blyth should ever have given his support to it.

Unaided morphological studies of microbes cannot lead to any final conclusions respecting the causation of infectious diseases; chemical studies supplemented by physiological experiments will alone suffice for that purpose.

Many investigators are of opinion that each infectious disease is originated (indirectly of course) by one particular microbe, but morphological investigation has altogether failed to give adequate proof of this contention, and in any case it would be hopeless to attempt the universal extermination of the micro-organisms which originate or are intimately associated with the production of disease, for they are ubiquitous and constitute an order in creation. Collectively, indeed, they constitute a most useful and necessary order in creation, for by their agency, or that of some of them, putrescible organic matter at large is converted by hydrolysis and oxidation into innocuous and useful, nay, essential ultimate products. But while it may be injurious to have such micro-organisms at work in our houses, it may be even more prejudicial to health to have them or others at work in or upon our bodies. If they effect a residence in or upon the human body, and *the conditions necessary* for their reproduction be present, disease may result and death may supervene.

What means and agents, then, are to be employed for the prevention of such diseases?

They are both general and special.

The general means include cleanliness, the studied exclusion of decomposable and putrescible matters, the banishment of putrefaction from and near human bodies and dwellings, and a due provision of pure air and pure water. Every medical practitioner and every sanitarian, irrespective of theories as to the exact causation of preventable disease, is assured of the help which filth and insanitary surroundings give to contagious illnesses. That being so, every chemical reagent which admits of being usefully employed in ensuring chemical purity is a disinfectant in the best sense of the word.

Liebig pointed out that miasmatic diseases are endemic in places where the decomposition of organic matter is constantly taking place, as in marshy districts, and that these diseases become almost surely epidemic when a marshy area is dried up by continued heat.

Besides this, it has been shown that animal substances, in a state of decomposition, can excite a diseased action in the bodies of previously healthy persons. This is often experienced in anatomical theatres; the slightest wounds made with instruments which have been used in dissecting putrefied bodies not rarely lead to dangerous and even fatal results. In such cases, poisonous matter is communicated to the blood in the living body and, even in such infinitesimal amounts, is capable of producing the most terrible results.

The late Dr. Haviland, who made a special study of the geographical distribution of disease, wrote as follows:[*] 'Typhoid fever has no reason for existing at all, but whilst the porous soils of the sites of our villages are being polluted as they are, we must expect well-contamination and its sequel—fever. One great source of well pollution, which I have known to be the origin of much fever, is the farmyard and its manure-heaps. At present the rural sanitary authorities are generally composed of farmers and others who cannot, or will not, see anything wrong in their barbarous muck-heaps. The medical officer of health sees their effect daily. The effect of vegetable decomposition on the human system is varied, but marked. Let us take first the decomposition which produces ague and other forms of fever, as witnessed in the Fenlands, the Pontine marshes and in other swampy grounds. Or remember the peculiar fever that is the result of living near the localities where flax is steeped and decomposed, or where indigo is allowed to ferment.

[*] See his paper previously quoted on p. 230.

Then, again, we must not forget that during the American civil war, some few years ago, a form of fever arose, simulating measles, which was traced to the decomposition of the straw on which the soldiers were bedded.'*

Attention has already been directed to the peculiar infectant which is contained in putrilage, and which Burdon Sanderson proved to be of a particulate non-living nature. It is a most virulent blood-poison, and must, from the method of its production, inevitably result as a product of the putrefaction of flesh wherever it may occur. That being so, it is most probable that its formation also results from the putrefaction of other animal and vegetable matters containing albumin, since its production from flesh is traceable to the same chemical principle. Sepsin, as this poisonous matter is termed, is a mere chemical product of change capable of exerting a pathological effect as hundreds of other chemical substances exhibit peculiar pathological effects. Thus, the inhalation of chloroform produces insensibility to pain and if taken in excess results in death. Similarly, if a septic poison be received into the system, it will produce effects which, when recognized, are expressed as fever, and from which death may result.

Many years ago Dr. Semmelweis established the fact that a number of deaths occurred in a lying-in hospital at Vienna from the conveyance of putrescent matters to the genitals of the patients in an extraordinary manner.

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* Professor Virchow's pamphlet, previously referred to, is full of most valuable and precise information on this subject.

The physicians in attendance on the women were largely employed in dissecting, and it was known that these same operators would often leave the dissecting-room to examine women in labour and thus introduce on their hands the poisonous matter which led in so many cases to puerperal fever and finally to death.*

We are left, then, in no kind of doubt that at least many, if not all, infectious diseases have their origin in putrefactive and allied processes, and that sepsin and the albumoses are to be regarded as types of real infectants, or contagions.

Hence, in sanitary practice we aim at preventing putrefaction in undesirable places, and the agents employed to prevent such processes are termed antiseptics. Indeed, an antiseptic may be defined as a substance which, when properly applied, prevents the formation of septic poisons in its vicinity. Such substances are also not rarely termed disinfectants; and, indeed, it seems clear that if putrefactive change gives rise to infection, then agents which will either prevent or arrest this process are properly termed disinfectants.

Dr. Gamgee,† writing on this subject, says, 'I am now convinced that every good antiseptic is really a destroyer of disease germs: an arrest of development is ensured.'

If a beefsteak be placed in contact with air and

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* See Appendix to Liebig's 'Letters on Chemistry,' p. 530. This instance is by no means singular.

† *Chem. News*, January 27, 1871.

water and allowed to putrefy, the resulting product constitutes a most virulent fever-producing product; but if we place with the beefsteak a certain quantity of antiseptic material, the putrefaction does not occur and the poison is not formed. This is clear, and it is absolutely certain. It is equally certain that the poisonous matter, even if it be allowed to form, may be afterwards destroyed by certain other chemical substances which have the power of oxidizing and changing its nature, just as all the organic matter in nature is oxidized under ordinary atmospheric influences. In this way, as already stated, tyrotoxicon, for example, is quickly destroyed by exposure to the air.

The special means available for the prevention of infectious disease are really of the same order, but resolve themselves into the use of oxidizing agents, or antiseptics, or germicides, applied locally, when possible, at the very seat of disease, with the object of avoiding the results that follow from the unimpeded development in the human body of micro-organisms and their chemical products.

These microbes, or some of them, exhibit very tenacious powers of resistance (a feature which has received special attention in previous chapters) and some of their spores, at least, survive the application of parasiticides, even if employed of sufficient strength to poison the patient (host). The fully developed micro-organisms are more amenable, however, to such reagents than are the spores or immature organisms to which they give rise and by which they are reproduced to successive generations.

We must include, then, among disinfectant agents, those substances which destroy the life of microbes. Among such substances are many coal-tar preparations, such as Okol, Izal, Bactox, and Cyllin, also peroxide of hydrogen and the permanganates of potassium and sodium (which three latter are at least fatal to anaerobies generally), thymol, iodoform, corrosive sublimate, chloral, phenol, cresols and a large number of other substances, all of which act destructively to certain classes of micro-organisms.

The application of such chemical reagents to putrid mixtures results in the cessation of putrefaction, and the reason why such application remains efficacious is, either that the presence of the chemicals prevents the development of further spores into the mature state, or else that they kill off each organism as it is developed. They act in precisely the same way towards the microbes that initiate diseases.

The precise modes of action of disinfectants must necessarily be various in character. For instance, in addition to its valuable powers of oxidation, peroxide of hydrogen acts as a direct poison to anaerobic germs of the putrefactive type. It asphyxiates some microbes, by its active oxygen, just as carbolic acid acts as a direct poison to man. Some preparations (such as pyrogallic acid) may act in the directly opposite manner, viz., by absorbing the oxygen necessary for the life of other microbes. Other chemical reagents (such as tannin and alum) may render the medium in which the micro-organisms exist unfit for their further sustenance, either by entering into combination with the albuminous principles upon which they may have hitherto depended for food, thus converting them into substances which they cannot decompose, or by chemical action upon the cells of which they themselves are constituted. In this way they may be starved out of existence. Or yet again, just as a man may be anæsthetized by chloroform or ether, so also may be micro-organisms. Thus, Claude Bernard has shown that the sensitive plant loses its irritability when placed in contact with the vapour of ether, but regains it if the ether be removed : if not removed the plant dies. Again, if the yeast plant be placed in an etherized sugar solution, it will no longer act as a ferment, and ceases to be reproduced until the ether be removed : if not removed, the cells succumb to the ether and finally die.

It will be evident, then, that there are better ways of preventing disease than by attempting to annihilate micro-organisms on a wholesale scale. They can be starved out of existence, or they may be anæsthetized, or the general conditions surrounding their existence may be so influenced that further life becomes impossible. Collectively, all chemical agents, which lead by their employment either to the effectual suspension of their chemical processes or to the destruction of their poisonous products or to their death, are disinfectants.

Heat should not, of course, be referred to as a disinfectant, but only as a disinfecting agency.

Prevention is better than cure, for if the microbes of disease obtain access to the organs and tissues of the body, then the host may first succumb to the chemical reagents that are used with the view of destroying the parasites alone. The use of disinfectants for internal administration greatly limits the available number, and this is a subject that has received far too little attention. Almost the only direction in which it can be said to have been seriously tried is in connection with the treatment of throat and lung complaints by the process of inhalation.

According to Behring,* there are four possible ways of effecting internal disinfection :

(1) By killing disease-producing germs.
(2) By hindering their growth.
(3) By counteracting disease-producing properties.
(4) By antagonizing the action of or destroying altogether the various toxic substances produced by the bacteria.

Behring in his paper points out that, if a small piece of the spleen of a mouse which has died from anthrax be injected into another mouse, the latter also dies from anthrax; but the fatal results may be postponed or prevented by subsequent injection of a mixture of corrosive sublimate and chloroborate of soda.

He also states that by inoculating guinea-pigs with the blood of a guinea-pig suffering from diphtheria, they are rendered immune to this disease. He concludes that the protective action of the blood of immune

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* 'Disinfection of the Living Body,' *Brit. Med. Journ.*, August 22, 1891, p. 406.

animals is not dependent on its living elements, or at least is not limited to them, as is shown, he thinks, by the fact that it is exhibited by the extravascular cell-free blood serum ; on the contrary, the protective action is rather to be traced to the circumstance that the extravascular blood and the blood serum of immune animals, possess the property of destroying this specific diphtheritic poison without destroying the diphtheria *bacilli*.

The disinfecting action of the blood in animals affected with diphtheria is, therefore, to be sought for in the destruction of the substances produced by the diphtheria *bacilli*.

The bacteria-killing properties possessed by the living body, which were first referred to the cells of the body, are now regarded by a great number of observers as being due in part to the cell-free blood. Illustrative of this we have Professor Ehrlich's very instructive experiments, which have shown that mice and rabbits may in a short time be rendered so immune against certain vegetable poisons—castor-oil, for example—that they can withstand a dose a thousand times stronger than the originally fatal dose : other animals may also be protected by the injection of the blood of animals which have been rendered immune in this way.

Some years ago Dr. Cash, when working for the Local Government Board, tested a number of disinfectants by administering them for a prolonged period to animals which were ultimately inoculated with pathogenic micro-organisms. In this way he examined the action of sulphocarbolate of soda, phenylpropionic acid and its salts of potassium and sodium, all of which were practically valueless with regard to anthrax and tuberculosis. With perchloride of mercury (corrosive sublimate), however, he claimed to have succeeded in producing an immunizing action by administering minute doses daily to rabbits before inoculation of anthrax took place.

Elsewhere I have referred to similar observations made by Behring respecting terchloride of iodine in relation to tetanus. I cannot, however, share the view which he has expressed,* that we may achieve a brilliant reward by further work in this direction. If such an inquiry is to be recommended at all, it should be made subservient to a chemical appreciation of the issues that are involved and instead of experimenting haphazard with corrosive and poisonous chemicals, there should rather be employed substances, which, like peroxide of hydrogen (alone or associated with innocuous antiseptics), may be reasonably expected to produce a result of the kind that is wanted—viz., the prevention of the formation of toxic bodies in the living body and the destruction of them, if and when formed.

There are many who think with Drysdale, that probably the best means of protecting persons against such diseases as small-pox will be found in the extended art of vaccination, and that the most efficient treatment of other diseases, such as ophthalmia, is the practice of inoculation. Unfortunately, we are

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* In an address reported in *Pharm. Journ.*, November 25, 1893.

at present without sufficient information to warrant the employment of such methods on any serious scale in other diseases, and even so far as they have been employed the results cannot on the whole be regarded as satisfactory.

In the use of disinfectants for the prevention of infectious diseases (in contradistinction to their cure), regard must be had also to their general characters and their influence on health.

Dr. R. Angus Smith has said tersely enough, 'We live in air, and the air flows continually into our blood; no wonder, then, that we are influenced by climate, which means the condition of the air.'* Now, commercial carbolic acid (in common with many coal-tar derivatives) is a deoxidizing agent which, when added to the air, vitiates it both by diminishing the available oxygen, as well as by its poisonous action. Similarly, sulphurous anhydride uses up useful and life-giving oxygen by becoming oxidized into sulphuric acid, although for fumigating purposes it may often be usefully employed. For such purposes, however, the sulphur candles which I have recently introduced have great advantages (see p. 315).

Coming now to the general employment of disinfectants for universal use, a preparation must have the following characters:†

'Firstly, it should not be dangerous if by any chance it be taken internally, and we know that in the case of carbolic acid, for instance, fatal accidents from its use are of constant occurrence. Secondly,

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* 'Air and Rain,' p. 3.

† *Standard*, September 11, 1878.

it should not be destructive of any substances to which it is applied, as such a quality would necessarily limit its action and it could not be used, as noted above, to saturate sheets and cut off infection. Thirdly, it ought not to be offensive, for, even postulating the efficacy of an evil-smelling disinfectant, it is never likely to become popular; and it is to the general, we might almost say the universal, use of disinfectants that we must look for any permanent mitigation of the evil exhalations that so often pollute the atmosphere and which almost invariably carry with them the germs of disease. Many disinfectants offered to the public fulfil one or two of these requirements; while others, though effectual enough, contain recognizable elements of danger. Only one or two may be used with confidence wherever a disinfectant is needed, always remembering that as the nation is reputed happiest which has no history, so that individual may be esteemed the most fortunate who manages so to purify his premises and order his household as to have no need to use a disinfectant at all.'

Of the few disinfectants which may lay claim to all these characters, there are none better than the so-called 'Sanitas' preparations and appliances, for the existence of which I am personally responsible.

The following is a list of some of the better-known antiseptic, disinfectant, and germicidal reagents:

'Sanitas' Fluids, Oil and Emulsion (containing in their several forms Peroxides, Thymol, soluble Camphor, etc.).
Peroxide of Hydrogen.
Ozone.
Permanganates of Potassium, Sodium and Calcium.

Chromic Acid.
‘Okol.’
‘Bactox.’
‘Izal.’
‘Cyllin.’
Carbolic Acid (Phenol), and its higher Homologues.
Salicylic Acid.
Phenylpropionic Acid.
Phenylacetic Acid.
Sulpho-phenic Acid.
Perchloride of Mercury (Corrosive Sublimate).
Eucalyptus Oil.
Thymol.
Chloride of Zinc.
Sulphate of Zinc.
Sulphurous Anhydride.
Iodoform.
Subnitrate of Bismuth.
Chloride of Lime (Bleaching Powder).
Chlorine (Gas).
Sulphate of Iron.
Chloride of Copper.
Sulphate of Copper.
Lime.
Perchloride of Iron.
Iodine.
Creasote.

Each of these substances acts in its own special chemical manner, but, broadly speaking, those disinfectants which are also oxidants are to be preferred for two excellent reasons: firstly, because they are antagonistic to the whole class of anaerobic germs, and secondly, because, in addition to any germicidal and antiseptic properties they may possess, they have the power of chemically altering, by oxidation, the products of the life action of germs in general, thus assuring the destruction of the organic poisons associated therewith.

As regards the comparative antiseptic action of various chemical compounds in relation to organic matters, and even apart from any consideration of their values as disinfectants for use either generally or in the specific treatment of disease, the following results of an investigation* which I conducted a few years since will be found interesting.

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* *Journ. Soc. of Chemical Industry*, November, 1887, and November, 1888.

In the earlier stage of the investigation, the comparative antiseptic values of the several substances were determined in respect of two standard mixtures, viz., extract of beef and flour-paste. As, however, the results were mutually confirmative, there was no occasion to employ in the later observations more than one standard, for which purpose extract of beef was chosen.

In reviewing the results which were first published in connection with these experiments, several medical papers commented upon the fact that putrefactive agencies were alone examined: this was coupled with an expression of regret in one case that specific micro-organisms isolated from all others and known or assumed to be the direct or indirect cause of specific diseases, were not studied. Now, in reference to this matter, I may at once state that such experiments were not required for the purpose I had in view. Moreover, not only was it then very difficult to obtain such specimens, but, as a matter of fact, the prohibitive effects of various chemical agents are more or less general in character in the sense that, as they act in relation to any one micro-organism so they do to others, either by destroying them or so altering the composition of the medium that it becomes either incapable of sustaining the life or permitting the development of the respective species.

It has been shown that micro-organisms do not of themselves give rise to disease, but that under favourable circumstances—that is to say, by development in suitable media—they cause the formation of certain chemical products which are noxious in character and behave as poisons to the human organism. This is the view I have consistently taken since I first interested myself in the subject, and it is gratifying to know that, while when first propagated it was held up to a good deal of scorn, it is now almost universally accepted, but of course, as is not unusual in such cases, but few writers now remember to have held or expressed any other view of the case.

It is not at all improbable that the same or allied poisons may be elaborated or produced by different micro-organisms, so that if it can be shown that antiseptics act uniformly as a class in prohibiting the processes of chemical change or fermentation by which such poisonous products arise, my earlier experiments, in common with those about to be described, are perfectly reliable for guidance in dealing with sanitary matters and the prevention of disease.

That antiseptic agents act more or less uniformly and are therefore to that extent comparable, is borne out by the fact that the processes, for the inhibition of which they are applied, are also uniform in character. Writing broadly, it is fair to state that most processes of fermentation or chemical change induced by micro-organic life depend upon two chemical acts, the one hydration and the other oxidation; that is to say, more or less complex molecules (like albumin) are split up in the first place into a certain number of more simple bodies, and oxidation of these or some of them proceeds simultaneously or subsequently. It is not improbable that the more active poisons are produced when the chemical changes are mainly hydrolytic in character.

As further bearing upon these views, it may be noted that in course of some observations made by Burdon Sanderson * upon the results of an experimental investigation then lately carried out by Dr. Klein and Mr. Lingard, he characterized them as affording 'solid ground for the anticipation that whatever means may be found effectual as prophylactics against septic infection, will also be effectual, *in so far as they are applicable*, against tuberculosis.'

In commenting upon the same researches, Dr. George Buchanan† carried the argument even further, and finds one noteworthy point vouched for by Dr. Klein, viz., that 'when it is possible to recognize, as in the case of anthrax, tubercle, and swine-fever, the minute organisms that play an essential part in the disease, and to compare them with other and similar organisms which are not so much infective as putrefactive, it is found that chemical agencies which are wanting in destructive effect upon the putrefactive organism have a power, often when present in extremely minute quantity, of arresting or destroying the life of the infective organism.'

In order to bring the later results of my observations into general accordance with the former ones, I deemed it advisable to repeat the whole of the tests originally made with chlorides, nitrates and

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* 'Report of Medical Officer of Local Government Board,' 1884, p. 184.

† *Ibid.*, p. 33.

sulphates in respect of extract of beef. For this purpose, 5 lb. of lean fresh beef was minced and then digested with water at a temperature under 40° C. during three hours, after which the extract was made up to 4 litres, and when cold was strained several times through fine muslin, to remove the undissolved portions and the solidified fat. In each observation 95 c.c. of this extract was taken, and to it was added 5 c.c. of the particular antiseptic solution to be tested. These antiseptic solutions, except where otherwise noted, were of 5 per cent. strength; but in cases where the substances were not perfectly soluble, the solutions containing the undissolved portions in suspension were used. The series of experiments first to be described were commenced on November 19th, 1887, and the following record will show the respective days on which the several mixtures became putrid:

Chlorides.

On the fourth day, the mixtures containing the following chlorides had become putrid: Chlorides of potassium, sodium, ammonium, barium, strontium, calcium and magnesium, as also the standard extract.

On the ninth day, the chlorides of iron, lead, zinc and tin.

On the fifteenth day, chloride of aluminium.

The mixtures containing the chlorides of copper and mercury remained intact.

Nitrates.

On the fourth day, the nitrates of potassium, sodium, ammonium, barium, strontium, calcium, magnesium and iron.

On the sixth day, nitrate of zinc.

On the ninth day, nitrate of lead.

The mixtures containing nitrates of copper and mercury alone remained intact.

Sulphates.

On the fourth day, the sulphates of potassium, sodium, ammonium, magnesium, iron and manganese.

On the fifth day, sulphate of zinc.

On the eleventh day, sulphate of aluminium.

The mixtures containing the sulphates of copper and mercury alone remained intact during the whole period of observation, viz., sixteen days.

It may be noted, as a rule, that as the mixtures became putrid, the colour changed from a dull dirty red to bright scarlet, a change probably associated with the initiation of oxidation by the agency of aerobic micro-organisms.

The next lot of observations were made in February, 1888, using a similarly prepared extract of beef (containing 1·796 grammes of total solid constituents dry at 100° C.) with some selected chlorides, nitrates, sulphates and the following other substances:

5 c.c., 10 c.c., 15 c.c., and 20 c.c., of ordinary 'Sanitas fluid' of commerce respectively and 5 c.c.

'Mercuric Bactericide' (that is a solution containing

5 per cent. mercuric chloride in a five-volume solution of peroxide of hydrogen).

The mixtures broke down in the following order:

On the third day, the standard solution was putrid.

On the fifth day, the sulphate of zinc and nitrate of lead mixtures.

On the sixth day, the 5 per cent. 'Sanitas fluid' mixture.

On the seventh day, the chlorides of lead and tin mixtures.

On the twelfth day, nitrate of mercury and chlorides of iron and aluminium mixtures.

On the fifteenth day, chloride of zinc mixture.

On the twenty-first day, nitrate of zinc mixture.

In this series it will be observed that nitrate of mercury broke down on the twelfth day, thus confirming the general evidence adduced by the earlier series of experiments, that this salt is not so reliable as either the chloride or the sulphate.

The mixtures containing 10 c.c. 'Sanitas fluid' and upwards, remained quite free from putrefactive change collaterally with the mixtures containing 'Mercuric Bactericide' and the chlorides and sulphates of copper and mercury during the whole period of observation, viz., thirty-four days.

These results give the information which was asked for, in course of the discussion on my earlier paper, by Mr. A. H. Hutchinson, concerning the antiseptic value of 'Sanitas fluid,' 10 c.c. of this reagent being equal in effect to 5 c.c. of a 5 per cent. solution of mercuric chloride.

The remaining series of observations were made with solutions of peroxide of hydrogen of so-called five-volume strength, having dissolved therein 5 per cent. of the following substances respectively :

Potassium hydrate (caustic potash), potassium chlorate, bisulphate of potassium, borax, borax neutralized with boric acid, sodium benzoate, ethylic ether, glacial acetic acid, quinine disulphate, quinine sulphate dissolved in a slight excess of sulphuric acid, chloroform,* phenol (absolute carbolic acid), chloral, pure hydrochloric acid, oxalic acid, boric acid and sulpho-phenic acid.

On the second and third days, the standard extracts broke down in all cases ; so also did the sodium benzoate and neutral borax mixtures.

On the third day, the ether and caustic potash mixtures.

On the fourth day, the quinine disulphate mixture.

On the fifth day, the potassic chlorate mixture.

On the seventh day, the chloroform mixture.

On the tenth day, the borax mixture.

On the thirteenth day, the boric acid mixture and the mixture containing quinine sulphate dissolved in an excess of sulphuric acid.

On the seventeenth day, the mixture containing bisulphate of potassium.

On the nineteenth day, the acetic acid mixture.

On the twenty-fourth day, the chloral and oxalic acid mixtures.

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* This antiseptic mixture was made up as follows : 5 c.c. chloroform + 50 c.c. absolute alcohol + 45 c.c. of 10 vol. H_2O_2.

On the twenty-seventh day, the sulpho-phenic acid mixture.

After thirty-nine days, the following mixtures were still good—hydrochloric acid and phenol.

Now, in dealing with these results, it must be borne in mind that all the test solutions contained peroxide of hydrogen, which exhibits of itself a considerable antiseptic property, so that the comparative results of the experiments present the specific additional values, so to speak, of the dissolved substances.

Of course, also, the tests, in common with the previous series, were somewhat severe, as they only give the antiseptic values of 5 c.c. of 5 per cent. solutions when diluted twenty times.

One of the most interesting facts elicited by this inquiry is the pronounced antiseptic value of chloral, which may therefore find in the future an extended use in the domain of medical practice.

Only somewhat less pronounced is the antiseptic character of potassium bisulphate.

Again, sulphate of quinine, if administered together with sulphuric acid, may be expected, not only to act as a tonic, but also to produce an antiseptic state of the human body.

It is interesting also to observe that borax is much more effective than when neutralized with boric acid, notwithstanding that that substance has a higher antiseptic value than borax.

Of the other pronounced antiseptics, phenol is, of course, well known, but its application is limited on account of its dangerous character.

The influence of the acid reaction is significant; acetic, oxalic, sulpho-phenic and hydrochloric acids exhibiting very marked antiseptic action.

Acetic acid has been known for ages to be a good antiseptic, whilst hydrochloric and other mineral acids formed years ago the subject of study by Dr. John Dougall,* and were then found to be powerful antiseptics and disinfectants. Unfortunately, they are much too corrosive to be of extended use, either in the household or for medical applications.

Sulpho-phenic acid (in common with phenylacetic and phenylpropionic acids) is strongly antiseptic in character, but in the human organism it would probably yield phenol and thus exhibit toxic effects.

As regards sulphuric acid (the influence of which is perhaps seen in the result of the observations made with quinine sulphate dissolved in it, and with bisulphate of potassium), it may be remarked that Mr. J. P. Laws has made some interesting observations† concerning the restraining and killing power of that substance, both of which he found to be considerable. The antiseptic properties of chloroform water have been studied by E. Salkowski,‡ but in the form of an alcoholic solution they do not appear at any rate to be so pronounced as those of borax.

As a matter of fact, experience appeared until lately

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* 'Trans. Nat. Assoc. for the Promotion of Social Science,' 1874, pp. 708-719.

† 'Report of Medical Officer of Local Government Board,' 1884, p. 208.

‡ *British Medical Journal*, May 5, 1888.

to point to corrosive sublimate as the most powerful antiseptic yet discovered. Klein at one time endorsed this view, while Koch claimed that a solution of 1 in 5,000 can be relied upon for perfect disinfection, since it suffices, according to him, to annihilate all life in micro-organisms and their germs within a few minutes. Klein, I think rightly, regards this statement as an exaggeration of its powers, but there is no doubt of the effects of somewhat stronger solutions. Unfortunately, again, the terribly poisonous nature of the substance absolutely disqualifies it for general use.

Since then several very powerful germicides have found their way into commerce, and notable amongst these are 'Okol,' 'Bactox,' 'Izal' and 'Cyllin.'

It is only fair that I should again insist upon the great value of 'Sanitas fluid' as a disinfectant for popular and medical use, inasmuch as it is wholly innocuous and thoroughly reliable as a germicide, as an antiseptic and as an oxidant; in point of antiseptic power it has been shown that 10 c.c. is equal in effect to half that quantity of a 5 per cent. solution of perchloride of mercury.

Precise studies of its germicidal properties have been recently made by Mr. C. G. Moor, M.A., F.I.C., and Dr. John Thresh, F.I.C., and an account of their investigations is given in Chapter XIV.

With respect to the comparative antiseptic values of the better-known chlorides, nitrates, and sulphates, the results confirm generally the earlier ones, but the chloride of aluminium appears to have a somewhat higher value than that formerly assigned to it.

It may be said by way of summary that the chlorides, nitrates and sulphates of the alkalies exhibit but slight antiseptic effects, while those of the alkaline earths are not much better. The compounds of manganese, zinc, tin, iron, lead and aluminium are all of more or less pronounced value. As a rule the chlorides are to be preferred. The compounds of copper and mercury are comparatively most effective; the nitrate of mercury is, however, not so reliable as the chloride, which is the most active antiseptic amongst these classes of substances.

The general results of this investigation will, I hope, be of service in this way, among others, that when a so-called new disinfectant or antiseptic preparation is submitted to the public, directly the composition is known the approximate value may be approximately ascertained by reference.

The use of antiseptics in the practice of surgery has now become almost general, thanks to the advocacy, in particular, of Lister. A large part of the total mortality experienced in surgery was due to blood-poisoning which resulted from the absorption into the system of decomposed secretions from wounds. The decomposition in question is common putrefaction initiated in the secretions by air-borne micro-organisms, and the practice of using antiseptics for preventing putrefaction in wounds is sometimes termed 'antisepsis.' Some writers view this prevention of the development of bacteria in wounds as something quite distinct from disinfection proper, by which expression they seek to represent the annihilation of micro-organisms alone ; but this distinction is altogether too nice and unreal. At least, it matters not at all whether we speak of disinfecting wounds or keeping them in an antiseptic condition, so long as the object of the process, viz., a healthy state, be attained and maintained. To use Lister's own word's,* 'We do not require any scientific theory in order to believe in antiseptic treatment ; all you have to believe is that there are such things as putrefaction and other septic agencies ; that our wounds are liable to these ; that they are very pernicious ; that these things come from without, and that we have the means of preventing them by various chemical agencies.'

A wound which is attacked by atmospheric germs becomes infected ; any chemical reagent which, by its presence, prevents this infection is an antiseptic, and if any such substance removes existing infection (as proved by the restoration of the wound to a healthful condition by its use), then that antiseptic is also a disinfectant and it is downright nonsense to combat the statement.

The practice of antiseptic surgery depends, then, upon the employment of measures (notably cleanliness and filtration of air) for keeping air-borne germs out of wounds and (what is more important) for preventing their development in the wounds (if introduced) by the use of antiseptics.

There is one great danger in the practice of antiseptic surgery, although it is by no means unavoidable, and that is, the possibility of poisoning patients by

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* *Lancet*, November 3, 1883, p. 765.

the absorption of noxious antiseptics. Iodoform, subnitrate of bismuth and corrosive sublimate exhibit very powerful toxic effects, while hundreds of lives have been lost owing to the general use of carbolic acid as a disinfecting agent. Now that there are better preparations known to science, such as 'Sanitas fluid,' which is equally reliable and quite non-poisonous, the necessity for using poisonous antiseptics and disinfectants no longer exists, and their employment is to be condemned in the strongest possible terms, since it unnecessarily exposes suffering humanity to danger of life and limb from their toxic effects.

It is a great mistake often made by surgeons, to imagine that in the practice of antiseptic surgery they require to use the most corrosive and actively poisonous substances they can command. It should be remembered that the process of putrefaction does not attack living tissue. but only dead matter ; the surgeon therefore should as carefully remove (by cleansing operations) dead tissue—thus minimizing the chances of infection—as he attends to the use of his antiseptics, for it is this dead matter that constitutes the chief pabulum of disease germs in the case of wounds.

Disinfection, then, should be practised with the object of either interfering with the multiplication of the microbes associated with specific diseases. or of so influencing the conditions of their life that they shall cease to produce the poisonous substances constituting the real direct causes ; for the microbes themselves are universally distributed in nature, and it is idle to think of exterminating them. But although they cannot be exterminated, they can be controlled in relation to disease, just as can be done in connection with the process of putrefaction as observed in the laboratory. This process, in all probability, amounts to the same thing as disease, with this difference, that it is best known in connection with lifeless matter derived, however, from living sources.

The various ways in which microbes can be controlled have been already described and it only remains to indicate the general manner in which disinfection is to be carried on in connection with each particular disease. This will be studied in the next chapter.

For accounts of the prohibitive and destructive effects of some chemical substances upon particular micro-organisms, I may refer my readers to the publications of the Medical Officer of the Privy Council and Local Government Board, 1870-1887; but at the same time, I am constrained to add that many more recent investigations, although of great value in themselves, are not calculated to determine the practical value of the substances investigated as disinfectants for general use.

Standardization of Disinfectants.

Attention has already been directed in this chapter to certain experiments made by the author concerning the antiseptic power of various substances which it was hoped would be of service (see p. 299) as affording a basis of comparison of the relative value of new disinfectants or antiseptic preparations which might be introduced in future. In fact, it was an attempt, and perhaps the first serious one which was made at what is now termed the 'standardization of disinfectants'; but some few years since the matter was carried further by Dr. S. Rideal and Mr. Ainslie Walker using another (germicidal) test which was not available at the date of the author's earlier investigations.

In the Rideal-Walker method, pure carbolic acid is taken as the standard and a measured quantity of the disinfectant to be tested is mixed with the same amount of a particular culture of *Bacillus typhosus*, at the same time and temperature. Equal quantities of the medicated cultures are then transferred to equal volumes of the same medium (broth) and incubated during a given period at the same temperature, the absence or presence of living germs in the last culture medium after, say, forty-eight or seventy-two hours affording the index of efficiency or want thereof.

In other words, a particular dilution of the disinfectant under trial is found that performs the germicidal work of a known strength of carbolic acid, and using the standard as a denominator, the arithmetical ratio gives the so-called 'carbolic acid co-efficient' of the disinfectant under examination.

Unfortunately the results afforded by this test are more or less unsatisfactory for a number of reasons, some unavoidable and others avoidable. From many experiments made by others and in my own laboratory in association with my friend Mr. R. C. Woodcock, F.I.C., F.C.S., it is obvious that the results of such tests differ principally because it is impossible to first of all standardize the culture of *Bacillus typhosus* which is employed, different strains exhibiting varying powers of resistance according to the case from which they have been derived, and (after isolation) the different life-histories of the several cultures, as also with the varying quantities and qualities of the associated substances constituting the medium. Thus, working under otherwise absolutely identical conditions, a sample of 'Sanitas Okol' showed a co-efficiency of 24 with one culture, as against one of 20 only, using another distinct culture. This one result is typical of hundreds of others illustrating the same undoubtable fact, and it sufficiently serves to show that the Rideal-Walker test has only a limited value, which may be defined as follows—viz., that, working with the same culture and under absolutely identical conditions otherwise, it serves to determine the relative germicidal power of miscible fluids of the same class as compared with that of carbolic acid and under that particular set of conditions. As against this admission it is to be pointed out that these conditions are not by any means identical with those under which practical disinfection has to be carried out in everyday life.

The results afforded by this test vary also according to the nature (*i.e.*, precise composition) of the nutrient medium which is employed, the temperature at which the observations are made, the duration of the periods of exposure, the manner in which the medium is prepared as regards its acidity, etc., and method used for obtaining same, the degree of miscibility of the disinfectant with the culture medium, the associated organic matter, etc.

Every culture differs more or less from every other culture and the most expert bacteriologists cannot guarantee the absolute purity or unmixed nature of the organisms.

Another objection concerns the more or less imperfect degree to which the subject disinfectant becomes really mixed with and therefore placed in contact with the organisms, while a third difficulty is experienced in the varying chemical and physical action of the disinfectant not merely on the organisms themselves, but also in respect of the culture medium.

Combination, decomposition, coagulation, precipitation, obscuration—all sorts of difficulties are experienced in practice, so that the results have only a certain value as regards any one preparation, and it is impossible to obtain any reliable comparison even of it with other articles unless they be practically identical in chemical and physical properties.

In addition to what I have already pointed out, there is a further objection to placing reliance on this test, viz., that which relates to the so-called personal factor; for while fairly uniform results, using the same preparation and the same culture, may be obtained by the same experimenter, varying results are obtained by other experimenters using the same materials.

The disturbing influence of fat or oil is doubtless due to its action in assimilating the oily particles which are set free whenever emulsions of the coal tar order are made for testing purposes. Most of these disinfectants form milky solutions when admixed with water, the milkiness being due to the separation of the oily particles constituting the active principles, a circumstance which in itself is sufficient to prevent the Rideal-Walker test from being a thoroughly good one; for the result indicates the germicidal action of only that part of the active principles which comes into real contact rather than the total effect, in consequence of part of the oily particles which are set free, aggregating and possibly remaining outside the arena of action.

In particular, the bacterial method of testing disinfectants is open to the cardinal objection that *it does not test the real disinfectant values* of preparations, but only the *relative germicidal values under the particular set of conditions observed in the method which is employed*, and these in turn *do not simulate the conditions under which disinfectants are used in practice*. It ignores all other conditions and all other qualifications and disqualifications. There is no absolutely scientific test for ascertaining the relative values of disinfectants, and there cannot be until we know more precisely the nature and constitution of infectants.

It has been shown in the preceding pages that bacteria are not infectants themselves; they are only the agents which produce them, and nothing is known with absolute certainty respecting the precise conditions under which they are produced, or of their constitution. Presumably, real infectants are chemical in nature; but they are not, so far as is known, the *inevitable* result of the growth or culture of any particular kind of organism in any or all media, but are only produced under conditions not yet ascertained and that cannot, therefore, be formulated. Practical disinfection, therefore, necessarily resolves itself, as an art, into the observance of all measures based upon general scientific knowledge which are calculated to prevent the accumulation of dead organic matter derived from animal and vegetable sources, and the chemical changes to which they are subject under the living attacks of micro-organisms.

Consequently, the relative values of disinfectants cannot be measured by *germicidal power* under an artificial set of conditions, but only by the determination of all contributory — chemical and physical — qualifications and disqualifications.

That germicidal value is of importance goes without saying, but antiseptic value is equally important; more important still is what we may style oxidative value, whilst other kinds of chemical action must not be overlooked. All these properties, however, are of mere temporary value, because in the end the organic matter in which the infectant resides and from which it is generated, must be disposed of by oxidation—rapidly, as in the practice of combustion, or more gradually in the natural manner, that is to say, by the action of the very micro-organisms to which germicides are fatal.

To that extent, therefore, the use of strong germicides is even objectionable, because they only prevent or delay the natural operation by which ultimate purity and freedom from infection can be secured.

To further exemplify the importance of studying all properties of disinfectants, it is obvious that a dangerously poisonous preparation cannot be administered where internal application is called for; a non-volatile substance cannot be used for aerial disinfection (except by the spray), and a non-miscible article cannot be employed for disinfecting a liquid with which it cannot be admixed.

In brief, the relative values of disinfectants primarily and absolutely depend upon their adaptability to the required purpose, and no bacterial tests afford any acceptable basis for comparison. For many qualifications the bacterial test cannot be used at all, as, for example, determining the value of disinfectants to be specifically employed for oxygenating the air of a sick-room.

In connection with this attempted standardization of disinfectants there has almost consequently followed an attempt at determining their relative values for general use as based upon cost prices, but this is even more delusive than the Rideal-Walker test itself.

Undoubtedly there are evils in the disinfectant trade, as in all other branches of commerce, which call for amendment. There are preparations, for example, which have for many years past been freely sold as non-poisonous, whilst scientific chemists are perfectly well aware that any value they may have depends mainly, if not exclusively, upon the (unguaranteed) percentage of carbolic and cresylic acids and their higher homologues that may be contained therein. Others are represented to contain active principles which are unknown to chemical science and its exponents, while yet again many are more or less worthless from whatever point of view they may be regarded.

It is of course most desirable that the published 'directions for use' should give the proportions or dilutions which should be observed to secure reliable disinfection according to the particular case and application, but to compare disinfectants as a class by any arbitrary standard is at once grossly unfair and wholly misleading.

Corrosive sublimate is one of the most powerful bactericides, but it is quite useless as an oxidizing agent ; it is also deadly poisonous and therefore absolutely inadmissible for internal application, so that it cannot in any legitimate sense be compared either with oxidizing agents that are capable of destroying the toxic products that bacteria can produce, or with milder antiseptics that act with reliability when used sufficiently strong, and yet (being non-poisonous) may be administered internally.

Articles that stain or destroy linen, carpets, and clothing cannot be properly compared for value by any standard with others that are effective disinfectants and yet are immune from these obvious disadvantages.

Chemical preparations that have strong and repugnant odours and possibly soak up oxygen from the air, cannot be compared with sweet-smelling articles that invigorate the air of sick-rooms by their active oxygen and fragrant antiseptic principles.

Chemicals that burn the hands and other living tissues cannot be reasonably compared side by side with others that may be successfully used for irrigating open wounds and the diseased surfaces of the body.

Again, suppose a room requires to be disinfected after a case of infectious illness: how is it possible to compare the relative values of a 'sulphur candle,' or a 'formic lamp' (either of which may be used), with a poisonous liquid which, being non-volatile, would necessarily have to be applied by the spray?

In fact, the whole idea is based on what is either ignorance of the principles which underlie the scientific use of disinfectants according to the needs of each particular case, or on a desire to secure advantage for one particular disinfectant to the corresponding detriment of others. At first blush it appears wonderful to find that any analysts and medical men could lend themselves to its advancement; but it must be remembered that their services are employed and paid for in the usual professional course, while several of the scientists whose names have been used in support of the attempted standardization of disinfectants are known to be financially interested in the sale of particular disinfectants.

To properly judge of the value of a disinfectant it is not enough to make so-called bactericidal tests It must be used for this and that purpose, careful note being made of the effects that are produced; it must be employed in actual cases of disease and sickness and its value judged by the results obtained over long periods of time. When that has been done and a proper judgment formed of its value, then the printed 'directions on the bottle' should indicate in what strengths it should be used for any and each particular purpose. That is what is wanted and that only, so that the public can choose which article they like from among the many that are offered in unrestricted and fair competition, now using so much powerful poison for the one application if they so choose, or so much more of another but less obnoxious or corrosive preparation if so minded, either for the same or other purposes at will.

Bacteriological tests are very showy in character, but betray too often a very superficial knowledge of the subject to which they are applied. Every student who gets to the depth of the matter and makes himself acquainted with the real relations of germs and disease will appreciate the truth of the objections which upon scientific grounds I have urged against these so-called tests.

In conclusion, it may be noted that the disinfectant which has the highest published claim for germicidal value according to the Rideal-Walker test is 'Sanitas Okol,' with a carbolic co-efficiency of from 22 to 24, varying within these limits with the particular strain of bacillus, the composition of the culture broth, and other details.

CHAPTER X.

TREATMENT OF THE SICK—NOTES ON THE CHIEF INFECTIOUS DISEASES—MEASURES OF DISINFECTION TO BE OBSERVED IN EACH.

Persons who are attacked with any infectious disease should be immediately isolated from friends and relations, and the nurse and doctor should alone visit them. The sick-room intended for occupation in such cases should be as near the top of the house as possible, and requires some preparation beforehand. It should be well ventilated and all superfluous furniture and effects removed. There should be no carpets, curtain hangings, pictures, books, or unnecessary clothing in the room, which should, indeed, be provided only with absolutely necessary articles.

It is best to keep a fire in the room, with the object of promoting ventilation and carrying any infective particles which may be floating about in the air of the room through the fire or up the chimney, as also for burning any infected material.

Outside the door of the sick-room it is well to hang a sheet, so arranged that before the door is opened it can be restored, so as to make a tolerably perfect screen for intercepting the air that may come from inside the room. This air may be contaminated with the virus of the disease and hence it requires disinfection, which may be effected by keeping the sheet moistened with a disinfectant, such as 'Sanitas fluid,' or, better still (on account of its deliquescent character), 'Sanitas sea-water.' A spray-producer may be used for moistening the sheet from time to time, and also for spraying the fluid about the sick-room. Nothing is more grateful to the patient than the free use of 'Sanitas fluid' in this way: 'It has a most pleasant, agreeable smell and refreshes and purifies the room' (Sir Henry C. Burdett), besides which it keeps the air oxygenated and disinfected.

The ventilation of the room can be well carried out by a plan first suggested by the late Mr. Hinckes Bird, which consists in raising the lower sash some few inches and placing beneath it a bar of wood, so as to entirely close the space; air can then freely enter the room (up between the overlapping sashes) without creating a draught.

Personal cleanliness of patients is of the highest importance, and (subject always to the opinion of the doctor in attendance) copious ablution is to be recommended. It is a good plan to keep all water used for such operations in an aseptic state by the addition of a little 'Sanitas fluid' or other suitable chemical reagent.

Before removing any linen or clothing from a sick-room, it should be first steeped in a disinfectant solution (say 'Sanitas Okol,' 1 : 500) and then wrung out and, after removal, instantly boiled in water, using plenty of soap and some more of the germicidal disinfectant.

Cups, glasses, spoons and other articles which have been handled by the patient, should also be immersed in the diluted disinfectant solution before removal from the sick-chamber.

The dresses and clothing worn by attendants should be as non-porous as possible, cotton stuffs being for this reason much preferable to woollen garments.

Any dry food not eaten by the patient should be burned in the fire in the room, and any liquid food, together with all slops and the excreta, should be mixed with the disinfectant before removal. 'Sanitas powder' or 'Sanitas special fluid' may be used for this purpose. Disinfection of the excreta in cases of cholera, typhoid fever and dysentery is of special importance.

The expectorations of sick persons should be received in vessels provided for the purpose and containing a strong disinfectant.

It is a good plan also to keep the air and contents of a sick-room in an antiseptic condition by the evaporation from time to time of a little 'Sanitas oil' floating on water.

Handkerchiefs should not be allowed for use by the patient, but only rags that can afterwards be burned in the room. The breath of patients should not be inhaled by attendants.

The medical officer of health for the district should immediately be made acquainted with the outbreak of any case of infectious disease.

After recovery of the patient, everything in the sick-room that is not valuable and that can be burned, should be destroyed in the fire. All linen should be steeped in disinfectant solution before removal and then well boiled with plenty of disinfectant soap.

Clothing and bedding should not be removed until after fumigation of the room, and if then there is an opportunity of getting them disinfected in a heating apparatus such as is employed by many sanitary authorities, so much the better. Before the patient leaves the sick-room, if possible, and in any case before mixing with other members of the family, a bath to which has been added two or three spoonfuls of 'Sanitas special fluid' should be taken, washing all over and using disinfectant soap.

Fumigation may be carried out by closing the windows, doors, chimney and keyholes, and using the 'Formic fumigator.'

Before conducting the fumigation, any articles of wear or bedding unavoidably left in the room should be spread out as much as possible, or hung on lines so as to freely expose them to the fumes of the disinfectant.

If preferred, sulphur may be burned in the room, and for this purpose nothing is more convenient than the sulphur candles which I have introduced for the purpose.* They take fire directly a light is applied to the cone or ribbon (constituting the wick or lighter,

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* They are made by the Sanitas Company, Limited, and sold as 'Kingzett's Patent (water-jacketed) Sulphur Fumigating Candles.'

projecting from the surface of the candles) and continue to burn steadily and thoroughly. Each candle contains 1 lb. weight of sulphur and is sufficient for the disinfection of at least 1,000 cubic feet. The cubic capacity of a room is ascertained by multiplying the length by the width and the height. In one form of these candles (the one I particularly recommend) there is a water-jacket, from which water is evaporated by means of the heat generated by the burning sulphur; as this condenses gradually on all objects in the room, it brings the sulphur dioxide gas—the disinfecting agent—into material contact with them, thus securing efficient disinfection, by reason of the fact that the gas is soluble in water.

It is best to strip the walls of all paper and to burn it afterwards, and the ceiling and walls should either be limewashed, or whitened with 'Sanitas' distemper. All furniture, woodwork, and metalwork should be polished with 'Sanitas' disinfectant furniture paste and the floor should be scrubbed with disinfectant soap, using water containing in each bucket, say, half a teacupful of 'Sanitas special fluid.' Before use, the room should be left, with opened windows, unoccupied for at least a week. In case of death, the body should be well sprayed with dilute disinfectant and burial should take place as early as possible.

During infection, if there are any children, they should be kept from school and not allowed to go again until the medical attendant gives his consent.

Small-pox belongs to the class of eruptive fevers, and is altogether a terrible disease. The incubation takes about fourteen days, after which there is headache and backache, and then spots appear on the face and wrists, which are sometimes mistaken for signs of measles. In this disease, the scales and powder which brush off the skin are highly infectious. To prevent their general diffusion, which would, if not guarded against, very likely infect other persons, it is advisable to anoint the body of the patient daily with a mixture of 'Sanitas oil' (1 part) with olive oil (7 parts), or with a mixture of 'Sanitas oil' and vaseline. After recovery, some weeks should elapse before the patient is allowed to mix with other people.

According to Weigert, the lymphatics of the skin in the region of the pocks are filled with micrococci; but similar micrococci occur also in the fluid contents of vesicles in the skin produced by non-infective inflammations and there is as yet no proof of any intimate causal relation between these germs and small-pox.

Medical opinion is to the effect that the best protection against small-pox is afforded by vaccination in infancy and it is generally considered advisable to revaccinate children at fifteen years of age in order to ensure perfect protection thereafter.

Scarlet Fever and *Scarlatina* are names for one and the same disease. This is also an eruptive fever, the first sign of which is, generally, sore throat, accompanied or quickly succeeded by shivering, headache, heat of skin and, perhaps, vomiting. On the second or third day the eruption appears on the neck, face, or chest, or on the arms near the elbows. Later on, the breath may become offensive and an offensive discharge may pass from the nose.

In this disease the skin requires anointing, as in small-pox; indeed, the greatest care should be taken to prevent dissemination of the meal-like particles or flakes that may peel off the skin. The oiling of the skin should be commenced almost from the first recognition of the disease and continued until the cure has been completed. Attention should also be paid to the disinfection of the discharges by means of 'Sanitas powder.' After some time, baths taken daily, or on every alternate day, are permitted to the patient, but of course the water should be used warm and in an antiseptic state, and after each bath the skin should be again anointed. In severe cases of fever the skin may also be sponged with 'Sanitas fluid' and tepid water (1 : 9).

The throat affection, when present, is best treated by inhalation of the mixed vapour of 'Sanitas oil' and water; or the throat may be sprayed several times a day with 'Sanitas fluid,' diluted with twice its own volume of water; or, again, a gargle of this mixture may be employed.

Six weeks should be allowed to elapse after the skin has ceased to peel before the recovered patient is allowed to go amongst other persons.

Micrococci (*Micrococcus scarlatinæ*) have been described as occurring in the blood, in ulcerations of the throat, and adhering to the scales of the desquamating epidermis in scarlet fever; but, notwithstanding certain investigations, which have led, according to some, to the identification of the organisms which cause this fever, the precise relations of them to the disease remain to be definitely ascertained.

From an investigation made by Dr. Klein and some inquiries conducted by Dr. Power, it would appear that there is some near relationship between scarlet fever and scarlatina of the cow, and that milk not infrequently conveys the infection to human beings.

Typhoid Fever (enteric or gastric fever) begins with a feeling of illness and diarrhœa, and the patient is generally more or less delirious in this disease. It is wholly preventable, inasmuch as it owes its origin to sewage contamination of air, food, or drink. It is often accompanied by ulceration of the bowels which not infrequently results in fatal hæmorrhage.

The eruption consists of a few (sometimes many) scattered rose-coloured spots, which can be felt with the finger, and they occur in successive crops. The contagion is eliminated in the discharges from the bowels and hence it is of the very highest importance to disinfect these by the addition of plenty of 'Sanitas powder,' or some other germicidal agent. Similarly, soiled linen must be very carefully disinfected, using a 1 : 500 mixture of 'Sanitas Okol' and water.

Although Klebs and Eberth have described bacilli found in inflamed Peyer's glands, mesenteric glands, spleen, larynx and lungs of patients who had died from typhoid fever, Klein has expressed the opinion that it is doubtful whether they can be considered as necessarily and ultimately connected with the disease, 'seeing they are not constant, and only occur in the mesenteric glands and spleen, *i.e.*, in localities into which an immigration of putrefactive bacilli from the bowels may easily take place.' He adds that the bowels in typhoid fever always contain innumerable masses of micrococci in colonies.*

Fraënkel and Simmonds claim to have produced a form of typhoid fever in monkeys, mice and rabbits, by inoculating them with a culture of the so-called *Bacillus typhosus.* This bacillus quickly loses its life by exposure to a temperature of 55° C. (Janowski), and light is detrimental to it.

Typhus Fever is said to be often indistinguishable from typhoid fever, and until recently it was regarded as the same disease. It is, however, rarely accompanied with diarrhœa, and the rash comes out about the fifth to the eighth day of the fever, whereas in typhoid it begins from the seventh to the fourteenth day.

The treatment of both diseases is practically identical, but in typhus great advantage is derived from the free employment in the sick-room of aerial disinfectants such as ordinary 'Sanitas fluid' and free ventilation. The use of an antiseptic mouth-wash by the patient is also to be recommended.

Cholera, in its origin, is similar to typhoid fever, in the sense that it is more or less a filth disease, and the contagion is carried with the discharges from the bowels. Intemperance in eating and drinking is supposed to facilitate infection, and in times of

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* *Practitioner,* June, 1884, p. 410.

threatened attack, unripe and over-ripe fruit, tainted vegetables and fish, etc., are to be specially avoided.

The use of adequately filtered water would greatly reduce the number of cases of typhoid fever and cholera ordinarily, as well as when these diseases are epidemic, and the Berkefeld filter is the best that can be employed, in my opinion, because it gives a plentiful supply and absolutely sterilizes the water by screening off all bacteria that may be contained in it.

I have already pointed out in an earlier chapter, that the comma-shaped bacillus (*Spirillum choleræ Asiaticæ*), supposed by Koch to cause cholera—or, at least, a growth which cannot with certainty be distinguished from it—has been found by Lewis in the mouths of healthy persons, but Klein has not given his support to Koch's views. Koch found that it was necessary to have the nourishing medium alkaline in character and that the bacilli are killed by drying. Their habitat is the intestinal canal, and they are said to be always present in the 'rice-water' stools of cholera patients.

Diarrhœa is allied to cholera, and in both diseases special attention has to be paid to the disinfection of the discharges.

Diphtheria begins with general depression and sore throat, followed by stiffness of the neck and swelling. In fact, it has been described as a contagious and epidemic sore throat. The poison which causes this disease is supposed to be often carried in or derived from sewer gas. In bad cases, the leathery false membrane which spreads over the throat, covering the larynx and extending to the palate, uvula, nostrils, cheeks and gums, produces suffocation by obstructing the air, and is accompanied with much sloughing and fœtor of the breath. Sometimes the disease is followed by sudden attacks of temporary paralysis.

In this disease, obviously, the mouth and throat and all discharges therefrom, particularly require disinfection. Local application of disinfectants, such as peroxide of hydrogen (10 volumes solution) 1 to 2 of water or 'Sanitas fluid' (1 : 2), made by means of a spray-producer and the douche, are to be advocated; or, instead, 'Sanitas oil' may be applied to the mouth and throat by means of an atomizer.* A gargle, of a strong solution of peroxide of hydrogen (2 volumes strength), is particularly recommended, as, in common with 'Sanitas fluid,' it destroys the infection and the leathery membrane which is produced by it.

The infective agent is supposed by some to be the so-called Klebs-Löffler bacillus (*Bacillus diphtheriæ*), and many interesting observations have been made by injecting the poison—a deutero-albumose, accompanied by an organic acid—obtained from diphtheritic tissues, into rabbits. Weakness of the hind-legs is thus caused, also a wasting of the body and partial or complete paralysis. The bacillus, when inhaled by human subjects, is supposed by Roux and Yersin to produce a local ferment which, when absorbed, digests the proteids of the body and forms the albumose and organic acid above spoken of. These act on the

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* See *Brit. Med. Journ.*, July 23, 1881.

nerves and cause the weakness of limbs or paralysis which are observed. The diphtheritic poison is obtained for the most part from the spleen in cases of the disease (see p. 247). In endocarditis (involving heart disease) a similar poison, producing, however, fever instead of paralysis, is found present in the spleen.

Several observers have shown that in diphtheria the membranes include micrococci; but Klein remarks, in his work already referred to, 'cultivations and inoculations with pure cultivations of this micrococcus are still wanting.'

Measles is ushered in with fits of sneezing, dryness of the skin and watering of the eyes; after some days, a mulberry-coloured rash breaks out on the forehead and gradually extends to other parts of the body. It is 'catching' before the rash appears. In this complaint patients exhibit a tendency to contract bronchitis and other lung complaints; hence it is essential to protect them from draughts and to keep the temperature of the room higher than usual. It is also best to keep the room darkened, as the glare of light is painful to the eyes.

It is only the putrid or malignant form of the disease that is eminently dangerous.

All discharges should be disinfected and such general measures of isolation and disinfection are to be taken during the treatment of the disease as have been recommended in cases of scarlet fever.

There is at present no absolute proof that this affection is caused by micro-organisms, although Drs.

Canon and Pielicke of Berlin claimed to have discovered the true *bacilli.*

Whooping-cough commences with the usual signs of fever accompanied with a cough, and often precedes or succeeds measles. The froth which children affected with this complaint spit out should be collected in some vessel and disinfected. Handkerchiefs which are used for wiping the mouth should also be disinfected before sending to the wash, but, preferably, pieces of rag should be used instead and burned afterwards. The inhalation of the vapour of 'Sanitas oil' gives great relief in the treatment of this disease.

Afanassief detected the presence of a bacillus in the phlegm of patients suffering from whooping-cough, and it is said to have produced an affection resembling that complaint by injecting a culture of the microbe into the trachea of dogs and cats.

Chicken-pox is a mild eruptive disease which is infectious in character. At first there is a slight feverishness, followed by small conical pimples having a white head, which appear on the breast, shoulders and neck. On the second day they develop into a form reminding of blisters, and on the following day the fluid which they contain becomes opaque, after which they break up and fall off piecemeal. Probably the vesicles contain the infectant so that disinfecting measures should be taken accordingly by inunction with a mixture of 'Sanitas oil' and olive oil (1 : 7).

Erysipelas appears somewhat suddenly and is generally preceded and accompanied by signs of fever; the affected skin is red, hot, tender and is often blistered. It is frequently associated with sore throat, and generally appears on the head or face, which sometimes swells enormously. It is an infective disease which requires treatment under general measures of disinfection, and particularly so when persons suffering from wounds are near at hand. Very serious consequences result from the infection of wounds, and women in confinement, with erysipelas.

It would appear from the investigations of Lukowsky, Orth and Fehleisen, that erysipelas is intimately connected with a micrococcus (*Micrococcus erysipelatosus*) which is smaller than that which is found associated with vaccinia and abounds in the lymphatics of the skin at the margin of an erysipelatous zone.

The micrococcus was successfully cultivated by Fehleisen, who is stated to have produced typical erysipelas in the human subject by inoculation with the cultivated microbe.* The vitality of the micrococcus is destroyed by antiseptics.

Phthisis (*Pulmonary Consumption*).—Nearly 100,000 persons die annually from this disease in Great Britain, and it has been calculated that, of all premature deaths, 26 per cent. result from disease of the lungs. Although the lungs are more particularly affected in this disease, the whole body becomes involved, and there is a gradual wasting away, or consumption, as it is termed. The disease may last only a few months, or it may drag its course over long weary years. Tuberculous consumption is characterized by the

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* See Woodhead's 'Bacteria and their Products,' p. 327.

formation of cheese-like matter, termed tubercles, in the lungs. They vary in size from a millet-seed to a bean, and occur both separately and massed together. Being deposited upon the surfaces, they gradually cause the destruction of the breathing structure, a process which in course of time, unless arrested, results in death.

Tubercles are often found present in the expectoration (sputum) of consumptive persons, and there is practically no doubt that the disease is infectious to the extent that it may be conveyed by breathing an atmosphere contaminated with the virus of its products (tuberculous matter). Koch has concluded that 'in all the morbid processes which, on account of their course as well as of the characteristic microscopical structure and the infectious properties of their products, must be considered true tuberculosis, there always occur in the tuberculous centres rod-like formations (tubercle bacilli), which can be demonstrated with the aid of particular methods of colouring. This holds true both with the tuberculosis of man and of different animals.' Koch, in fact, affirms these bacilli to be the specific cause of the disease, and he has performed the usual cultivations and inoculations which are deemed to furnish the necessary proof.

Klein,* however, disputes the identity of human miliary tuberculosis and tuberculosis of cattle, and finds that the bacilli found in the two affections are morphologically distinct and are differently distributed. Neither does he agree with Koch, Watson

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* *Practitioner,* August, 1884, p. 81.

Cheyne and others, who maintain that 'each tubercle owes its origin to the immigration of the bacilli; for there is no difficulty in ascertaining that in human tuberculosis, in tuberculosis of cattle and in artificially induced tuberculosis of guinea-pigs and rabbits, there are met with tubercles in various stages—young and adult—in which no trace of a bacillus is to be found; whereas in the same section cheesy tubercles may be present, containing numbers of tubercle bacilli.' What, then, seems to be absolutely proved beyond doubt is that tuberculous matter alone produces tuberculosis, but that tubercles do not owe their origin to the immigration of the bacilli. Is tuberculous matter, then, another non-living infectant comparable with the albumoses?

It is worth mentioning that Schuchardt and Krause found tubercle bacilli in fungoid and scrofulous inflammation, and other observers have found them in the tissue of lupus.

It should also be stated that Klebs, Toussaint and Schüller maintain that tuberculosis is due to a micrococcus and not to a bacillus at all. In the presence of such conflicting evidence what is to be believed?

At the same time, the experiments made by Burdon Sanderson must not be forgotten. He showed that in a number of guinea-pigs inoculated with pyæmic matter, which outlived pyæmic poisoning, the lungs, liver and spleen became tuberculous after a certain time; he therefore regarded it as 'open to inquiry whether or not injuries which are of such a character that air is completely excluded from contact with the injured part, are capable of originating a tuberculous process.'

As regards the existence of the *Bacillus tuberculosis*,* there can, it is said, be no doubt; but it is possible that it only acts in common with other irritants and that consumption ensues only in those instances where the ground, so to say, is favourable for the propagation of the micro-organisms. That is to say, the germ itself may be, and probably is, ubiquitous, but it is only propagated in large numbers and produces its characteristic products in the lungs of persons who are by numerous circumstances predisposed to the disease. In other words, phthisis may, perhaps, occur without tuberculosis, and, on the other hand, phthisical patients may become tuberculous.

Impure or imperfectly oxygenated air is considered to be particularly conducive to consumption; indeed, the causes may be stated to be all those which occasion debility, such as hereditary predisposition, want of proper nourishment, overcrowding, impure air, etc.

As regards the use of disinfectants† in connection with this disease, if we believe that consumption is essentially tuberculous and that tubercle is dependent on either a micrococcus or a bacillus, we must resort

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* Consult Dr. R. Douglas Powell's paper on 'The Causative Relations of Phthisis,' and the discussion which follows it. *Brit. Med. Journ.*, October 11, 1884. Also paper by Dr. J. H. Bennett. *Ibid.*

† Compare papers by W. Williams, M.D., M.R.C.P., and J. Carrick Murray, M.D., *Brit. Med. Journ.*, July 23, 1881, and by A. W. Mayo Robson, *Brit. Med. Journ.*, June 21, 1884. Also Lectures on 'Consumption,' by Dr. Burney Yeo (J. and A. Churchill).

for a cure to a disinfectant which will arrest the development of the micro-organism without harming the host. Such an agent is 'Sanitas oil,' which may be used to keep the atmosphere of an apartment constantly aseptic, and the vapour of which, also, may be freely inhaled, with impunity to the health of the patient. Whether or not it kills the micro-organisms in the lung-tissue, it can hardly fail to prevent their development and prevent putrefactive decomposition and fever. I should think also that the administration of a dilute solution of peroxide of hydrogen, under medical control, would be found of great value by reason of its power of oxidation.

The sputa of consumptive patients should, of course, be disinfected.

Acute Croupous Pneumonia is supposed to be caused by a micrococcus which can be conveyed in the sputum.

Relapsing Fever is, as its name implies, of a periodic character and only occasionally visits some of our large towns. It is sometimes called famine fever, which denomination it has obtained from the liability of the starving members of a population to be chiefly attacked. It attacks very suddenly, and is accompanied by shivering and chilliness, a white tongue, high temperature and quick pulse. The temperature rises also towards the crisis and often reaches 106° F. Its cessation is as sudden as its onset.

The disease is a comparatively mild one, and by no means dangerous if carefully attended. It is supposed to be caused by a spirillum, which is found in large numbers in the blood of persons during the onset of the attack, but which is absent during the intervals. This micro-organism has not been cultivated outside the living body, although Vandyke Carter produced relapsing fever in monkeys by inoculation with human blood containing the spirillum.

Influenza is a disease of much the same order, and the inhalation of the vapour of 'Sanitas oil' is to be recommended, both for its prevention and its cure. Drs. Pfeiffer, Kitasato and Canon claim to have discovered a bacillus which causes this disease.

Yellow Fever, an epidemic disease, which is attended with yellowness of the skin, hæmorrhage of the bowels and delirium, has its habitat mainly in tropical climates. Occasionally it has occurred in Spain and France. As in typhus, one attack gives immunity from a second. It is not very, if at all, catching.

Dr. Domingos Freire has given a report of experiments which are said to have established the facile transmissibility of yellow fever by inoculation, and the specific cause is said to be a cryptococcus. The same investigator claims, also, to have found a means of attenuating the virus of the disease, which consists in the cultivation of other micro-organisms known to be antagonistic to the cryptococcus.

Puerperal Fever, *Pyæmia*, *Septicæmia* and *Blood-poisoning* are states of disease directly produced by the introduction into the system of poisons, of which the substance named sepsin (Burdon Sanderson) is illustrative. These poisons are elaborated by the micro-organisms which are found in putrid mixtures.

In puerperal fever, micrococci have been found in the form of zooglœa in all affected organs.

In septicæmia, Klein has found in the bloodvessels of the swollen mesenteric glands, large numbers of minute bacilli, while in gangrenous septicæmia around wounds, Arloing and Chauveau also found short bacilli.

In open wounds and closed ulcers, micrococci and bacilli are found in abundance.

The use of disinfectants, such as 'Sanitas fluid' and oil, for the purification of air and wounds largely contributes to the prevention of such complaints and their consequences.

Woolsorters' Disease and Malignant Pustule are said to be caused by the bacillus which also causes splenic fever or anthrax in cattle.

The spores of anthrax are of an extremely resistant character,* but the fully developed germs are readily killed by a number of chemical reagents. It is probable that these micro-organisms are very widely distributed in Nature and that they only produce disease when they propagate under special conditions. Assuming, that is to say, that they produce disease, indirectly, by virtue of certain chemical poisons which they elaborate or secrete, such poisons are only produced under special conditions. It is almost certain

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* 'According to a Berlin bacteriologist, the spores of anthrax are not destroyed after twenty minutes' immersion in a 1 per 1,000 solution of corrosive sublimate; after thirty-eight days' immersion in a 7 per cent. solution of carbolic acid the spores were still capable of growing.'—*Medical Press and Circular*, August 20, 1890.

that if admixed with antiseptic or disinfectant preparations under conditions which would otherwise lead to disease, they are innocuous.

That they indirectly lead to disease seems to be well proven.

As reported in an earlier chapter (see p. 237), Klein states that by passing *B. anthracis* through different species of animals they become endowed with different properties. Thus, the blood bacillus obtained from sheep or cattle dead from anthrax, invariably kills other sheep or cattle inoculated with it; but after cultivation in living white mice it loses this virulence, and a transitory illness is all that it can then produce in sheep or cattle. The explanation of this astonishing fact is altogether wanting: at first blush it would appear to indicate morphological change of the germs themselves, but this is a conclusion that cannot be entertained and if the fact points to anything at all, it is to the conclusion that germs do not constitute *contagium vivum*, but only produce contagious poisons.

It would be of the highest importance to make experiments with *B. anthracis,* similar to those conducted in connection with septicæmia by Burdon Sanderson; for example, to cultivate pure growths in different media and make comparative tests of the effects produced in animals by inoculation; also to sterilize such mixtures in a way that would not chemically alter their composition, with the view of ascertaining if the effects are still producible — that is, whether they are due not to the bacilli, but to their products; again, to mix disinfectants with the mixtures containing the cultivated bacilli and then ascertain the effects of inoculation with the disinfected mixtures. It is by the application of such tests that precise information concerning the disinfecting qualities of different substances is to be obtained. It is insufficient to test disinfectants by ascertaining their effects on the bacilli themselves. That is a matter which, after all, probably concerns micro-organisms more than ourselves.

Malarial Fever.—This disease is attributed by Klebs and Tommasi-Crudeli to a bacillus which occurs in the soil, and they produced by inoculation of rabbits a febrile disturbance which they considered to correspond with malarial fever in man; but this has been disputed by Sternberg upon the basis of experiments with material taken from the soil of malarious districts in America. On the other hand, Laveran and others claim that certain micro-organisms named *Plasmodium malariæ*, which are allied to the *Flagellata*, occur in the blood of patients suffering from malaria, and they are said to produce intermittent fever in man by intravenous injection.* Professor Tommasi-Crudeli does not concur in the view that the *Plasmodia* are the cause of malaria. Some further reference to this disease will be made in a later chapter (see pp. 357-359).

Glanders is attributed to the *B. mallei*, which was studied by Schütz and Löffler in 1882 and is found

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* See lecture on 'The Parasite of Malaria,' by Dr. Patrick Manson, in *Lancet*, January 6, 1894.

in the organs of horses and sheep dead or dying from this disease.

Swine Plague has formed the subject of special investigation by Klein, who attributes it to a bacterium identical in morphological respects with *B. subtilis.* The respects in which they differ have yet to be ascertained. *B. subtilis* is very widely distributed, but is considered innocuous.

Cattle Plague (Rinderpest).—Micrococci are supposed (upon the usual basis of cultivation and inoculation experiments) to cause this disease, but their specific nature is not considered well established.

Gonorrhœa is stated to be caused by the *Micrococcus gonorrhœa*, but according to evidence furnished by Welander* proof of the pathogenic nature of the gonococcus is still wanting.

Syphilis has been attributed to a *Bacillus* which has been studied by Lustgarten, while Eve and Lingard have also observed and isolated a *Bacillus* from the blood.

Some forms of *Sore-throat* are also attributed to micro-organisms.

The poisons, whatever they be, that are associated with local ulcerations, such as gonorrhœa, syphilis, diphtheritic sore-throat, gangrenous wounds and so on, are undoubtedly destroyed by chemical oxidants to the extent that they can be placed in contact with them. In this clearly defined direction, therefore, the usefulness of disinfectants (among them 'Sanitas fluid') in connection with these complaints is obvious, and they

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* See *Brit. Med. Journ.*, October 18, 1884.

should be employed exactly upon the same principles that antiseptic surgery is practised. Peroxide of hydrogen, which is one of the constituents of 'Sanitas fluid,' is capable of destroying by oxidation all these poisons that are of the nature of ptomaines or albumoses, while both it and the other constituents prevent their further formation and destroy the microbes which give rise to them.

It is the duty of the local Sanitary Authority, after receiving a certificate from a qualified medical practitioner indicating the necessity for disinfecting or cleansing any house or part thereof, to serve a notice on the occupier or owner, requiring him to disinfect and cleanse. In case of failure to comply with such order, the Sanitary Authority may carry out the disinfection and recover the cost, but for the poorer classes no charge is made. The Sanitary Authority may also disinfect or destroy any infected clothing, bedding, etc., compensating the owners for the loss. The letting of houses or apartments which have not been properly disinfected after infectious cases is also attended with statutory penalties, whilst any person suffering from an infectious disease (or anyone in charge of a person so suffering) who wilfully exposes himself in public is liable to a penalty.

CHAPTER XI.

ALIMENTATION AND FOODS.

LIFE is sustained, of course, by means of food, which is required not merely to make good the losses that are continually taking place, but also to supply the animal heat of the body.

It is computed that on an average a man requires the daily assimilation of rather more than 1 lb. 2 oz. of chemically dry solid matter to maintain his body-weight, and as nearly 1½ lbs. of oxygen, by weight, are partly absorbed through the lungs, the total quantity of solid and gaseous matter thus assimilated amounts to nearly 2¾ lbs. daily. The waste takes place partly through the alimentary canal (equal to about 800 grains of dry solid matter per day) and the rest is lost through the agency of the lungs, the skin and the urine. These various excretory products amount, of necessity, to about 17,000 grains per day, being, of course, approximately equal in amount to the dry solid food which is taken and the oxygen which is absorbed through the lungs. It will be understood that they constitute the waste products resulting from the metamorphosis of the animal tissues.

Some foods being nearly identical in chemical nature with some of the substances entering into composition of the tissues, presumably require but little change before they admit of assimilation, while others are not assimilated at all, but only undergo and induce changes in the human body, serving incidentally other functions equally important in character.

While it is possible to sustain life upon a restricted number of kinds of foods, it is far preferable to use a mixed diet, comprising nitrogenous, saccharine, amyloid, fatty and saline compounds, so that all the various substances necessary for repairing the tissues of the body may be available in the food.*

Roughly speaking, we may divide food into two classes—viz., Inorganic, and Organic. In the first class we have water and certain salts, such as sodium chloride, phosphates of calcium and iron; whilst in the second class we have three different types of food: nitrogenous food (which consists chiefly of albuminates), fats and oils, and carbohydrates (under which head come starch and sugar).

The principal function of the water is to dissolve the food and so enable it to be conveyed to the different parts of the body; it also materially assists in the removal of the waste or excretory products from the living body and (by evaporation from the skin) causes the temperature of the body to be

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* For full details concerning the chemical composition of the different parts of the human body, and the chemistry of nutrition, etc., see Kingzett's 'Animal Chemistry' (published by Longman and Co.).

lowered when from any cause, such as violent exercise, it is abnormally raised.

The mineral salts are essential for the growth and repair of all the tissues of the body; thus phosphates are necessary for the formation of bone, and iron salts for the red blood-corpuscles and colouring matters present in the muscles, whilst chlorine in combination plays a very important part in the process of digestion.

Nitrogenous Foods.—The presence of nitrogen is an absolutely essential condition for all organic life, and no manifestation of energy can take place in any tissue from which it is absent. Up till quite recently it was thought that muscular force was entirely dependent on the changes which take place in the muscular tissue and that it could therefore be measured by the amount of urea which is excreted (urea being the chief product of such change).

Drs. Fick and Wislicenus have, however, shown by their experiments in connection with the ascent of the Faulhorn, that a non-nitrogenous food will sustain the body during severe exercise for a short time and without any notable increase in the formation of urea; whilst, on the other hand, the excretion of carbonic acid and water is found to increase proportionately to the amount of exercise. In any case the energy of the body is due to the oxidation following upon digestion of the food-stuffs, and the amount of this oxidation can be determined, as Pettenkofer and Voit have shown, by the nitrogenous substances composing the tissue.

Fats and Oils.—These bodies are compounds of glycerol with the fatty acids. They are not acted on either by the saliva or the gastric juice and therefore do not undergo any change until they reach the small intestine, where they are emulsified by the bile and pancreatic juice and so rendered capable of absorption by the lacteal vessels. The chief function of this class of foods is to renew the fatty tissue which by oxidation supplies the body with heat and energy; they also assist in the digestion of other foods and in the removal of the excreta.

Carbohydrates.—These bodies are compounds of carbon, hydrogen and oxygen, the hydrogen and oxygen being present in the same proportions as in water, hence the name carbohydrate. In the process of digestion, starch, cane-sugar, dextrin, and milk-sugar are partially converted into grape-sugar by the saliva; they then pass through the stomach without undergoing any further change and on reaching the small intestine, the conversion into grape-sugar is completed by the pancreatic juice; the grape-sugar thus formed is then taken up by the blood and carried along the portal vein to the liver, where it is stored up as glycogen, or liver-starch, ready for subsequent use, either for the formation of fatty tissue or else for increasing the heat and energy of the body. Although, as we have shown, the functions of the fats and carbohydrates are very similar, it does not appear that they can entirely replace one another without interfering with the health of the body.

The vegetable acids, such as acetic acid, tartaric acid, oxalic acid, etc., form another small but very important item in the human diet. They are mostly present in the food in the form of alkaline salts, which are converted in the body into carbonates, thus preserving the alkalinity of the blood, tissues, and secretions. When these organic acids have been absent for some time from the food, the blood becomes impoverished and the disease known as scurvy results. Formerly sailors used to suffer a great deal from this complaint, owing to the difficulty experienced in obtaining fresh meat and vegetables, which are the chief sources of these acids. Of late years, however, scurvy has become much less common, owing to the large replacement of sailing vessels by steamers, thus reducing the time between ports, and to the use of beverages such as lime-juice, which contain organic acids.

In order to preserve health for any considerable period of time, it has been found absolutely necessary to have a diet containing all these different groups of food-stuffs, although fats and carbohydrates appear to be to a certain extent interchangeable. With respect to the quantity and nature of the food which should be consumed in the course of the day, in order to keep up the strength of the body, without at the same time overtaxing the digestive and excretory organs, no very definite rule can be laid down, as it varies so much, not only with the age and sex of the individual, the amount of work that is done, but also to a certain extent with the climate. We may, however, take Moleschott's figures for medium work, in the annexed table, as representing the proper average diet for an adult man; whilst for an adult woman the average diet should be from three-fourths to four-fifths of this amount.

	Medium Work.				Severe Work.	
	Moleschott.		Pettenkofer and Voit.		Moleschott.	
	Grms.	Oz.	Grms.	Oz.	Grms.	Oz.
Proteids - -	130	4·59	137	4·83	140	4·94
Fat - - -	84	2·96	117	4·12	90	3·17
Carbohydrates -	404	14·26	352	12·40	434	15·31
Salts - - -	30	1·06	30	1·06	32	1·13

As already mentioned, the amount of food required to preserve health varies very much with age, and to a smaller extent with each individual. During childhood, from birth to puberty, the body is developing, and therefore food has to be supplied for the growth of the tissues as well as for maintaining the heat and energy of the body, so that a working lad really requires more food than a working full-grown man; on the other hand, in old age the supply of food should be diminished.

The following table ('Physiologie des Kindsaters,' Tübingen, 1877) shows the minimum daily supply of food necessary at different ages:

Condition.	Weight in Grammes.		
	Proteids.	Fats.	Carbohydrates.
Child up to 1½ years (average)	20-36	30-45	60-90
From 6 to 15 years (average)	70-80	37-50	250-400
Man (moderate work)	118	56	500
Woman (moderate work)	92	44	400
Old man	100	68	350
Old woman	80	50	260

A mere chemical analysis of a food—that is to say, the determination of the amount of nitrogen, carbon and salts which it contains—is, however, not sufficient to determine its nutritive value; we must also know to what extent it is capable of being assimilated by the digestive juices. Comparing animal and vegetable foods with respect to their digestibility, it appears that the animal proteids and fats are generally more digestible than those obtained from vegetables. There is also an appreciable difference in the digestibility of different kinds of flesh; thus, fish has been found to be less digestible than meat, while beef is more digestible than either pork or veal. The following details may be taken as giving a rough average of the time the different kinds of food remain in the stomach. The flesh of animals remains from 2½ to 4, or even 5 hours in the stomach; starchy foods, such as boiled rice and sago, from 1½ to 2 hours; white bread about 3 hours, and brown bread still longer.

Cooking is also a matter of great importance to be considered in connection with this subject. All vegetables are rendered much more digestible by cooking; but with meat this is not so; indeed, raw meat is, if anything, more digestible than when cooked, particularly if the meat is at all overdone. On the other hand, cooking makes the food more palatable and enables us to take our nourishment hot, which in the case of a weak digestion is a great advantage, as no energy is then wasted in heating it up to the temperature of the body. Another great advantage of cooking is, that it destroys all the numerous parasites which are often present in meat and vegetables, though it appears that it does not kill all the bacteria and other micro-organisms which are present.

Sleeping diminishes digestion; it is therefore undesirable to take a heavy meal shortly before going to bed, and, for a similar reason, it is best to sit quiet immediately after a meal, and not to take violent exercise too soon. It is also a bad thing to take food too often and at irregular intervals. There is no doubt that, at the present day, the habit of taking a great deal more food than is necessary is very frequently to be met with, particularly among men of the upper classes. The primary effect of gluttony is to cause indigestion, with diminished absorption, but also more food may be absorbed than is required by the body for carrying on its functions, in which case the body gains weight, chiefly in the form of fat.

The effect of eating too much meat is to overtax the liver, kidneys and other excretory organs, with the result that gout and diseases of the liver and kidneys may set in, while an excess of fats and carbohydrates tends to produce dyspepsia and obesity. On the complete withdrawal of food, general weakness, more especially of the heart and respiratory organs, sets in, combined with a gradual wasting of the body, followed by death.

Of more interest and importance, however, is the effect of an insufficient supply of food; for in our prisons and workhouses, where care is very properly taken not to give more than the necessary amount of food, it may sometimes happen that the food-supply is insufficient. Dr. G. Wilson reported, for example, that when he was medical officer at the Portsmouth convict prison, he proved from observation that the full labour diet

$$C = 5{,}289 \text{ grains}$$
$$N = 255 \text{ grains}$$

was inadequate to sustain prisoners employed at hard navvy work for any length of time, and their average loss of weight was so great, that they had constantly to be shifted to lighter labour in order to enable them to recover. Generally speaking, an insufficient supply of food-stuffs leads to a weakening of the body, which is thus less able to withstand the effects of cold and attacks of disease; more especially is this so if work has to be done at the same time.

Meat consists chiefly of proteids and fats, but it also contains a small amount of salts; carbohydrates are absent or only occur in small quantities in meat. Although the meat of animals suffering from disease may in some cases be none the worse as food, or at any rate only slightly deteriorated, yet, on the other hand, it is usually unwholesome and often dangerously so. The same remark applies in a less degree to meat in which decomposition has begun; for when putrefaction first commences the meat is quite wholesome, and many people eat game and venison with impunity when putrefaction is pretty far advanced.

Milk is the natural food for the young of all mammalia, and it contains all the different groups of food-stuffs mentioned in the standard diet; the proportions of these food-stuffs varies, however, very much with different animals, and we may therefore presume that the milk of one animal is not altogether suitable for nourishing the young of another species: certain it is that a baby thrives very much better on its mother's milk than when fed artificially with cow's milk. The chief source of difference between human milk and that of the cow is that the latter contains a much larger proportion of casein, and when in the process of digestion the milk is curdled by the gastric juice, the curd of human milk is found to form loose flocculent masses, whilst the cow's milk forms a much more compact curd, which is much harder to digest. If, therefore, cow's milk be used for nourishing babies, it should be diluted with water, or preferably barley-water, which has the effect of making the curd looser and consequently more digestible, and a little sugar or, better, milk-sugar should be added. The average per cent. composition of cow's milk is, according to Wynter Blyth:

Fats	3·50
Casein	3·98
Albumin	0·77
Milk-sugar	4·00
Water	86·87

From which it will be seen that milk is a very valuable article of food, though it contains too large a percentage of albuminates to be used as a diet entirely by itself. For persons who are unable to digest milk it is best to curdle it first by adding a little rennet or acetic acid.

Milk after it has stood for some time becomes sour, owing to the conversion of the sugar into lactic acid by the agency of a small bacillus (*bacterium lactis*), and in this state it is decidedly unwholesome, particularly for infants. On standing still longer the milk becomes turbid, the lactic acid is converted into butyric acid, and putrefaction sets in.

Milk may be preserved in various ways: one method is to boil it for a short time and then seal it up directly, before it has time to cool; another method consists in evaporating it to dryness under reduced pressure. The most usual and best means of preserving it, however, is to concentrate it down to about one-third of its bulk, after the addition of sugar and then seal it up in tins. This is the ordinary 'Swiss Condensed Milk,' which is very largely used by children of the poor as a substitute for fresh milk. For very young children it is usual to dilute it with four or five times the amount of water; but the mixture thus obtained has too large a proportion of nitrogenous food-stuff, whilst it also contains too much sugar and too little fat. In some forms of condensed milk the addition of sugar is omitted, but in this case the milk will not keep good for long when once the tin has been opened; whereas the ordinary sugared 'Swiss Condensed Milk' will keep for some weeks.

One great source of danger in milk is the disease germs which it may contain, due either to dilutions with impure water, or else introduced by contact with someone (either the milkman or the dairyman) who may have been exposed to or be suffering from some disease. Many epidemics, particularly of typhoid and scarlet fever, have of late years been traced to an infected milk as their supposed source.

Milk also has a very powerful absorbing capacity for gases, and if allowed to stand in an unwholesome atmosphere, it may absorb foul and poisonous gases, and so become dangerous. Milk obtained from diseased cows is also a source of danger, though to what extent is not at all certain. There is, however, very strong evidence to show that cows suffer from a disease very similar to scarlet fever, and that the milk from an animal having this disease may cause an outbreak of this epidemic among those who drink it. Cows, particularly if stall-fed, are also subject to tuberculosis (the infectious nature of which disease seems now to be pretty well established), and it is quite possible that the comparatively large mortality among children from this complaint may be due, in part, to the milk, of which they consume much more than those more advanced in life. Outbreaks of illness have also been traced to milk from cattle suffering from foot-and-mouth disease, whilst in cows suffering from anthrax and cattle-plague the supply of milk stops at an early stage.

Butter is usually made by violently agitating cream, or sometimes milk, when the fat globules coalesce to form a thick mass, which after some further treatment makes its appearance as butter. The chief constituents of butter are the fats or glycerides of the fatty acids, fresh butter containing about 83 per cent. of these fats, and about 14 per cent. of water.

Margarine is made chiefly from refined fat of beef, which is reduced to a fine state of division and then churned up with milk in order to give it the flavour of real butter. The chief difference between butter and margarine is that the former contains about 6 per cent. of the volatile fatty acids, principally butyric acid, whilst margarine contains less than 1 per cent.

Cheese, another product obtained from milk, is also a very valuable food, as it contains a large amount of proteids and fats in a small bulk; it is, however, not nearly so digestible as butter and many people are unable to take it for this reason.

Bread.—The art of bread-making is prehistoric and no doubt dates back to a very early period in the civilization of man. We know it to have been practised in the Stone Age, for not only have the stones for grinding the grain been discovered in the lake dwellings of Switzerland, but also some of the bread, which has been preserved by charring. The cakes, which were somewhat round, were made of partially crushed corn, portions of the grains being in some cases plainly discernible (Keller's 'Lake Dwellings'). The making of bread is also mentioned very early in history, as, for example, in the Book of Genesis, where it is referred to on two or three occasions. Bread was originally made by simply mixing the flour into a paste with water and then baking it, and it is still made in this way in some parts of the world. Later there came the addition of leaven, that is to say, a portion of the dough kept from a previous baking in which the process of fermentation is far advanced; later still, we find yeast taking the place of leaven.

The effect of adding yeast or leaven to the dough is to cause a process of fermentation in the gluten of the flour, which partially converts the starch, first into sugar, and then into alcohol and carbonic acid gas; the result is that the dough swells out, being filled with small bubbles of gas, and the bread when baked is lighter, much more digestible, and also more palatable.

Bread is rich both in proteids and carbohydrates, but poor in fats; it is therefore usual to eat it with butter, bacon, cheese, or other bodies rich in fat, when it forms one of the most wholesome and nutritious foods that we possess. Bread is sometimes made by forcing carbonic anhydride into the dough under pressure, and also by the addition of baking powders, which cause the liberation of that gas. This unfermented bread is supposed to be better for not containing any alcohol, acetic acid, or other fermentation products; the advantage is, however, doubtful, as the yeast itself begins the process of digestion by converting the starch into sugar. Bread is now nearly always made from wheat flour, though other grains, such as rye and oats, are used to a certain extent in some localities.

The chief adulterations of bread are other kinds of starch (such as rice-flour and potatoes) alum and borax. The addition of different kinds of flour can mostly be detected by examination of the starch grains under the microscope. Alum is added to bread to whiten inferior flour and also to arrest fermentation; although its harmful effects are rather doubtful, it is, an adulteration and should therefore not be permitted.

Coffee is obtained from the seeds of *Caffea arabica*, a plant which grows in the tropics. It contains about 10 to 12 per cent. of nitrogenous substances, about 12 per cent. of fat, about 8 per cent. of sugar and dextrin and about 1 per cent. of 'Caffeine,' to which it is supposed to owe its stimulating action.

In order to prepare this beverage, the berries are first roasted and then ground, after which hot water is poured on to the coffee, allowed to stand for a short time and then strained off. Coffee acts as a powerful stimulant on the nerves and also increases the action of the heart and the respiratory organs; it is a most valuable stimulant in cases of fatigue or hard work, and, unlike alcohol, it produces no subsequent collapse. The most common adulterations of coffee are starch and chicory.

Tea consists of the dried leaves of the plant *Camellia* *thea*, which is grown in China, India and Ceylon, and the beverage is made by pouring boiling water on to the leaves and then allowing it to stand for a few minutes. Tea appears to considerably increase the action of the lungs; it also intends to induce perspiration, thereby cooling the body. Its most important property, however, is its stimulative action on the nervous system, which makes it a most valuable restorative in case of fatigue. Taken in excess, it produces nervous depression and insomnia, and many people are unable to sleep if they take tea in the evening; it also injures the digestion, owing to the astringent properties of the tannin.

The active principle of tea is allied to that of coffee, and is known as 'Theine.'

Cocoa and Chocolate both contain a large quantity of fatty food; they also contain a body, theobromine, which, like Theine and Caffeine, acts as a nerve stimulant.

Alcohol.—Under this head we have to consider the effects, beneficial or otherwise, produced by beer, wine and spirits. When taken into the stomach, alcohol seems to be absorbed without any alteration, and can be detected in nearly all the organs of the body shortly after; it also very soon begins to pass out of the body by the lungs, skin and urine. How much of the alcohol thus passes out unaltered is a much-debated point, but it is generally admitted now that a good deal undergoes metamorphosis in the body, though as to what are the products of this transformation we are, at present, in the dark. It does not seem probable that alcohol is decomposed into carbon dioxide and water in the body, as the amount of carbon dioxide given out by the lungs diminishes after a dose of alcohol. A more probable theory is that it is converted into acetic acid, though the evidence on this point is very conflicting.

In small doses alcohol appears to aid digestion—possibly by assisting the emulsification of fatty substances and increasing the secretion of saliva and gastric juice—but in large doses it undoubtedly checks it; it also appears to slightly lower the temperature of the body, though a fairly strong dose of alcohol given to a man accustomed to take wine and spirits does not seem to have any appreciable effect on his temperature. It appears that if a healthy man takes more than from one to one and a half fluid ounces of alcohol in twenty-four hours, it makes its appearance in the urine and may therefore be considered injurious. For women the injurious dose is probably less, whilst healthy children should not take alcohol in any shape.

Alcohol acts on the nervous system chiefly as a stimulant and tends to make people more genial and unreserved, which is, no doubt, the chief cause of its popularity. It also produces a sensation of comfort and warmth, for which reason it is very usual to take spirits when exposed to cold and wet, 'just to keep out the cold,' as the saying is, though in cases of prolonged exposure, alcohol should be avoided, as it appears to diminish the power of resistance to intense cold, as also to disease.

Alcohol increases the action of the heart, and at the same time allows the bloodvessels to dilate more easily, but for which there would be great danger of their rupturing. It must be regarded as having some value as a food, and wine and beer contain other substances in addition to alcohol which are food-stuffs. Thus, in wine we have a small amount of albuminates and a considerable amount of sugar and vegetable salts, whilst beer contains a valuable tonic in addition.

Wine and beer should, therefore, be drunk in preference to spirits, not only on this account, but also because there is a danger with spirits of not sufficiently diluting them with water. Even wine and beer, however, should only be taken in moderation, as otherwise they lead to gout and other diseases.

Port wine	contains	from about	17 to 20	per cent.	alcohol.
Sherry	,,	,,	15 to 17	,,	,,
Claret	,,	,,	6 to 9	,,	,,
Hock	,,	,,	5 to 6	,,	,,
Beer	,,	,,	5 to 6	,,	,,
Proof spirit	,,	,,	57	,,	,,

According to Dr. A. Luff,* alcoholic drinks which have been obtained by fermentation, but not subsequently distilled, such as wines and beer, appear to exercise a more harmful influence in the production of gout than the same quantities of alcohol consumed in the form of distilled spirit, such as whisky and brandy.

In elderly and feeble people a moderate amount of pure whisky undoubtedly does good.

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* See his article entitled 'Diet in Gout,' in the *Practitioner* for May, 1904.

PART II.

CHAPTER XII.

MALARIAL FEVER AND ITS CAUSES—THE EUCALYPTUS GLOBULUS AND ITS SANITARY PROPERTIES—HYGIENIC UTILITY OF CAMPHOR, PERFUMES, ETC.

In preceding chapters attention has been directed to the putrefactive changes to which animal and vegetable matters are subject and it has been shown that these changes are intimately associated with the production of infectious diseases.

It has, indeed, been demonstrated that many infectious diseases have their origin in putrefactive processes, while certain miasmatic diseases are both endemic and epidemic in places where organic matters are constantly undergoing change, as in marshy and damp districts. It will now be our object to illustrate this last-named statement somewhat more fully.

In his 'Letters on Chemistry' (p. 230) Liebig says: 'In no case may we so securely reckon on the occurrence of epidemic diseases as when a marshy surface has been dried up by continued heat, or when extensive inundations are followed by intense heat';

and in the appendix to the same treatise there are recorded the following historical observations, which lend great weight to this view.

In constructing the railway from Strasburg to Basle, it was found necessary to excavate certain fields to a depth of two or three feet, thus causing a number of hollows in the neighbourhoods of Bollweiler and Feldkirch. In spring and autumn these hollows filled with water and this partially drying up in the summer, created perfect morasses abounding in the infusorial life characteristic of stagnant water. Thus there was introduced intermittent fever into these neighbourhoods and year after year the epidemic became worse and worse.

In 1843, of the 1,446 inhabitants of Bollweiler, 36 were attacked with intermittent fever; 166 cases occurred in 1844; 743 in 1845 and 1,166 in 1846. The mortality increased in a corresponding proportion.

Again, in the same year (1843), of the 480 inhabitants of Feldkirch, 2 were attacked with the same disease; 20 were attacked in 1844; 135 in 1855; 376 in 1846, and the annual mortality rose from 11 to 18.

These particulars were augmented and confirmed by similar facts embodied by Drs. Weber, Sanger, and West, in a report to the Prefect of the Upper Rhine.

Under these circumstances, Dr. Dollfus-Ausset appealed to the Paris Academy of Sciences to use its influence and knowledge in instructing the administration concerning the best means of checking the disease, which had already decimated two villages, and was then threatening others.*

It does not, however, call for any such special cases to prove the source of malarial fevers. It is an observation which has grown with the world in age, that wherever there is matter of animal or vegetable origin in course of putrefactive or allied change, danger to human health is also lurking in the water and floating in the surrounding air. The mere presence of organic matter in the soil does not necessarily indicate danger to the neighbourhood, because, supposing the soil to be of a porous nature and in free contact with the air, the organic matter is very rapidly oxidized into innocent compounds—innocent compounds, that is to say, so far as infectious disease is concerned.

In writing of the effects of the surface of the soil on air, Dr. Angus Smith used these words :†

'If soil affects the atmosphere, how does it happen that it is such an excellent disinfectant? Substances are not purified in the air to the same extent in the same time as in the soil. The great amount of surface presented by the porous soil is mainly the cause of the rapid action, but the acid humates, and probably other substances, act chemically. There are modes of oxidizing in the air beyond the power of ordinary oxygen; one of these is by means of nitrogen oxides, and another by ozone; but even these require great time and space. If we throw sulphuretted hydrogen

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* *Comptes Rendus*, Séance of March 5, 1847, p. 779.

† 'Air and Rain,' p. 507.

water or its compound with ammonia on a few inches of soil, it passes through, oxidized in a few minutes; we obtain such an action in the air only in great volumes, although in the end the work done may be better for its purpose.'

Nevertheless, as shown when treating of sewage disposal by irrigation, it is possible to overload even porous soils which oxidize the most rapidly. That is to say, it is possible, in a given case, to have more organic matter than, under existing circumstances, admits of oxidation in a certain time; putrefaction is the first result, and this may lead on to intermittent fever and other diseases.

Again, Dr. Angus Smith truly says,* that 'there seems to be a confusion in many minds between peat-bogs and marshes, but the difference is very great. No peat-bog gives out marsh fevers and agues, although the cold and wet may induce rheumatism. The acid peat prevents decomposition and so removes all the results of putrefaction, which some people suppose to be the origin of the evil in marshes.'

The miasms of marshes, then, are matters which accompany, or result from, the processes of decomposition comprehended in the term 'putrefaction.'

Klebs and Tommasi-Crudeli (see *Practitioner* for August, 1879) claimed to have established malarial fever to be due to the action of *bacillus malariæ* (see p. 333), as they name a micro-organism which they detected in the soil and air of malarial districts.

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* 'Air and Rain,' p. 520.

They found that the malarial poison exists in quantity in the soil of malarious districts, even at times when man is not affected with the disease, and that the poison may be detected at such times in the stratum of air immediately above the soil. What is remarkable among the results of Klebs and Tommasi-Crudeli is, that they found large quantities of water render the germs inactive. Their method of experiment consisted in subcutaneously injecting liquids obtained from the soil into animals and noting the rise of temperature experienced, which was from the normal one to 41·8° C. Similar observations were made with the so-called artificially cultivated germs. The doubt attached to the interpretation of such experiments lies in this—that the subcutaneous injection of many liquid and solid matters produces corresponding results. Even these investigators found that the fluid freed from the bacillus produced an intermittent increase of body temperature!

The bacillus is developed in the presence of free oxygen, and thus belongs to the *Aerobies* of Pasteur.

According to Marchiafava, *bacillus malariæ* also occurs in the blood of patients suffering from malaria, but Sternberg has stated that the febrile disorder produced by inoculating rabbits with material derived from the soil of malarious districts in America has nothing in common with the human intermittent fever, and can be induced, indeed, by other bacilli.*

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* Klein on 'Micro-organisms and Disease,' *Practitioner*, June, 1884, p. 415.

Apart, however, from the doubt that exists as to the precise relation between malarial fever and the *bacillus* observed by Klebs and Tommasi-Crudeli, there can be no question that the real virus is a chemical poison originated by micro-organisms during a putrefactive or allied change in organic matter contained in soil. In this respect they may be supposed to comport themselves just as do the micro-organisms in putrefying flesh; that is to say, under suitable conditions, they elaborate products of chemical decomposition, which by their reception or formation in the human system initiate disease. In decomposing flesh, sepsin is produced and it is the active virus in septicæmia; similarly, in decomposing vegetable matter present in soil, a corresponding substance is produced, which may be termed malarin, and it constitutes the active virus of malarial fever. The micro-organism studied by Klebs and Tommasi-Crudeli may possibly be the originating cause, but that is not finally proved.

Laveran and others claim that the disease is produced by certain micro-organisms allied to the *Flagellata* termed *Plasmodium malariæ*,* but this is contested by Tommasi-Crudeli (see p. 333).

Having said so much by way of preface, we may at once proceed to the more immediate purpose in view, viz., that of describing the sanitary properties of the *Eucalyptus globulus*.

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* See paper by Dr. P. Manson in *Lancet*, January 6, 1894, p. 6.

The *Eucalyptus globulus* was discovered[*] by Labillardière, in the Island of Tasmania, in 1792; but its fever-destroying characters first attracted the attention of M. Ramel in 1856. In that year he sent some of the seeds to Paris, and in later years forwarded further supplies, claiming for it, at the same time, the power of destroying the miasmatic influence of marshy districts. Considerable credit is also due to Baron Sir Ferd. von Mueller (the Government botanist in Victoria), who originally brought the *Eucalyptus globulus* to the notice of M. Ramel, and a meed of praise is also merited by Sir W. Macarthen, of Camden, Sydney, Australia, who also exported some seeds in 1860 and claimed anti-miasmatic properties on behalf of the tree.

Since this now well-known tree was first brought before the notice of the public, its fame has been a rapidly increasing one, the evidence in its favour forming an almost unbroken chain down to the present time.

In a memoir by Prof. Gubler[†] there is adduced particular testimony to the fact that this so-called 'fever tree,' or 'fever-destroying tree,' exercises marked effects in relation to intermittent fever. It is pointed out that, in marshy districts near eucalyptus forests, the fever is practically unknown, and this

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[*] See Professor Bentley's (1874) lecture on the *Eucalyptus globulus*, and his more recent one printed in the *Pharm. Journ.* for March 4, 1878.

[†] *Journ. de Pharm. et de Chimie*, December, 1871 (*Pharm. Journ.*, New Series, vol. ii., p. 703).

state of things is attributed to the aromatic vapours which emanate from the tree and the preservative powers of the branches and leaves which fall upon the marshy soils. It was upon the basis of this knowledge that the Algerian and Corsican plantations, of which more will be said hereafter, were made.

In 1871 M. Raveret-Wattel published a report* to La Société d'Acclimatation, in which he said: 'Science is far from having said her last word respecting the part that may be played by these useful plants' — meaning the eucalypti, and these words have since been verified in a singular manner. M. Raveret-Wattel specially dwelt upon the importance which M. Ramel attached to the sanitary power of the eucalyptus and pointed out that it was very much doubted when first claimed. He thinks, however —and justly so—that the plantations which were effected in the most unhealthy parts of Algeria have quite established the correctness of M. Ramel's views. The endemic fever in these districts is stated to have been perfectly annihilated by the plantations in question, and the use of an infusion of the leaves of the tree became so popular as a remedy against fever (even in many cases where quinine is said to have been administered in vain), that M. Alurmada had his trees completely stripped of their bark by the populace. M. Raveret-Wattel remarked that the oil of eucalyptus would no doubt become very useful as a remedy in putrid fevers and for application in cases of fœtid suppuration, etc.

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* *Pharm. Journ.*, New Series, vol. ii., pp. 22 and 43.

In a paper contributed to the Californian Academy of Sciences* in July, 1872, by Mr. R. E. C. Stearns, he quotes from a letter written by Dr. A. B. Stout, in which occur these words :

'There can be little doubt but that the oil of eucalyptus, when it can be procured, will be an available remedy against malarious diseases of all types, and that the presence of the trees cultivated in gardens contributes to sanify the atmosphere from those emanations which give rise to epidemic diseases.'

As already stated, the anti-miasmatic power of the grown-up eucalyptus was particularly tested in Algeria, and the results were communicated by M. Gimbert to the French Academy of Sciences.†

This report instanced the case of a farm situated twenty miles from Algiers and notoriously known to possess a pestilential atmosphere, in which 13,000 trees were planted, with the effect of absolutely stamping out the previously endemic fever.

A Dutch landed proprietor also planted a number of eucalyptus-trees on the banks of the Scheldt, where he owned some property in a very malarious district. The effect was that the particular spot was rendered quite salubrious, while the surrounding neighbourhood remained as fever-stricken as originally.

A further and an interesting contribution to the history of the eucalyptus in Algeria was made a few years since,‡ to the pages of the *Pall Mall*. The

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* *Western Lancet*, vol. i., p. 696 ; *Pharm. Journ.*, vol. iii., p. 603.

† See *Pharm. Journ.*, vol. iv., p. 494.

‡ *Ibid.*, vol. iv., p. 731 (taken from the *Pall Mall*).

writer pointed out that it was only so recently as 1867 that the Algerian plantations became at all extensive in character, and then he goes on to describe what he himself had witnessed but a few days prior to writing. He had visited the estates of M. Ramel, M. Trottier, and M. Cordier, whose trees had all been grown from seeds. On M. Trottier's estates at Hussein Dey, the trees were fifty feet high.

'In this evergreen wood, all around us, were tall reddish smooth stems, with the bark hanging down in a ragged, untidy manner—for the tree sheds its bark in winter—and grey, willow-like leaves were waving on flexible boughs. . . . It produced a curious impression to walk in the dim twilight of this Australian-African forest, and to think that this was also a wood of the miocene period. Beautiful is not the word I should apply to its appearance; but in exchange for bare sun-baked earth or deadly swamps, I must say these eucalyptus forests are most grateful, and the smell delightfully resinous, warm, and gummy. . . . There seemed to be a general impression that the eucalyptus was a fever-destroying tree, and of the greatest importance to the colony from that point of view.'

I have not been able to obtain any reliable figures as to the distribution of *eucalypti* in various parts, although they are very widely distributed, plantations having been established all over the world. Thus, in South California, the *Eucalyptus globulus* is now planted by thousands, and it has been estimated that the gain made from growing the timber is even a greater one than that derived from cereals.

Mr. Bosisto, the well-known distiller of eucalyptus oils, has given some idea of the extent of area covered by *eucalypti* in Australia,* and its freedom from fever. In a paper communicated to the Pharmaceutical Conference some years since, he wrote: 'Of the whole indigenous vegetation of the Australian Continent, which is 2,500 miles west to east and 2,000 miles north to south, and in area amounts to some 3,000,000 square miles, the *eucalypti*, numbering 150 kinds or species, forms four-fifths.' The country, on the whole, may be said to be pretty free from violent endemic or miasmatic poisons; indeed, he adds, 'they might be said to exist only as the eucalyptus receded.'

In his report to the Commissioners of the Exhibition, Mr. Skene, writing of Victoria, states that the area of the whole colony amounts to 55,644,000 acres. Of this 5,560,000 acres are covered with dense mallee scrub; 6,225,000 acres consist of mountainous ranges, deeply wooded with gums, while the area of the open timbered country amounts to 38,922,000 acres. Upon the basis of these figures Mr. Bosisto has calculated that the extent of mallee country in New South Wales and South Australia is twenty times that of the area in Victoria.

From these and other considerations, which will

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* *Pharm. Journ.*, vol. v., p. 270, from a paper read by Mr. Bosisto before the Royal Society of Melbourne. See also *Pharm. Journ.*, vol. xvii., p. 13.

be dealt with presently, Mr. Bosisto concludes that the eucalyptus is established beyond all doubt as a fever-destroying tree.

Italy has also furnished some evidence upon this question. In a paper read before the Roman Academy of Medicine, on April 30th, 1876, Dr. Fedeli* alleged that wherever plantations of the eucalyptus existed, malaria was unknown, and where the malaria had been endemic, the cultivation of this tree sufficed to mitigate in all cases, and in some instances to entirely remove, the disease. A long discussion followed the reading of Dr. Fedeli's paper as to the specific manner in which the eucalyptus exercises its powers; but while different views were taken of this question, the testimony borne to its febrifugal virtues was perfectly unanimous.

It is of interest to note that since the reading of Dr. Fedeli's paper, the Italian Government has supplied landholders with large quantities of slips of the tree for forming plantations in all malarious districts.

According to a report made some years ago, 500,000 eucalyptus-trees were to be planted in Mexico, as some kind of protection against yellow fever and with the view of modifying the rainfall, but I am unaware whether this proposal has been carried out.

Some years since, at a Réunion at the Sorbonne, Dr. de Pietra Santra, a delegate from the Climatological Society of Algiers, recited some of the results

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* *Pharm. Journ.*, vol. vi., p. 912.

of the investigations made in Algeria with the view of determining the value of the eucalyptus in its relation to public health. The reports received from fifty localities, boasting the possession of more than 1,000,000 trees, showed, in the first place, that the eucalyptus exhibits a sanitary effect of the most unquestionable nature; secondly, that wherever the tree is cultivated, the intermittent fever decreases both in intensity and frequency, and lastly, that large tracts of marshy and uncultivated lands have been rendered healthful, and indeed quite transformed, by the agency of the eucalyptus. Dr. de Pietra Santra also stated that in Corsica, where more than 600,000 plants were growing, similar results have been observed.

Between Nice and Monaco there existed, until recently, such a very unhealthy district, that the Paris, Lyons and Mediterranean Railway Company were compelled to change their watchmen, who did service at a crossing in the neighbourhood, every few months. Some time since, however, a plantation of the *Eucalyptus globulus* was made there, and now there is said to be no more fever, and the necessity, therefore, for perpetual change of watchmen (to prevent death) is abolished.*

There is yet one other instance† of the wonderful hygienic properties of the eucalyptus which may be mentioned here, although briefly. In a desolate part of the Campagna there stands an old monastic institu-

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* *Chem. News*, December 22, 1876, from *Le Monde*.

† *Pharm. Journ.*, vol. vi., p. 624.

tion upon a spot consecrated by tradition as that whereon St. Paul was martyred. For centuries this part of the Campagna was a stronghold of pestilential fever, whilst prolonged residence in the monastic institution in question surely led to death. Some years ago, however, a band of Trappist monks planted the eucalyptus in its cloisters, and the trees have since grown to a great height, with the result that the place is now once more habitable, and fever, it is said, reigns there no more.

That this effect is largely due to the eucalyptus plantation there can be but little doubt. The place in question was the execution-ground and burial-place for criminals of old Rome, and it is said that 700 cartloads of human bones have been removed. The ground around has been deeply cultivated, thus assisting to make the spot habitable. As to the bones that have been removed, it cannot be supposed that at this remote time from the days of old Rome, any organic substance forming part of the once-buried bodies could remain in the soil and have successfully resisted oxidation by the atmosphere. Bones themselves are for the most part inorganic and so far harmless, and it would be more reasonable to look for malarial fever at Kensal Green than to search for it in an old Roman burial-ground, so far as it may be connected with the burials that have taken place at either locality.

No doubt the fever which once infested the Trappist Monastery at Tre Fontane, near Rome, has been overcome by general sanitary measures, but foremost amongst these was the cultivation of the eucalyptus plantation.

Some years since, Dr. Laughlan Aitken, of Rome, called in question[*] the value of the plantations at Tre Fontane, although he admitted that they had been kept in a flourishing condition by the zeal and activity of the Trappist monks, who increased the revenue of the monastery by the sale of 'eucalyptus elixir' which they prepared. Any improvement, he stated, which may be claimed, was due quite as much to the necessary subsoil draining and preparation of the ground as to any influence of the young gum-trees. That may be so, but I think that Dr. Aitken might, without damaging his scientific reputation, have given credit to the value of the eucalyptus-tree, seeing how far it has been substantiated by good chemical and other practical evidence.

Professor Tommasi-Crudeli, of Rome, has also expressed the opinion that plantations of the eucalyptus are of no value[†] in preventing the occurrence of malaria. He cited several instances from his experience in the Campagna, where these trees had been used and where they had for a long time given perfect satisfaction, until suddenly, in 1882, a severe attack of malaria occurred, while other districts where malaria used to manifest itself were free from attack. Such an experience really proves very little, because malarial fever is an infectious disease, the poison

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[*] Letter to *Brit. Med. Journ.*, September 27, 1884.

[†] See his address to the International Medical Congress, 1884, *Brit. Med. Journ.*, August 30, 1884.

of which may be conveyed in the air and in water, and in order to obtain general protection against attack, it would be necessary not only to have plantations of the eucalyptus covering the whole area under observation, but also to shut off contamination from exterior sources. The eucalyptus certainly gives some protection, even if absolute immunity cannot be claimed for it.

This protection is largely due to the essential oil (which is given off in a vaporous condition from the trees) and to the products of its atmospheric oxidation in presence of moisture; no doubt it is also due in part to the action of the trees in absorbing water from the soil. The shoots of the roots throw out thousands of thread-like fibres, forming a dense sort of woolly mat which sucks up a great quantity of water: that which is not utilized in the rapid growth of the trees is ultimately evaporated with the essential oil from the leaves.

All quarters of the globe have furnished evidence* of the sanitary value of the eucalyptus, and no one who is open to conviction can fairly withstand the conclusion that has been arrived at, after the study and experiments of the last half-century, which is to the effect that the *genus* is both fever-preventing and fever-destroying. Any doubt, however, on this matter will probably be removed by the chemical evidence which I shall furnish hereafter.

In addition to the direct evidence as to the hygienic

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* See also Consul Playfair's 'Report on the Febrile Virtues of Eucalyptus,' 1877.

importance of the eucalyptus already adduced, there is a large amount of indirect evidence leading to the same conclusion, and it is important enough to be briefly described in this place.

In his various papers, Dr. Gimbert, of Cannes, directed attention to the fact that the oil of eucalyptus is not merely of a pleasant balsamic nature, but that it speedily removes all unpleasant odours. He used the leaves largely, instead of lint, for dressing wounds, with very satisfactory results and showed that when eucalyptus oil is mixed with albumin or fresh fibrin, putrefactive change is entirely prevented.

M. Gubler has also given testimony to the value of tinctures, infusions and decoctions of the oil in surgery; while M. Mare used fresh young leaves to stimulate small wounds which were slow to cicatrize, and employed an aqueous infusion with great success in purulent catarrhal affections of the urethra and vagina. In consequence of these and similar observations, a large quantity of the alcoholic tincture of the leaves was for some years exported from Australia for use in European countries.

Mr. Stearns, who compared the disinfecting properties of oil of eucalyptus with those of carbolic acid, remarks: 'Its chief value is as a sedative and antiseptic in asthma and throat diseases, nasal catarrhs and affections of the mucous membranes.' In his own investigations he used both the alcoholic tincture and the spray of the pure oil.

Dr. Gimbert observed that the oil of eucalyptus and its various preparations diminish the vascular tension and, from inducement of a sense of comfort, tend to bring about sleep.

The success which attended the use of the same preparations in mitigating and curing ague, etc., led to the idea that the leaves of the eucalyptus contained some alkaloidal principle identical with, or similar to, quinine. This idea, however, was refuted by the experiments of Mr. Broughton, the Government chemist of Ootacamund, and later on by M. Rabuteau.* Mr. Broughton examined the leaves and bark, and states that neither quinine nor the other alkaloids of cinchona bark exist in the plant in any proportion. M. Rabuteau established the absence of all other alkaloids.

It is on record that in the Mauritius an infusion of the leaves of the eucalyptus was used on one occasion, with such great success in the treatment of malarial fever, that the leaves were sold at sixpence each!

Another useful application of the eucalyptus was discovered in its effects in the treatment of rheumatic complaints: 'Branches and leaves are put into hot water and I am assured by those who have tried it that such baths remove rheumatic pains, neuralgia and the debility left by the malaria incidental to the country.'†

Again, at a meeting of the Paris Société de Pharmacie, on November 4, 1874, M. Vidal communicated a note on the vermifugal characters of essence

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* *Comptes Rendus*, lxxv., 1431.

† Quoted from the contribution to the *Pall Mall* previously referred to (p. 362).

of eucalyptus when employed in the form of an enema, and gave details of the case of a Zouave who was afflicted with the presence of a number of *Oxyuris vermicularis*, which all ordinary vermifuges had failed to remove. He was completely cured in nine days, by using each evening an enema containing from fifty to sixty drops of the oil to a quart.*

A watery infusion of eucalyptus leaves is known in France to be useful in medicine and pharmacy and it is now to be found in the French Pharmacopœia.

The mere preservative properties of oil of eucalyptus are well known, and since the date of my own earlier researches they have been also investigated by Mr. T. Taylor.† He found that, although the oil of eucalyptus is but sparingly soluble in water, yet such a solution has powerful antiseptic and deodorizing powers, and is capable of considerably retarding certain fermentative changes and the putrefaction of albuminoids. He stated that: 'The fleshy sides of the skins of animals may be preserved from putrefaction by rubbing on them eucalyptus oil. It may also be combined with plaster and injected into the veins and arteries of animals for the purposes of preservation.'

The anti-miasmatic power of eucalyptus and pine forests has long been supposed to have some connection with the volatile oils which are naturally secreted by them and which find their way, by evaporation, into the atmosphere. But in explanation of these

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* *Pharm. Journ.*, vol. v., p. 474.

† *Ibid.*, January 12, 1878, being an extract from the Report of the United States Commissioner of Agriculture.

results, it has been generally held that the volatile oils have the power, in some way, of giving rise to ozone—a substance which, judging from its chemical properties, may be supposed to oxidize, or burn up the malarial matter infesting the soil and atmosphere of marshy districts.

Mr. Taylor perceived that the oxidant need not necessarily be ozone ; he was, however, quite satisfied that the oils of eucalyptus and turpentine, etc., do exhibit oxidizing effects, and he cited experiments in support of this view.

In connection with the salutary properties of pine, eucalyptus and camphor forests, and before we give the correct explanation, it will be of interest to take notice of a few facts which have become matters of general experience ; facts which, known from very early times, have come down to posterity without any adequate explanation.

For instance, it has been known for ages that the atmosphere of pine forests is most favourable to invalids suffering from pulmonary affections and even at the present time it is customary to send invalids to breathe the exhalations of the coniferæ. Such exhalations are generally, although quite erroneously, supposed to be strongly ozonic in character.

Dr. Cornelius Fox, in his interesting work on 'Ozone,' dwells upon this subject, and alludes to the fact recorded by Herodian, that, 'in a plague which devastated Italy in the second century, strangers crowding into Rome were directed by the physicians to retreat to Laurentum, now San Lorenzo, that by a cooler atmosphere, and by the *odour of laurel*, they might escape the danger of infection.'*

Referring to the hygienic utility of essences and perfumes, Dr. Fox says they 'demonstrate that the disciples of Empedocles were not in error when they planted aromatic and balsamic herbs as preventives of pestilence.' The investigations to which Dr. Fox makes reference were directed to the supposed production of ozone by the atmospheric oxidation of essential oils, and he goes on to say that, 'The ancient custom amongst physicians of furnishing the handles of their canes with vinaigrettes, the fumes of which might protect them from the noxious exhalations of their patients, and the old practice of strewing aromatic herbs, such as rue, before filthy prisoners in the dock of a criminal court, so that the olfactory nerves of the lawyers might be offended as little as possible; as well as that of providing the chaplain with a bouquet when accompanying a criminal to Tyburn, lose their absurdity under the light of these investigations. The efficacy of certain perfumes in warding off disease during exposure to fœtid air, which was thoroughly believed in by our ancestors, may be, perhaps, explained by the researches above referred to.'†

Patchouli oil is produced in enormous quantities, and is sent direct to Mecca, the Arabs believing in its health-giving properties and the protection it affords against infection.

Again, we have the case of camphor, which from

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* 'Ozone,' p. 121. By Dr. Cornelius Fox.

† *Ibid.*, p. 122.

time immemorial has enjoyed a reputation as an antiseptic, and which is to this day worn by thousands of persons about their clothes as a protective against infectious diseases, such as influenza.

Lastly, the efficacy of wooden hospitals in inducing the rapid convalescence of patients has been attributed to the resinous and turpentine-like substances existing in the wood, and which, by their evaporation into the atmosphere, pass, by way of the mouth, into the patients' bodies.

Reviewing, now, the facts recited in the foregoing pages, we are presented with a mass of indisputable evidence, showing: firstly, that the eucalyptus-tree prevents malarial fever; secondly, that the oil of eucalyptus also exhibits peculiar vermifugal, antiseptic and disinfecting properties; thirdly, that pine forests exercise important hygienic influences; fourthly, that turpentine, camphor and other volatile products generated naturally in pine and other forests, possess certain properties which render them valuable as sanitary appliances.

Disregarding all doubtful evidence, there yet remains the most abundant evidence of the hygienic value of eucalyptus, pine and camphor forests, and a large amount of positive data regarding the antiseptic, disinfecting and healthful properties of certain products natural to these forests. Still more striking is the fact that there is an intimate relation between the hygienic value of pine, eucalyptus and camphor trees; for not only are all these trees healthful, but their products exhibit similar properties and are, as I shall presently show, chemically allied. How far this resemblance holds good on further investigation and the extent to which the hygienic properties of these trees is connected with the volatile oils furnished by them, will be fully explained in the ensuing chapters.

Some time after the first edition of this work was published, eucalyptus oil was adopted by Lister for use in antiseptic dressings, in place of carbolic acid. He found that its antiseptic properties are quite as reliable as those of phenol, while it is free from irritating and toxic effects. Its volatility, while being advantageous in other respects, tells against its use to some extent, for gauze prepared from the oil is apt to lose its strength by keeping.

The testimony of Lister to the value of eucalyptus oil as an antiseptic for use in surgery, was supported by the results of Professor Schulz and Dr. Siegen,* of Deutz, and by its subsequent more or less general use.

'Sanitas oil,' which is obtained by the atmospheric oxidation of turpentine or eucalyptus oil, is, however, far superior to the raw oil of eucalyptus: it is now largely used as an antiseptic dressing and still more extensively for the treatment of lung and throat affections by inhalation.

The value of eucalyptus oil formed the subject of a publication by Professor Hugo Schulz, of Griefswald, in 1881,† in which is brought together a great

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* *Lancet*, September 4, 1880.

† The reader may also consult with advantage the articles forming a review of that book by Baron Sir Fred. von Mueller, contributed to the *Australian Medical Gazette* for October, November and December, 1883.

deal of recorded information respecting the chemical, physiological and medicinal properties of this substance ; but my earlier researches on the aerial oxidation of essential oils (including eucalyptus) and the study of the antiseptic and disinfectant properties of the products, were conducted and published long before that date, but through oversight or the neglect to acquaint himself with my investigations, Schulz gave himself a great deal of unnecessary labour, and after all, elaborated an erroneous chemical theory regarding the oxidation and action of eucalyptus oil.

CHAPTER XIII.

ESSENTIAL OILS AND THEIR ATMOSPHERIC OXIDATION IN NATURE, THE LABORATORY AND THE FACTORY —THE CHEMISTRY OF THE PROCESS.

IF we seek to establish the precise way in which the eucalyptus, the pine and the camphor tree exhibit a hygienic influence, we are forced by exclusion of other reasons to consider it mainly in relation to the essential oils naturally formed in these trees and to the emanation of which, in a vaporous condition, they owe their grateful fragrance. We may pass lightly over the drainage power of the trees, because, although this is a valuable feature of them, it is one which does not immediately concern us; moreover, it is common to all trees, although particularly exhibited in those which, like the *Eucalyptus globulus*, grow so rapidly. Any sanitary effect due to mere drainage of water from the soil is of a purely negative character, whereas the hygienic influence of these trees is of a positive character. They are healthful in themselves and the emanations which they diffuse into the atmosphere are specifically efficacious both as regards protection from the malarial poison and its destruction, as also for the cure of lung diseases. What, then, is the nature of this influence? is the question that must now be solved.

It was for a long time erroneously supposed that the oils to which plants and flowers owe their perfume, when exposed to the action of atmospheric oxygen, influence it in such a way that ozone is produced: hence it is stated in most of the older treatises on chemistry, as a fact, that ozone is produced. It was beyond dispute that an active agent resembling ozone in its properties is formed in this way; but the actual nature of this agent was (until established by my researches) entirely an open question.

There was a great difficulty in strictly diagnosing ozone from peroxide of hydrogen, and as the last-named substance was practically unknown outside the laboratory, whereas ozone was known to occur naturally in the atmosphere, the assumption which came to be accepted as an established fact, was somewhat excusable.

Schönbein, who was a great chemical authority a generation ago, thought that oil of turpentine gives rise to ozone by contact with air; by-and-by others taught this as a fact, and thus it passed into the text-books. For instance, it is so stated in Gmelin's 'Handbook, and in the earlier editions of Miller's 'Elements of Chemistry.' Lawes, Gilbert and Pugh expressed their belief that the supposed ozone existing in the vicinity of vegetation is due to the oxidation of the hydrocarbons evolved by plants,* and in a paper communicated to the Royal Irish Academy on January 9, 1871, Professor C. R. Tichbourne stated that when light resin oils are exposed to the action of the atmosphere under the influence of light, they produce an abundance of ozone, the boiling-point of the oil being raised simultaneously. This last fact may be at once explained: the oil absorbs atmospheric oxygen, giving rise to the formation of oxidized compounds, which boil at a higher temperature than the original hydrocarbons, and peroxide of hydrogen (not ozone) is a characteristic product of the oxidation.

It is not surprising that the difficulties which Schönbein and Berthelot (who also examined the oxidation of oil of turpentine) could not overcome, should also have misled others in more recent times.

Thus Professor Paolo Mantegazza† arrived at the conclusion that a large quantity of ozone is discharged by odoriferous flowers, including those of the narcissus, heliotrope, hyacinth and mignonette. Similarly, he concluded that among plants, the cherry-laurel, clove, lavender, mint, lemon and fennel produce ozone, as well as certain perfumes, including eau-de-Cologne, oil of bergamot, extract of millefleurs, essence of lavender, and the oils of nutmegs, aniseed, thyme, peppermint, etc.

In the well-known treatise on 'Inorganic Chemistry,' by Eliot and Storer,‡ there occur the following words:

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* *Journ. Chem. Soc.* (2), 1, 1863, p. 100.

† *Rendiconte del Reale Instituto Lombardo*, vol. iii., fasc. vi.

‡ Second Edition, 1868, p. 145. Van Voorst, London.

'The disinfecting power of ozone is interesting in connection with the observed facts, that ozone is abundant in the air of pine forests where turpentine abounds, and that pine forests are, as a general rule, remarkably free from malaria.'

At the time when that treatise was written chemists knew no better regarding the nature of the active principles engendered by the oxidation of turpentine. In 1878, however, and indeed, long before, there existed better knowledge of the subject, and so it is somewhat surprising that the old error should find its way into the generally excellent 'Treatise on Chemistry' by Roscoe and Schorlemmer.* They wrote: 'Turpentine and several other essential oils, when acted upon by atmospheric oxygen, transform a portion of it into ozone'—whereas they do nothing of the kind.

So also Dr. Moffatt† has published a number of papers in which it is stated that he found the oils of juniper and turpentine, etc., to produce ozone by contact with the air.

H. Fudakowski‡ and E. Schaer,§ and numerous other chemists have made the same mistake.

When I commenced my examination on this subject, about the summer of 1871, I was not acquainted with any of the publications of the late Dr. Day of Geelong; but late in 1875 and after I had arrived at

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* Published in 1878. Second Edition, p. 200.

† See *Sanitary Record*, October 26, 1877.

‡ *Deut. Chem. Ges. Ber.*, vi. 106-109.

§ *Ibid.*, vi. 406-410.

and published my main results, they were brought to my notice. Dr. Day made a large number of interesting observations upon various essential oils and certain fatty matters in connection with which he had noticed the formation of an active agent resembling peroxide of hydrogen in its properties; but the tests which he employed to detect it are equally influenced by ozone. Moreover, as he seems, in such of his papers as were published before any of mine, to speak of the substance not only as peroxide of hydrogen, but also as antozone, as if it were a distinct substance, his investigations did not materially advance our knowledge of the subject in question. It will be seen that my object was not only to establish the exact nature of the active principles, but the actual method of their formation, and in this I was happily successful.

It may, however, be at once admitted that Dr. Day, with great intelligence, applied his knowledge to the explanation of the hygienic influence exerted by the eucalyptus and also by wooden hospitals. While this is readily granted, it must be understood that, after all, his experiments did not satisfactorily settle the vexed question as to whether ozone or peroxide of hydrogen is produced by the oxidation of the essential oils.

Moreover, in common with all others whose names have been mentioned in connection with the study of the hygienic properties of the pine and eucalyptus, Dr. Day totally ignored the formation of those organic compounds which I discovered to accompany and to be intimately connected with the production of peroxide of hydrogen as products of oxidation and to which the antiseptic powers of these trees are principally due.

With these preliminary observations it will now be of interest to describe my experiments in as simple a manner as the nature of the subject admits. Those scientific readers who wish to acquire a more precise knowledge of the work can do so by consulting the publications* referred to below.

The plants which furnish essential oils in nature are very large in number, and comprise not only the members of the coniferous and aurantiaceous orders, but also the order *myrtaceæ.* It is to the essential oils emitted by these plants at ordinary temperatures, or to products of their atmospheric oxidation, that their intense odour is due.

In the *umbelliferæ* the oil is most abundant in the seeds; in the *aurantiaceæ* both fruits and flowers yield volatile oils; the *rosaceæ* contain oil only in the petals, while the *myrtaceæ* and the *labiatæ* supply it mainly from the leaves.

As is well known, many so-called essential or

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* 'On the Oxidation of the Essential Oils.' By C. T. Kingzett.
Part i. *Journ. Chem. Soc.*, Ser. 2, vol. xii., p. 511.
„ ii. *Ibid.*, vol. xiii., p. 210.
„ iii. *Chemical News*, vol. xxxii., p. 138.
„ iv. *Ibid.*, vol. xxxiv., p. 127.
„ v. *Ibid.*, vol. xxxix., p. 279.
„ vi. *Journ. Chem. Soc. Trans.*, 1894.

See also *Pharm. Journ.*, December 2, 1876; *Journ. Soc. Arts*, February 16, 1877, and March 8, 1878; *Brewers' Guardian*, September 18, 1877; *Sanitary Record*, December 13, 1878, and January 15, 1880; *Journ. Soc. Chem. Industry*, February 29, 1888; *Chemical Trade Journal*, February 17, 1894.

volatile oils, such as otto of roses, lemon, orange, bergamot, etc., are prepared on a large scale for commercial purposes.

In the following list the figures which are given represent the quantity in parts by weight of essential oil, which, in the experience of Messrs. Schimmel,[*] is yielded by one hundred parts of the raw material mentioned. The botanical names used by Messrs. Schimmel have been retained, although in some cases they differ from those now applied to the respective plants in this country.

Ajowan seed—*Ptychotis Ajowan*—3 per cent.
Almonds, bitter—*Amygdalus amara*—4 to 7 per cent.
Angelica seeds—*Archangelica officinalis*—1·15 per cent.
Angelica root, Thuringian, ditto, 0·75 per cent.
Angelica root, Saxon, ditto, 1 per cent.
Anise seed, Russian—*Pimpinella anisum*—2·8 per cent.
Anise seed, Thuringian, ditto, 2·4 per cent.
Anise seed, Moravian, ditto, 2·6 per cent.
Anise seed, Chili, ditto, 2·4 per cent.
Anise seed, Spanish, ditto, 3 per cent.
Anise seed, Levantine, ditto, 1·3 per cent.
Arnica flowers—*Arnica montana*—0·04 per cent.
Arnica root, ditto, 1·1 per cent.
Asafœtida—*Ferula asafœtida*—3·25 per cent.
Asarum root—*Asarum Europæum*—1·1 per cent.
Basilicum herb, fresh—*Ocymum Basilicum*—0·04 per cent.
Bayberry leaves—*Pimenta acris*—2·3 to 2·6 per cent.
Bearberry—*Arctostaphylos Uva Ursi*—0·01 per cent.
Betel leaves—*Piper Betle*—0·55 per cent.
Birch tar—*Betula alba*—20 per cent.
Buchu leaves—*Barosma crenulata*—2·6 per cent.
Calamus root—*Acorus Calamus*—2·8 per cent.

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[*] Abstracted from a Report (? 1888) of Messrs. Schimmel and Co., of Leipzig.

Canella—*Canella alba*—1 per cent.
Caraway seed, cult. German—*Carum Carvi*—4 per cent.
Caraway seed, cult. Dutch, ditto, 5·5 per cent.
Caraway seed, cult. East Prussian, ditto, 5 per cent.
Caraway seed, cult. Moravian, ditto, 5 per cent.
Caraway seed, wild German, ditto, 6 to 7 per cent.
Caraway seed, wild Norwegian, ditto, 6 to 6·5 per cent.
Caraway seed, wild Russian, ditto, 3 per cent.
Cardamoms, Ceylon—*Elettaria cardamomum*—4 to 6 per cent.
Cardamoms, Madras, ditto, 5 per cent.
Cardamoms, Malabar, ditto, 4·25 per cent.
Cardamoms, Siam, ditto, 4·3 per cent.
Carrot seed—*Daucus carota*—1·65 per cent.
Cascarilla bark—*Croton Eleuteria*—1·75 per cent.
Cassia flowers—*Cinnamomum Cassia*—1·35 per cent.
Cassia lignea, ditto, 1·5 per cent.
Cedar wood—*Juniperum Virginianum*—3·5 per cent.
Celery herb—*Apium graveolens*—0·2 per cent.
Celery seed, ditto, 3 per cent.
Celtic nard root—*Valeriana celtica*—1 per cent.
Chamomiles, German—*Matricaria Chammomilla*—0·285 per cent.
Chamomiles, Roman—*Anthemis nobilis*—0·7 to 1 per cent.
Chekan leaves—*Myrtus Chekan*—1 per cent.
Cinnamon, Ceylon—*Cinnamon zeylanicum*—0·9 to 1·25 per cent.
Cloves, Amboyna—*Caryophyllus aromaticus*—19 per cent.
Cloves, Bourbon, ditto, 18 per cent.
Cloves, Zanzibar, ditto, 17·5 per cent.
Clove root—*Geum urbanum*—0·04 per cent.
Clove stalks, ditto, 6 per cent.
Copaiba balsam, Para—*Copaifera officinalis*—45 per cent.
Copaiba balsam, E.I.—*Dipterocarpus turbinatus*—65 per cent.
Coriander seed, Thuringian—*Coriandrum sativum*—0·8 per cent.
Coriander seed, Russian, ditto, 0·9 per cent.
Coriander seed, Dutch, ditto, 0·6 per cent.
Coriander seed, East Indian, ditto, 0·15 per cent.
Coriander seed, Italian, ditto, 0·7 per cent.
Coriander seed, Mogador, ditto, 0·6 per cent.
Cubebs—*Piper Cubeba*—12 to 16 per cent.
Culilawan bark—*Laurus Culilawan*—3·4 per cent.
Cumin seed, Mogador—*Cuminum Cyminum*—3 per cent.

Cumin seed, Maltese, *Cuminum Cyminum*, 3·9 per cent.
Cumin seed, Syrian, ditto, 4·2 per cent.
Cumin seed, East Indian, ditto, 2·25 per cent.
Curcuma root—*Curcuma longa*—5·2 per cent.
Dill seed, German—*Anethum graveolens*—3·8 per cent.
Dill seed, Russian, ditto, 4 per cent.
Dill seed, East Indian—*Anethum Sowa*—2 per cent.
Elder flowers—*Sambucus nigra*—0·025 per cent.
Elecampane root—*Inula Helenium*—0·6 per cent.
Elemi resin—*Icica Abilo*—17 per cent.
Eucalyptus leaves, dried—*Eucalyptus globulus*—3 per cent.
Fennel seed, Saxon—*Anethum Fœniculum*—5 to 5·6 per cent.
Fennel seed, Galician, ditto, 6 per cent.
Fennel seed, East Indian—*Fœniculum Panmorium*—2·2 per cent.
Galanga root—*Alpinia Galanga*—0·75 per cent.
Galbanum resin—*Galbanum officinale*—6·5 per cent.
Ginger, African—*Zingiber officinalis*—2·6 per cent.
Ginger, Bengal, ditto, 2 per cent.
Ginger, Japanese, ditto, 1·8 per cent.
Ginger, Cochin China, ditto, 1·9 per cent.
Heracleum seeds—*Heracleum Sphondylium*—1 per cent.
Hop flowers—*Humulus lupulus*—0·7 per cent.
Hyssop herb—*Hyssopa officinalis*—0·4 per cent.
Iris root—*Iris Florentina*—0·2 per cent.
Iva herb—*Iva moschata*—0·4 per cent.
Juniper berries, German—*Juniper communis*—0·5 to 0·7 per cent.
Juniper berries, Hungarian, ditto, 1 to 1·1 per cent.
Juniper berries, Italian, ditto, 1·1 to 1·2 per cent.
Laurel berries—*Laurus nobilis*—1 per cent.
Laurel berries, California—*Oreodaphne Californica*—7·6 per cent.
Laurel leaves, ditto, 2·4 per cent.
Lavender flowers, German— *Lavandula vera*—2·9 per cent.
Ledum—*Ledum palustre*—0·35 per cent.
Lignaloe wood—*Elaphrium graveolens*—5 per cent.
Lovage root—*Levisticum officinale*—0·6 per cent.
Lupulin—*Humulus lupulus*—2·25 per cent.
Mace—*Myristica moschata*—11 to 16 per cent.
Marjoram herb, fresh—*Origan. Majorana*—0·35 per cent.
Marjoram herb, dried, ditto, 0·9 per cent.
Masterwort—*Imperatoria Ostruthium*—0·8 per cent.

Matico leaves—*Piper angustifolium*—2·4 per cent.
Matricaria herb—*Matricaria Parthenium*—0·03 per cent.
Melissa herb—*Melissa officinalis*—0·1 per cent.
Michelia bark—*Michelia Nilagirica*—0·3 per cent.
Milfoil herb—*Achillea Millefolium*—0·8 per cent.
Musk seed—*Hibiscus Abelmoschus*—0·2 per cent.
Mustard seed, Dutch—*Sinapis nigra*—0·85 per cent.
Mustard seed, East Indian, ditto, 0·59 per cent.
Mustard seed, German, ditto, 0·75 per cent.
Mustard seed, Russian—*Sinapis juncea*—0·5 per cent.
Myrrh—*Balsamodendron myrrha*—2·5 to 6·5 per cent.
Nigella seeds—*Nigella sativa*—0·3 per cent.
Nutmegs—*Myristica moschata*—8 to 10 per cent.
Olibanum resin—*Olibanus thurifera*—6·3 per cent.
Opoponax resin—*Pastinaca Opoponax*—6·5 per cent.
Parsley herb—*Apium Petroselinum*—0·43 per cent.
Parsley seed, ditto, 3 per cent.
Parsnip seed—*Pastinaca sativa*—2·4 per cent.
Patchouli herb—*Pogostemon Patchouli*—1·5 to 4 per cent.
Peach kernels—*Amygdalus Persica*—0·8 to 1 per cent.
Pepper, black—*Piper nigrum*—2·2 per cent.
Peppermint, fresh—*Mentha piperita*—0·3 per cent.
Peppermint, dried, ditto, 1 to 1·25 per cent.
Peru balsam—*Myroxylon Perieræ*—0·4 per cent.
Pestwort—*Tussilago Petasites*—0·056 per cent.
Pimento—*Myrtus Pimenta*—3·5 per cent.
Pimpinella root—*Pimpinella saxifraga*—0·025 per cent.
Poplar buds—*Populus nigra*—0·5 per cent.
Rhodium—*Convolvulus scoparia*—0·04 per cent.
Rose flowers, fresh—*Rosa centifolia*—0·05 per cent.
Rue herb—*Ruta graveolens*—0·18 per cent.
Sage herb, German—*Salvia officinalis*—1·4 per cent.
Sage herb, Italian, ditto, 1·7 per cent.
Sandal wood, East Indian—*Santalum album*—4·5 per cent.
Sandal wood, Macassar, ditto, 2·5 per cent.
Sandal wood, West Indian—*Unknown*—2·7 per cent.
Sassafras wood—*Laurus sassafras*—2·6 per cent.
Savin herb—*Juniperus sabina*—3·75 per cent.
Snake root, Canadian—*Asarum Canadense*—2·8 to 3·25 per cent.
Snake root, Virginian—*Aristolochia serpentaria*—2 per cent.

Southernwood herb—*Artemisia abrotanum*—0·04 per cent.
Southernwood root, ditto, 0·1 per cent.
Spearmint—*Mentha crispa*—1 per cent.
Star anise, Chinese—*Illicium anisatum*—5 per cent.
Star anise, Japanese—*Illicium religiosum*—1 per cent.
Storax—*Liquidambar orientalis*—1 per cent.
Sumbul root—*Ferula Sumbul*—0·3 per cent.
Tansy herb—*Tanacetum vulgare*—0·15 per cent.
Thyme, wild—*Thymus serpyllum*—0·2 per cent.
Valerian root, German—*Valeriana officinalis*—0·95 per cent.
Valerian root, Dutch, ditto, 1 per cent.
Vetiver root—*Andropogon muricatus*—0·2 to 3·5 per cent.
Water fennel seed—*Phyllandrium aquatica*—1·3 per cent.
Wormseed—*Artemisia maritima*—2 per cent.
Wormwood herb—*Artemisia absinthium*—0·3 to 0·4 per cent.
Zedoary root—*Curcuma zedoaria*—1·3 per cent.

The essential oils mainly consist of hydrocarbons —that is to say, substances exclusively composed of carbon and hydrogen—but many of them also contain oxidized bodies which, at least in numerous instances, are formed from the hydrocarbons by the action of atmospheric oxygen and moisture. No doubt, many of the gums and resins which occur in nature are intimately related to the essential oils, and are probably, in some cases, derived directly from them.

Ordinary oil of turpentine, representing the hydrocarbon part of the essential oils of different kinds of pine-tree (*Pinus maritima*, *Pinus australis*, *Pinus Tæda*, etc.) when analyzed, is found to contain 88·23 per cent. of carbon and 11·76 per cent. of hydrogen; and these figures lead to the chemical formula $C_{10}H_{16}$ as representing the constitution of turpentine. The mere analysis alone is not sufficient to fix this as the true formula; it might be C_5H_8, or

$C_{15}H_{24}$, or $C_{20}H_{32}$, all of which substances would give the same percentage composition. There are, however, other considerations, of which we shall say more presently, which fix the true formula of oil of turpentine hydrocarbons as $C_{10}H_{16}$. These are called 'terpenes,' in order to diagnose them from other substances which accompany them in the crude oils.

Similarly, other terpenes—that is to say, hydrocarbons of the same empirical formula — have been obtained from the oils of lemon, sweet orange, eucalyptus, camphor, bergamot, lime, neroli, coriander, juniper, caraway, camomile, hop, parsley, wintergreen, thyme, valerian, copaiba, cubebs, birch, elemi, etc.

There are other essential oils which, while they do not yield true terpenes, are yet intimately related to these substances. For instance, oil of cloves yields the hydrocarbon $C_{15}H_{24}$, oil of peppermint $C_{10}H_{18}$, and oil of roses $C_{10}H_{20}$.

Although the true terpenes are identical in composition and are represented by the same formula, they yet comprise a certain number of distinct hydrocarbons; distinct, that is to say, in the sense that all their properties are not uniform, while some of them are shared in common. The explanation of this fact is to be found in differences in the way in which the constituent atoms of the different terpene-molecules are arranged. Such facts are not at all uncommon and are well understood in chemistry. For instance, carbon exists in the form of the diamond and as coke; oxygen exists also in the state of ozone, and other substances are capable of assuming various natural forms, although identical in mere matter.

A special property of all the terpenes consists in the avidity with which they absorb oxygen, either in the pure state, or from ozone, or from the atmosphere. In illustration of this fact, there are here reproduced two tables from my papers published at different times. The oils in question were placed along with known quantities of air or oxygen contained in tubes sealed at one end, and after exposure under various circumstances for given periods, the amount of oxygen absorbed was measured by ascertaining the remaining amounts. The results do not indicate the total amounts of oxygen absorbable by the various oils forming the subject of experiment, but merely the comparative amounts that were absorbed during the period of observation.

Name of Oil.	Cubic centimetres of Oxygen absorbed.	In Number of Days.	=Daily.
Turpentine—			
(*a*) in sunshine -	220 from oxygen gas	6	36·6
(*b*) in shade - -	20 ,, ,, ,,	36	0·6
Caraway - - -	18 ,, ,, ,,	6	3·0
Bergamot - -	12 ,, ,, ,,	4	3·0
Juniper - - -	5 ,, ,, ,,	2	2·5
Cubebs - - -	4 ,, ,, ,,	2	2·0
Lemon - - -	16 ,, ,, ,,	13	1·2
Naphtha - - -	25 ,, ,, ,,	33	0·7
Camomile - -	6 ,, ,, ,,	11	0·55
Turpentine (in shade)	10 ,, ,, ,,	14	0·75

The experiments recorded in the next table were conducted by charging a number of very long sealed tubes with equal volumes of air, oil and water, and exposing them to summer sunlight for a few hours, but not sufficiently long for the whole of the atmospheric oxygen to be absorbed in any single instance. The residual, unabsorbed gas was afterwards measured in the laboratory. Calling the largest amount of oxygen absorbed 100, then :

1. Russian oil of turpentine absorbed - - - -	100
2. Swedish " " - - - -	100
3. Some turpentine which was obtained in Geneva absorbed	89·4
4. American oil of turpentine absorbed - - - -	78·9
5. Oil of eucalyptus absorbed - - - - - -	75·0
6. An evidently adulterated Swedish turpentine absorbed	52·6
7. 'Scotch-distilled American turpentine' absorbed -	42·1

The oils numbered 1, 2, 4 and 5 were undoubtedly genuine commercial oils ; the oil 3 was, perhaps, French oil of turpentine, and in this case only was the sample rectified by distillation before making the experiment, since it had undergone great oxidation by keeping for many years. The oils 6 and 7 had been sent as samples and were evidently not genuine; probably both had been largely adulterated with so-called pine-oil of commerce or with resin-spirit.

The absorption of oxygen (even from the atmosphere) by essential oils and their true chemical terpenes, takes place at the ordinary temperature, although, of course, it happens more slowly at a low than at an elevated one ; more slowly, therefore, in winter than in summer ; more slowly in shade than in direct sunlight ; more slowly in the dark than in diffused daylight ; but in all cases, even if pure oxygen or ozone be used instead of air, the products are identical.

Now, if the pure hydrocarbons obtained from essential oils be placed in contact with a mixed solution of iodide of potassium and starch, they will not colour this test mixture* at once, but only after standing some time exposed to the air. On the other hand, if the experiment be made with those hydrocarbons which have been previously allowed to absorb oxygen from the air, a coloration is produced at once. The potassic iodide is decomposed ; iodine is set free, and this combining with starch, forms a blue compound, causing the coloration in question. Similarly, if the essential oils be exposed to the air in shallow vessels covered loosely with bibulous paper soaked in the same test mixture, the coloration of the paper gradually ensues. That is to say, the oils evaporate slowly and combining with atmospheric oxygen, produce the active principle, whatever it may be, which thus comes into contact with the test paper and influences it. If the evaporation be assisted by placing the vessels upon a warm metallic plate, the reaction is obtained more speedily and is of a more intense character.

If, instead of soaking the paper in the above-named mixture, it be moistened with acetate of lead, or sulphate of manganese, no coloration is then produced ; nor are solutions of these respective substances coloured, even when placed in contact with the oils themselves and on free exposure to the air. This fact seems, at once, to indicate that the active agent is not ozone ; for if it were, affirmative results should be obtained.

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* This mixture has been stated in a previous chapter to be a test for both peroxide of hydrogen and ozone.

Moreover, Soret proved that oil of turpentine readily absorbs ozone;[*] it is therefore utterly impossible that a substance which absorbs ozone should also produce it under identical conditions.

After studying the influence of peroxide of manganese, peroxide of lead and hyposulphite of sodium upon oxidized oils containing the active principle, and having observed that these substances totally destroyed it, a fact of an important nature was experienced.

Quantities of the oils of turpentine and caraway were, severally, oxidized to a considerable extent; they were then washed with water to remove any peroxide of hydrogen,[†] and finally introduced into vacuous bottles containing mixed potassic iodide and starch, when the blue coloration was at once produced. It having been proved that the active principle, as directly formed, could not be ozone, and as the method of experiment excluded the possibility of its identity with peroxide of hydrogen, this new fact admitted of one explanation only, which is as follows: The essential oils absorb oxygen from the air, pure oxygen and ozone alike, and there is thus produced an additive product of an organic nature, exhibiting

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[*] I have since confirmed this statement, and have ascertained that by the action of ozone upon turpentine, a substance is produced which yields peroxide of hydrogen on treatment with water. It is presumably identical with the peroxide which results from the atmospheric oxidation of turpentine. (See my paper, *Journ. Chem. Soc. Trans.*, 1880, p. 800.)

[†] It was previously ascertained that any peroxide of hydrogen either contained in or mechanically attached to the oxidized oils is entirely removed by washing them with water.

properties resembling to some extent those of ozone and peroxide of hydrogen; in other words, an organic peroxide is produced.

At the same time, it was observed that the active principle of oxidized oil of turpentine is entirely destroyed by heating it in contact with dry chloride of zinc to a temperature of 75° C.; whereas, in absence of the chloride of zinc, it was not materially affected by being heated to this point. Similarly, other dehydrating and deoxidizing substances were found to destroy the active agent.

Having got so far, steps were next taken to more particularly ascertain the precise conditions upon which the formation of the active substance depends, and it was found to be produced whenever oil of turpentine (for example) is placed in contact with air only; that is to say, it was ascertained that the presence of water is not essential. It was noticed, however, at an early stage of the research, that the production of the active substance was much facilitated by carrying on the oxidation of the oil (by means of a current of air) *in the presence of water*, at a slightly elevated temperature. In order to obtain further information, great quantities of turpentine were oxidized in this way

It at first appeared strange to find that the water standing underneath the turpentine after these experiments, contained, beyond question, peroxide of hydrogen. It was found possible to concentrate the solution by carefully-conducted evaporation. With the potassium iodide and starch mixture it gave the blue coloration; with chromic and sulphuric acids it gave the characteristic reaction wherein the violet perchromic acid is first produced and subsequently decomposed with evolution of oxygen; it also evolved oxygen gas when treated with an acid solution of permanganate of potassium. In brief, there was obtained an aqueous solution containing sufficient peroxide of hydrogen to produce twice its own volume of oxygen gas.

It was thus proved that during the oxidation of oil of turpentine neither ozone nor peroxide of hydrogen is directly produced, but that the active substance which is first formed yields peroxide of hydrogen as a secondary product when treated with water. So that if the oxidation takes place originally in the presence of water, peroxide of hydrogen is always obtained in the aqueous solution.

All these observations accorded with the conclusion that the oxidized compound first produced is an organic peroxide; and as Brodie had described a method for the production of camphoric peroxide, it seemed that my product might possibly be this same substance.* In any case, it may be supposed to be

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* More recently (*Journ. Chem. Soc. Trans.*, 1884, pp. 93-99) I have repeated the experiments made by the late Sir Benjamin Brodie, and have shown that camphoric peroxide, or rather a compound of it with barium, is not produced, as he erroneously supposed, by acting with peroxide of barium upon camphoric anhydride. He represented the reaction by the equation:

$$C_{10}H_{14}O_3 + BaO_2 = C_{10}H_{14}BaO_5;$$

whereas I have shown that the reactions which really take place are as follows:

decomposed by contact with water by some such reaction as is here represented :

Camphoric peroxide + water = soluble camphor + peroxide of hydrogen.

$$C_{10}H_{16}O_4 + H_2O = C_{10}H_{16}O_3 + H_2O_2.$$

Assuming the last given reaction to be correct, my camphoric peroxide may be regarded as a hydrated and oxidized product of the composition $C_{10}H_{14}O_3H_2O$.

This idea receives support from the fact that I found soluble camphor (the substance $C_{10}H_{16}O_3$) in the aqueous solution accompanying the peroxide of hydrogen. But whether my camphoric peroxide has or has not the composition as here represented, it is, at any rate, slowly decomposed by contact with water, and the aqueous solution is found to contain peroxide of hydrogen, soluble camphor ($C_{10}H_{16}O_3$), and a substance resembling thymol ($C_{10}H_{14}O$).

The great proof that peroxide of hydrogen only results as a product of secondary decomposition, is afforded by the observation that when the oil is oxidized in the absence of water and afterwards agitated with large volumes of water, it still retains its active properties and yields more peroxide of

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$$C_{10}H_{14}O_3 + H_2O = C_{10}H_{16}O_4$$
$$C_{10}H_{16}O_4 + BaO_2 = C_{10}H_{14}BaO_4 + H_2O_2.$$

That is to say, the camphoric anhydride is first resolved by contact with water into camphoric acid, and this, by reaction upon the peroxide of barium, yields camphorate of barium and peroxide of hydrogen.

This investigation, however, leaves the existence of my peroxide as obtained by the air oxidation of terpenes, where it was, and I retain the name of camphoric peroxide.—AUTHOR.

hydrogen on further standing with water. The oxidized oil may even be dissolved in alcohol and poured into water and yet, after separation, it will retain some undecomposed camphoric peroxide. This may be well shown by mixing it with potassium iodide and starch (in the presence of a suitable acid) and estimating the iodine thus set free by means of a standard solution of hyposulphite of sodium. If the oxidized oil contained peroxide of hydrogen in mere admixture, this latter substance would be entirely removed by simply shaking with water: that, however, does not occur.

If the oxidized oil be subjected to careful distillation, it yields in the earlier stages, among other products, two oily bodies, one having a camphoraceous odour (possibly Sobrerone), $C_{10}H_{16}O$, and another of the composition $C_{10}H_{16}O_2$. Water is at the same time formed.

The substance left in the retort has the composition $C_{10}H_{14}O_2$, and in properties resembles resin. Probably it is derived from the decomposition of camphoric peroxide. As a matter of fact, upon hydration it yields a substance having the composition $C_{10}H_{16}O_3$, and which is, perhaps, identical with the soluble camphor above described.

When the strongly oxidized oil of turpentine is placed in a retort and heated to 160° C. (the boiling-point of pure turpentine), and after the distillation has proceeded for some time the temperature suddenly rises and violent decomposition ensues.

It was first observed by Woodcock that oxidized American turpentine gradually deposits a remarkable white amorphous body, which is soluble only in chloroform and carbon disulphide, but this substance is not formed from oxidized Russian turpentine.* According to my analyses the chemical composition of this substance is represented by the formula $C_{20}H_{27}O_3$.

Being desirous of establishing some kind of relation between the terpenes of turpentine and the other essential oils, as also to obtain some further explanation of the facts which had been discovered, the later method of experiment—viz., oxidation in presence of water by a current of air—was extended to various different substances. Those examined at that time were:

Cymene, $C_{10}H_{14}$ (from several different sources).
Hesperidene, $C_{10}H_{16}$ (the terpene of oil of orange-peel).
Myristicene, $C_{10}H_{16}$ („ „ „ nutmeg).
Menthene, $C_{10}H_{18}$ (from solid Japanese camphor).
Oil of wormwood (containing, according to Wright, much $C_{10}H_{16}O$, and a little terpene, $C_{10}H_{16}$).
Oil of citronella (containing much $C_{10}H_{16}O$, and *no terpene*).
Yhlang Yhlang (containing no terpene).
Hydrocarbon from oil of cloves, being $C_{15}H_{24}$, as shown by Church.
Patchouli (containing no terpene).

The cymene (from every source) yielded peroxide of hydrogen in the aqueous solution, as did also all the terpenes as well as those oils which contained even the smallest quantity of terpene; menthene ($C_{10}H_{18}$) behaved similarly. On the other hand, the hydrocarbon from oil of cloves ($C_{15}H_{24}$) and those oils

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* See abstract of my paper (communicated to the Chemical Society) on 'The Oxidation of Terpenes and Essential Oils' in *Chemical Trade Journal*, February 17, 1894.

which contained no terpene, gave no trace of peroxide of hydrogen.

From these and other experiments which need not be referred to in this place, two inferences may be made:

1. That all essential oils (of which ordinary turpentine is illustrative) which contain a hydrocarbon represented by the formula $C_{10}H_{16}$, as also all pure terpenes, give peroxide of hydrogen when their oxidized products are treated with water.

2. That the production of peroxide of hydrogen in this way is related to cymene, for both Oppenheim and Wright have proved that cymene may be obtained from all the true terpenes ($C_{10}H_{16}$),* and it has been shown that cymene gives peroxide of hydrogen, while menthene gives both cymene and peroxide of hydrogen.

These conclusions were subsequently confirmed by the observation made by Wright, that the $C_{15}H_{24}$ hydrocarbon from oil of cloves, which does not yield peroxide of hydrogen, fails also to yield cymene when subjected to the process by which all true terpenes ($C_{10}H_{16}$) yield it.

Another confirmation was afforded by the experiments of Pattison Muir, who found† that oil of sage absorbs oxygen and produces peroxide of hydrogen. He afterwards showed that the oil contained a quantity of a terpene ($C_{10}H_{16}$).

Whatever worth, then, the above-stated hypothesis

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* Tilden has also shown that all terpenes yield the Nitroso derivative $C_{10}H_{15}$ (NO).

† *Year Book of Pharmacy*, 1876, p. 561; 1877, p. 498.

may have, the fact is established beyond doubt, that all oils which contain either cymene or terpene (such as oil of eucalyptus, ordinary turpentine and camphor oil) give rise to the production of peroxide of hydrogen, when subjected to the process described in the foregoing pages.

To revert once more to the atmospheric oxidation of oil of turpentine. There are various kinds of this oil known to commerce, differing according to the species of tree from which they are obtained and probably (to some extent) upon the climatic and geological conditions of the localities in which the trees are grown. Moreover, all turpentines are not alike in their power of absorbing oxygen, some absorbing it much more freely than others.

It was observed, in certain cases, that an oil of turpentine which absorbs oxygen from the air at any given rate, will absorb it much less rapidly if freed from accompanying oxidized substances by distillation. In other words, when once the process of oxidation has begun, it continues more and increasingly rapidly, so that the greater the amount of oxidized matter contained in the oil, the greater the oxidation under given conditions.

From these facts it may be inferred that in nature, the process of oxidation which occurs in the immediate neighbourhood of the trees, takes places, in all probability, much more rapidly than in the laboratory ; since, as produced in the trees, the oil is accompanied with the products of oxidation, to which reference has been made.

It is indeed remarkable that turpentine in course of oxidation is capable of imparting to fresh turpentine the same and equal facility to absorb oxygen. The comparatively slow rate at which the atmospheric oxidation of fresh turpentine proceeds, and the greater rate attained after the molecules have undergone that change which induces a rapid oxidation, is seen by the following figures, which relate to an experiment conducted some years ago upon about thirty gallons of turpentine in the presence of water :

After 37 hours' exposure to a current of air each 100 c.c. of the aqueous solution contained	0·0551	grm. H_2O_2.
„ 41 „ „	0·2000	„
„ 54 „ „	0·3000	„
„ 58 „ „	0·4500	„

As the oxidation of the oil goes on, its density gradually increases by the absorption of oxygen. This fact is illustrated by the following figures :

In one experiment the original density of the oil of turpentine used was 0·864.

After 24 hours' oxidation it was	0·880
„ 28 „ „ „	0·881
„ 32 „ „ „	0·888
„ 41 „ „ „	0·949

In another experiment—

After 16 hours' oxidation it was	0·8886
„ 20 „ „ „	0·8996
„ 26 „ „ „	0·9060
„ 39 „ „ „	0·9136
„ 46 „ „ „	0·9366
„ 48 „ „ „	0·9476
„ 300 „ „ „	1·2350

It thickens as it increases in density and acquires a powerful odour, reminding of camphor and peppermint at once.

With the increase in the density of the oxidized oil, its boiling-point also rises, as was shown by the experiment now to be described. The turpentine used in the experiment boiled as in column (1):

(1) Original Oil.		(2) After 24 hours' Oxidation.	(3) After 27 hours' Oxidation.
10 per cent. distilled over at	157° C.	162° C.	165° C.
20 ,, ,, ,,	159	165·5	166
30 ,, ,, ,,	160	168	170
40 ,, ,, ,,	160	171	171
50 ,, ,, ,,	160·5	174	174
60 ,, ,, ,,	161	181	185
70 ,, ,, ,,	162	193	206
80 ,, ,, ,,	164	210	—
90 ,, ,, ,,	166	—	—

The results here tabulated were arrived at by taking 100 c.c. of each product and subjecting to careful distillation, care being taken to record the temperature after the collection of every 10 c.c. distillate.

It has been stated above that soluble camphor and a body resembling thymol accompany the peroxide of hydrogen in the aqueous solution which is obtained by atmospherically oxidizing turpentine in presence of water. This solution gives all the reactions characteristic of thymol. When evaporated to dryness on the water-bath, all the thymol-like substance is dissipated in the vapour, and the peroxide of hydrogen is, of course, entirely decomposed; there remains in the dish a dark-coloured substance, which, when hot, is soft and viscid and smells like melted sugar. On cooling, it sets into a solid, adhesive mass, bitter to the taste and possessing decided antiseptic properties, of which more anon. This substance constitutes the so-called soluble camphor.

In recapitulation of the foregoing details it may be stated that, when turpentine is exposed to the action of air it absorbs oxygen and gives rise to the production of a peculiar organic peroxide which remains dissolved in the body of the oil, communicating thereto properties resembling those of ozone and peroxide of hydrogen. Inasmuch as the oil is volatile, these properties are communicated also to the surrounding atmosphere. If the oxidized oil be treated with water, or, what amounts to the same thing, if the oxidation of the oil be conducted in the presence of water, then, upon examination, the aqueous solution is found to contain peroxide of hydrogen, and it is accompanied by a substance resembling thymol ($C_{10}H_{14}O$) and the other substance named soluble camphor ($C_{10}H_{16}O_3$).

The same products are obtained by the atmospheric oxidation of oil of eucalyptus, camphor oil, and every other essential oil which contains either cymene ($C_{10}H_{14}$), or a terpene (that is, a hydrocarbon of the formula $C_{10}H_{16}$).

It will be observed that my process of atmospheric oxidation of essential oils is an exact imitation of the one which necessarily occurs in nature in connection with every plant that secretes these so-called oils, and which is, of course, attended with the same results. So far, therefore, as the properties of pine, camphor and eucalyptus forests may be connected with the special presence of peroxide of hydrogen, these are now well explained. In the next chapter, experiments will be described to show that all the different products are powerful antiseptics or disinfectants, and thus we shall finally be enabled to apply the derived knowledge in explanation of some important processes of Nature's Hygiene, which have been described in earlier parts of this work.

Before proceeding to these fresh studies, it will be convenient to so far anticipate the contents of the next chapter, as to assume that the products of the atmospheric oxidation of turpentine possess sanitary properties valuable enough in themselves to make it desirable that they should be commercially available.

The practical conduct of this manufacture may now be briefly described. A number of specially made Doulton-ware receivers or other vessels lined with pure metallic tin, are charged with water and essential oil in the proportions found to be best by experience, and the contents are maintained at a temperature of about 140° F. by placing the receivers in vats of water heated by steam. Under these conditions a current of hot air is pumped through each oxidizer during a prolonged period varying in practice from 96 to 300 hours. Under these circumstances the air current carries with it, when leaving the oxidizers, a large quantity of turpentine (or whatever other essential oil may be in course of oxidation) in the state of vapour, and this is condensed by passing it into and out of various compartments of cold water, or up and down coke-scrubbers. The turpentine collects on the various surfaces of the cold water, or in the cisterns at the bottom of the coke-scrubbers and from time to time it is drawn off and restored to the oxidizers.

The chemical changes which occur in these vessels have been already described in the preceding pages, so that here it is only necessary to recapitulate the main particulars. The turpentine absorbs the oxygen from the air which is forced through it, and it is thereby oxidized, giving rise in the first place to the production of camphoric peroxide; then by secondary reactions, the various other substances characteristic of the aqueous product are formed. These secondary products at once dissolve in the water which is below the turpentine in the receivers. At first these changes take place slowly, but they proceed with increasing rapidity from the first moment and the oil of turpentine becomes yellowish-red and thicker as the operation goes on. It will be seen from this statement that the strength of the aqueous solution which forms underneath the turpentine depends to some extent upon the time during which the process of air-oxidation is carried on. At the start we have only water and turpentine in contact; but as the turpentine becomes oxidized, it yields to the water those substances which are produced by the secondary reaction of the water upon the oxidized oil.

The successful conduct of this process is not unattended with difficulty. It must be remembered that one of the ultimate products of the process is peroxide of hydrogen. This begins to form from the first moment, and continues to be produced during the whole time; but it is so readily decomposed again that, unless a number of precautions and conditions are carefully observed and maintained, there is a liability of obtaining a product devoid of peroxide of hydrogen. Thus, if the temperature in the vats be allowed to rise too high, or if an insufficient depth of turpentine be kept in the oxidizers, there is a danger of decomposing the whole of the peroxide of hydrogen existing at the time of the neglect. On the other hand, if the temperature be too low, it is produced very slowly.

In fact, the producer seeks to effect the greatest possible atmospheric oxidation of turpentine in the least given time, obtaining thereby the oxidized oil and the aqueous solution containing as much dissolved camphoraceous principles as possible, together with the maximum quantity of peroxide of hydrogen. This is done because, as will be explained hereafter, the oxidizing powers of the aqueous solution are due to the presence of the peroxide of hydrogen, while the strictly antiseptic characters are mainly traceable to the camphoraceous ingredients, notable amongst these being the soluble camphor and thymol. This product, termed 'Sanitas fluid,' is now very largely used as a general disinfectant, also as a toilet preparation and as an antiseptic in the practice of modern surgery. It is colourless, fragrant, non-poisonous and does not stain linen.

At the termination of the manufacturing operation here so briefly traced, there remains in the oxidizers, floating upon the surface of the aqueous solution, a quantity of oxidized oil of turpentine containing a large amount of the camphoric peroxide. This oxidized oil, or 'Sanitas oil,' as it is known in commerce, is sold of specific gravity 950 (compared with water 1000 and turpentine 865), and is much more powerful as an antiseptic and disinfectant than the aqueous solution; it is now largely used as an antiseptic dressing and for the preparation of gauze, disinfecting emulsion, powder, soaps and other articles; also for fumigating sick-rooms and especially for the specific treatment of lung and throat complaints by inhalation; it is also used for varnish-making and for bleaching wax and feathers. It is a powerful parasiticide, makes an excellent embrocation for use in rheumatism, and constitutes one of the best agents for the destruction of ringworms.

By its evaporation, an artificial atmosphere can be produced, containing all the active principles which are generated in pine and eucalyptus forests, and thus these are rendered available for the treatment of phthisis, bronchitis, diphtheria and other complaints, without sufferers resorting to foreign lands for that purpose.

In a paper* communicated to the Society of

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* *Journ. Soc. Chem. Industry*, 1882, p. 479.

Chemical Industry some years ago by Armstrong, attention was directed to the remarkable differences in the optical character of a number of samples of Russian turpentine, and from the rotatory powers then given in illustration of that fact, he infers that the proportions in which its two chief recognized constituents are present probably vary considerably, and that they are, perhaps, accompanied with other isomeric hydrocarbons.

I have found* that not only do different samples of Russian turpentine present differences in optical character, but that they exhibit also equally striking differences in specific gravity and susceptibility to oxidation by air.

For a long time I entertained the hope that a study of the physical properties of different samples, and the chemical history of their oxidation by air, would lead to the discovery of some simple relation between the results, whereby the behaviour of any particular sample upon exposure to oxidation could be inferred beforehand. While, however, I have not been so fortunate in this respect as I had wished, the results seem to be of sufficient interest to warrant record.

Parcels of Russian turpentine brought direct from the importer, derived, it is believed, from a common source and obtained by the same distillation, are by no means uniform in quality; the contents of each barrel differ, as a rule, in one or more respects, from those of every other barrel. This variability in composition is, doubtless, attributable in the main to the

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* *Journ. Soc. Chem. Industry*, January 29, 1886, No. 1, vol. v.

method of distillation which is practised in Russia, but, in part, to the fact that the turpentine is not yielded by a single species of pine. Although the trees which are employed are chiefly the *Pinus sylvestris* and *Pinus ledebourii*, they are not exclusively used; and as in the method of preparation the wood itself is subjected to distillation, it necessarily follows that at each stage of the process relatively different quantities of the several kinds will be undergoing both distillation and destructive distillation.

There is no evidence that the oils of turpentine which are furnished by the *Pinus ledebourii* and other kinds of tree are identical with that obtained from the *Pinus sylvestris*. Further, there is reason to believe that the turpentine obtained from the different parts of a tree is not absolutely uniform in composition. For instance, Tilden* found that a sample of *Oleum foliorum Pini sylvestris* furnished upon fractionation two terpenes, one of which, smelling like ordinary American turpentine, boiled at 156° to 159°, but was more strongly dextro-rotatory than australene (a column of 100 mm. rotated the plane of polarization $+18° \; 28'$); whereas the other terpene boiled at 170°, but was lævo-rotatory (per 100 mm. $= -4°$), unlike sylvestrene (b.-p. 171° to 171·5°), which is dextro-rotatory (100 mm. $= +17°$). Tilden concluded, however, that it was sylvestrene, but this does not appear to be proved. Later on, Atterberg†

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* *Journ. Chem. Soc. Trans.*, 1878, p. 83.

† *Journ. Chem. Soc. Abstracts*, 1882, p. 410.

obtained from the oil extracted from the needles of *Pinus pumilio* a hydrocarbon which he also regards as identical with sylvestrene, but which exhibited a rotatory power of − 5·38°. The question arises, then, is this terpene, which resembles sylvestrene in its boiling-point only (so far as yet known), but which differs from it in its optical character, a distinct hydrocarbon ?

Again, 'pine-cone oil,' which is obtained by distilling with water the cones of *Abies pectinata*, differs in properties from 'dwarf pine oil,' which is similarly obtained from the young tops and cones of *Pinus pumilio*, while both of these oils are said to be dissimilar to 'pine-leaf oil,' which is yielded by the leaves of *Pinus sylvestris* or *Pinus abies.*

Russian turpentine undoubtedly contains products of the destructive distillation of both rosin and the wood, including various hydrocarbons (cymene, benzene, toluene, xylene, paraffins, etc.), creosote, and tar and other acids. Atterberg has demonstrated the probable presence of furfurane (tetraphenol) and sylvane (C_4H_3OMe), a homologue of tetraphenol, in the low boiling portion of the wood oil obtained by the dry distillation of pine wood.*

Considering all these circumstances, it is not matter for surprise that Russian turpentine should, as found in commerce, present such want of uniformity in odour, colour, boiling-point, specific gravity, optical behaviour and oxidizibility. Indeed, it would appear that the only method of obtaining an absolutely

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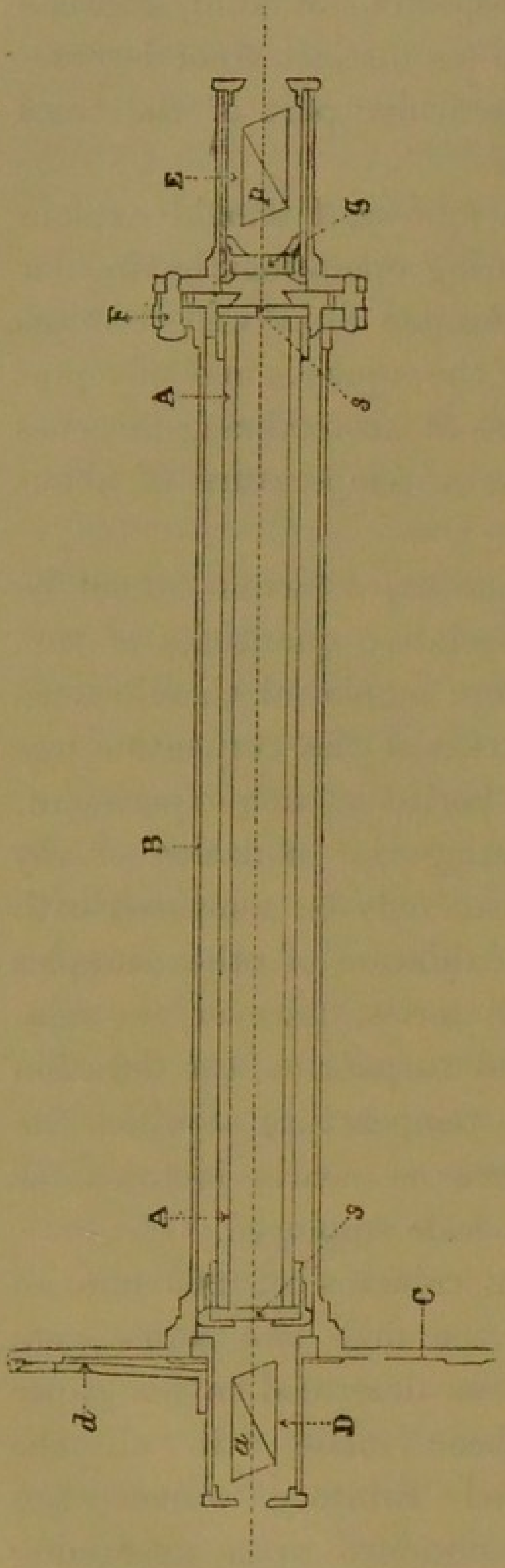
* *Journ. Chem. Soc. Abstracts*, 1880, p. 663.

uniform turpentine oil (irrespective of kind) consists in the separative distillation (as distinct from destructive distillation) of one particular part of the trees belonging to a single species.

With reference to what follows, I should explain that it refers to manufacturing operations having for object the production of 'Sanitas fluid' and 'Sanitas oil,' they being respectively the aqueous and oily products obtained by my process of air-oxidizing terpenes in the presence of water at a temperature of about 60° C. (140° F.).

The results of the various experiments cannot be compared together, as the relative quantities of turpentine and water which were employed therein were not uniform, and the oxidation of the turpentine was not carried on for the same period in each experiment. In brief, the results attending the oxidation of any one sample of turpentine can only be compared with the results attending the oxidation of other samples in the same series. In each series, however, the relative quantities of water and turpentine, the duration of the air-current and the temperature at which the process was conducted, were as nearly identical as could be arranged upon the scale employed.

The rotatory powers (for columns of 200 mm. of the turpentines used) in the first two series were determined by Armstrong, as described in his paper to which reference has been made. In all the other series the reported rotatory values are merely the scale readings obtained upon examining layers of 200 mm. in the 'Portable Saccharimeter'



of Carl Zeiss, of Jena (supplied by Mr. Baker, of London), by turning the rotating eyepiece until both semicircles of the rock-crystal plate acquired as nearly as possible the same reddish-violet colour. I may, however, mention that two samples of American turpentine examined by this instrument gave the same scale reading of 23·5°.

The instrument consists of a glass tube, A, of exactly 200 mm. in length, closed by parallel plates of glass, *s*, *s*, at both ends, which is inserted into a brass tube, B. This brass tube carries a divided circle, C, divided by half-degrees, and upon this circle a shorter tube, D, rotates and contains a Nicol prism, *a* (the analyzer). The rotation of D is measured on the divided circle by means of an index-pointer, *d*. The other end of B bears, by means of an eccentric pivot, F, a short tube, E, with another Nicol prism, *p* (the polarizer), and a double plate of rock-crystal, *q*.

The amount of oxygen absorbed by the turpentine in each observation was calculated by multiplying the increase in its specific gravity by the number of gallons of the product.

The peroxide of hydrogen observed in the aqueous solution does not represent the whole amount obtainable, but only the quantity actually present therein at the time of examination.

The amount of peroxide of hydrogen obtained per lb. of oxygen absorbed by the oil of turpentine, has been calculated in each instance by dividing the grammes H_2O_2 by the lbs. of oxygen absorbed.

I should remark, in respect of Series I., that as no accurate record was kept of the quantity of aqueous product, I have been obliged to assume that exactly the same quantity was obtained in all instances. The last eight cases in this series serve to illustrate the difficulty experienced in maintaining as many oxidizers under absolutely identical conditions. Nevertheless, it may be noted that the average quantity of peroxide of hydrogen obtained in these eight cases, where the same bulked turpentine was employed, was 107 grms. per 1 lb. oxygen absorbed by the turpentine, and this figure fairly agrees with the oil of nearest rotatory power in the preceding cases, in each of which turpentine from separate barrels was oxidized.

SERIES I.

Rotatory Power, 200 mm. Turpentine used.	Lbs. of Oxygen absorbed by the Turpentine.	Grammes H_2O_2 obtained.	Grammes H_2O_2 obtained per 1 lb. Oxygen absorbed by Turpentine.
30·10	0·96	125	130
31·20	2·52	385	154
32·27	1·87	255	136
32·27	7·50	324	43
32·50	3·00	232	77
34·80	3·15	264	84
36·18	7·75	417	53
36·40	5·94	463	78
37·50	5·83	630	108
39·44	7·15	992	138
39·52	5·81	695	120
39·58	3·75	477	127
40·42	5·04	802	159
42·10	3·96	904	228
44·11	3·24	422	130
46·45	5·83	621	106
38·26 (Bulked).	6·30	867	137
	5·28	650	123
	5·72	686	120
	3·60	473	131
	4·80	542	113
	3·84	394	103
	7·65	541	71
	6·75	403	60

SERIES II.

Rotatory Power (Scale Readings), 200 mm. Turpentine.	Lbs. of Oxygen absorbed by Turpentine.	Grammes H_2O_2 obtained.	Grammes H_2O_2 obtained per 1 lb. Oxygen absorbed by Turpentine.
31	4·93	46	9
32	4·76	128	27
35½	11·20	675	60
36	11·20	1131	100

SERIES III.

Rotatory Power (Scale Readings), 200 mm. Turpentine.	Lbs. of Oxygen absorbed by Turpentine.	Grammes H_2O_2 obtained.	Grammes H_2O_2 obtained per 1 lb. Oxygen absorbed by Turpentine.
31	3·00	55	18
38½	6·66	617	92
39	7·00	542	77
39½	6·50	499	77
39½	7·35	573	77

SERIES IV.

30	6·80	278	41
30½	3·36	166	49
32	3·74	129	34
32	6·40	332	52
32	2·88	45	15
34	4·05	219	54
36	3·60	462	128
37½	6·00	389	65
38	4·80	479	99
38	4·76	336	70
39	3·60	293	81
41	8·05	540	67

SERIES V.

30	4·20	324	77
30½	3·00	263	88
31	1·30	117	90
31	3·00	130	43
31	10·85	701	64
31½	9·10	631	69
33	5·40	398	74
33	4·95	253	51
33½	5·75	624	108
35	3·90	239	61
36	7·80	712	91
36½	3·60	250	69

Series VI.

Rotatory Power (Scale Readings), 200 mm. Turpentine.	Specific Gravity of Turpentine.	Total Solid Residue left by 100 c.c. Turpentine, dry at 100° C.	Lbs. of Oxygen absorbed by Turpentine.	Grammes of H_2O_2 obtained.	Grammes H_2O_2 per 1 lb. Oxygen absorbed by Turpentine.
30	0·8642	1·166	4·42	681	154
31	0·8620	1·432	0·78	149	191
32½	0·8722	1·330	3·84	290	75
35	0·8671	1·286	0·92	229	246
35	0·8703	1·750	—	161	—
36	0·8649	1·338	2·52	320	126
37	0·8661	1·080	0·93	136	145
37½	0·8696	2·370	4·46	213	47
37½	0·8706	1·300	3·74	399	106
37½	0·8721	1·372	—	146	—
37½	0·8670	1·370	—	267	—
38	0·8697	0·912	5·48	615	112
38½	0·8689	1·610	3·86	235	61
38½	0·8658	0·738	4·80	814	170
38½	0·8633	0·794	1·03	375	362
39	0·8706	0·920	3·60	707	195
39	0·8672	0·802	4·44	503	113
39	0·8632	0·496	1·90	272	142
39½	0·8656	0·778	2·44	272	111
39½	0·8677	1·298	3·44	525	152
40	0·8698	1·400	7·24	791	109
40	0·8697	1·236	5·27	984	186
40½	0·8669	1·190	5·61	534	95
41	0·8653	1·308	1·31	358	272
44½	0·8650	0·990	5·40	1069	198

In Series I. to V. the specific gravity of the turpentine was not determined, but was calculated at 0·865; in Series VI., however, it was determined by weight in the usual manner, but that of the oxidized oil was still done by the hydrometer.

In Series VII. the specific gravities of the oxidized oils, as also those of the turpentines employed, were determined by weight. It is seen from these results that Russian turpentine as met within commerce ranges in specific gravity from 0·8620 to 0·8722, and that it contains from 0·496 to 2·37 per cent. of matter (by weight in volume) which is non-volatile at 100° C.

SERIES VII.

Rotatory Power (Scale Readings), 200 mm. Turpentine.	Specific Gravity of Turpentine.	Lbs. of Oxygen absorbed by the Turpentine.	Grammes of H_2O_2 obtained.	Grammes H_2O_2 per 1 lb. of Oxygen absorbed by Turpentine.
34½	0·8646	—	66	—
34½	0·8662	—	612	—
35½	0·8683	2·010	274	136
38½	0·8666	—	562	—
39	0·8641	1·829	311	170
39	0·8685	0·465	166	357
39	0·8656	3·151	591	187
40	0·8642	0·232	31	133
40	0·8641	2·324	427	183
41	0·8666	1·620	483	298
41½	0·8651	—	531	—
41½	0·8642	4·450	954	214
44	0·8660	0·588	356	605

It is almost impossible to draw any conclusions regarding the production of peroxide of hydrogen in relation to the rotatory powers of the turpentines examined; but if it be safe to conclude anything at all, it is that the oils of the higher rotatory values serve best, and that next in order come those of low rotatory value. If this conclusion be drawn, then we must look, not alone to sylvestrene (+34° per 200 mm.: Atterberg, confirmed by Tilden) as the source from which the peroxide of hydrogen is obtained, but also to a hydrocarbon of comparatively high rotatory power not identical with the chief constituent of American turpentine (australene), for that substance is not readily oxidizable and is not a prolific source of peroxide of hydrogen.

I, however, hesitate to draw any hard-and-fast conclusion.

I cannot confirm the statements which have been placed on record regarding the marked physiological effects, including violent headache, induced by Russian turpentine. Such effects have never been observed in the works of the 'Sanitas' Company, Limited, where the air is continually loaded with the vapour of Russian turpentine and other essential oils. On the other hand, the atmosphere is balmy, pleasant and healthful.

In conclusion, I cannot support the claims that have been made from time to time in respect of the medicinal and sanitary properties of the oil of turpentine furnished by the Pumilio pines which are grown in the snow. It consists of a mixture of terpenes, having no extraordinary properties or value. I contend that in order to carry out a rational pine treatment of lung and throat diseases, recourse must be had, not to raw turpentine of any kind, but to those products of oxidation which are generated therefrom, as I have explained, and of which 'Sanitas oil' (air-oxidized turpentine) is to be regarded as a saturated solution.

CHAPTER XIV.

PROPERTIES OF THE INDIVIDUAL AND COLLECTIVE PRODUCTS OF THE OXIDATION OF ESSENTIAL OILS, CONSIDERED AS ANTISEPTICS, DISINFECTANTS, OXIDANTS AND GERMICIDES.

As is well known, most of the essential oils—and certainly those of turpentine, eucalyptus and camphor—possess, even in their raw or natural condition, very decided antiseptic characters. But, since in nature these oils undergo oxidation when volatilized into the atmosphere (containing also aqueous vapour), we must test the properties of the products of oxidation which are thus generated if we would obtain a proper understanding of the sanitary influences of pine, eucalyptus and camphor trees.

It was from the well-known oxidizing effects of peroxide of hydrogen and its consequent use as a disinfectant, that I was first led to the investigation of this branch of the subject. During my earlier experiments, it was ascertained that beyond its well-known and valuable powers of oxidation, it also exhibits very peculiar antiseptic properties; this fact was new to science.

The investigation was continued with the view of ascertaining and explaining the antiseptic and disinfecting properties of the aqueous solution ('Sanitas fluid') and the oxidized oil ('Sanitas oil'), which are obtained by oxidizing the oils of turpentine, eucalyptus, or camphor, etc., by air in the presence of water.

The following experiments were communicated to the British Association Meeting of 1876.

Experiments with Peroxide of Hydrogen.

The solution which was employed was one of what is called '10-volumes strength'; that is to say, it was capable of evolving ten times its own volume of oxygen gas when decomposed, in accordance with the following equation:

$$H_2O_2 = H_2O + O.$$

One hundred cubic centimetres of the solution would thus furnish 1,000 c.c., or a litre of oxygen gas.

The experiments were conducted during hot summer weather.

Ten c.c. of the peroxide of hydrogen, added to 400 c.c. of fresh milk, preserved it from souring for six days, oxygen gas being gradually evolved in the meantime. It was only after ten days that the mixture became thick and sour.

Five c.c. preserved 47 c.c. grape-must from fermentation for some twenty-four hours, after which bubbles of oxygen gas escaped; finally, the mixture had an apple-like colour.

Five c.c. preserved 15 c.c. of white of egg, mixed with 10 c.c. water, perfectly fresh for many days.

Five c.c. preserved 400 c.c. 'bitter beer' unaltered for twenty-six days; it then soured, but fungus did not appear.

Five c.c. preserved 30 c.c. flour-paste for six days free from sourness and mould.

Now the real quantities of peroxide of hydrogen and decomposable substances employed in the above experiments stand about as follows:

							Per cent. of H_2O_2 =	
0·304	grm.	H_2O_2	and above	400	grms.	milk	0·076	per cent.
0·152	,,	H_2O_2	,,	47	,,	must	0·3	,,
0·152	,,	H_2O_2	,,	15	,,	white of egg solution	1·0	,,
0·152	,,	H_2O_2	,,	400	,,	beer	0·04	,,
0·152	,,	H_2O_2	,,	30	,,	paste	0·5	,,

These experiments were only intended to show that peroxide of hydrogen possesses antiseptic and preserving powers, and were not meant to determine the extent of such influences, but they at least demonstrated that its prophylactic energies are very great.

Messrs. Guttman and Fraenkel, apparently unaware of this prior publication, gave confirmation to my results by some experiments which were published in Virchow's *Archiv*, and to which the *Lancet* (1878, vol. ii., p. 839) subsequently directed further attention. These experiments confirmed the fact that peroxide of hydrogen preserves urine and meat infusions from putrefaction, while it also prevents the fermentation of grape-sugar.

More recently still, the antiseptic properties of peroxide of hydrogen were studied by M. Baldy and also by MM. Paul Bert and Regnard.* After the publication of these researches I took occasion to bring my own earlier investigations to the knowledge of the lamented M. Paul Bert, and in reply he acknowledged my claim of priority and promised to admit and state it to the Academy of Sciences.

The peroxide of hydrogen employed by M. Baldy was prepared after the well-known process of Thénard, care being taken to neutralize the solution by means of argentic sulphate, and diluting it before use so as to work with a solution capable of yielding about twice its own volume of oxygen when subjected to decomposition into water and oxygen.

The observation made by M. Baldy late in 1881, viz., that a small quantity of the peroxide removed the fœtidity from 12 to 15 litres of putrid water, and further trials convinced him that peroxide of hydrogen is an antiseptic agent which is not inferior in any respect to carbolic acid, while it is entirely free from the disagreeable and dangerous character of that compound.

MM. Bert and Regnard, confirming my earlier experiments, have shown that an extremely dilute solution of oxygenated water prevents the fermentation of glucose by the agency of yeast, prevents mycodermic growth in red wine, prevents the lactic fermentation in milk and the putrefaction of albumin, etc. On the other hand, they found that this antiseptic agent was incapable of arresting the changes

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* *Compt. Rend.*, 94. 1383-1386.

induced by soluble ferments, such as diastase, in suitable media. I, too, have for many years been aware of the fact that the peroxide exercises no effect upon the transformation of starch into sugar by means of saliva. The distinction thus arrived at is most important, because, if peroxide of hydrogen, or 'Sanitas fluid,' be employed for internal administration, we have a guarantee that its presence in the system will not substantially arrest or interfere with the many digestive, assimilative and other processes carried on in the living body by means of ferments of the pancreatic type.

Incidentally, it may be observed that the study of peroxide of hydrogen presents many interesting points when compared with M. Bert's investigations of the action of compressed oxygen. Demarquay is stated to have observed that oxygen gas exercises upon wounds a singular stimulating effect, thus inducing rapid cicatrization; while Bert thoroughly studied the influence of compressed oxygen upon living organisms to which he found it proves fatal, although it leaves soluble ferments intact.

It is also of importance to bear in mind the remarkable attenuating influence which M. Pasteur found oxygen to exercise upon such morbific germs as those which are associated with chicken cholera and splenic fever, to the existence of both of which peroxide of hydrogen will almost certainly, in my opinion, be found fatal.

It was to be expected, from what has gone before, that this compound would be found of peculiar benefit for the treatment of wounds and throughout the whole range of antiseptic surgery, an expectation which was amply realized in the practice of M. Baldy, M. Regnard, and in particular of M. Péan, in the hospital of St. Louis. To be brief, it was demonstrated beyond question that all wounds which are treated with peroxide of hydrogen progress well, healing by first intention and giving no trouble whatever, the discharges being healthy in character and free from odour. Chronic ulcers, similarly treated, yield equally good results, as also cases of gangrene, together with fœtid suppurations and bad ozænic discharges.

M. Péan performed many important operations in an atmosphere impregnated with peroxide of hydrogen instead of carbolic acid, with more than an average amount of success, and M. Baldy employed gauze and wool soaked in the peroxide and kept in contact with wounds by means of bandages, in cases where prolonged contact was desirable. He also found that it may with safety be used as an injection for washing out cavities of the body, and he hoped to derive much benefit from its internal administration, particularly in the treatment of diabetes and certain pulmonary affections.

Peroxide of hydrogen destroys pus with rapid evolution of oxygen, while its oxidizing effects upon animal and vegetable matters in a state of incipient change or advanced decomposition have been considered in an earlier chapter.

Dr. Day, of Geelong, believed that it possesses the power of oxidizing and annihilating the poisons of small-pox, scarlet fever and typhoid fever, and has himself furnished some of the data* upon which he arrived at this conclusion, which is evidently not without foundation. Between April, 1873, and the same month of 1875, he treated fifty-one cases of scarlet fever by anointing the bodies of his patients with lard containing peroxide of hydrogen, and in some cases he caused his patients to gargle a very dilute solution of the same reagent. Under this judicious treatment, there was extension of the disease to other persons only in four houses and there were no deaths. Subsequently, Dr. Day treated other sixty-four cases, of which only six proved fatal, whilst there was spreading of the disease only in three cases. These facts go far to teach the disinfecting value of peroxide of hydrogen; for while theorists continue to talk at random about the germs of scarlet fever, there actually exists a substance which seems at once to cure the disease and prevent any extension of the infection.

Although we cannot accurately define the precise manner in which the peroxide of hydrogen acts on the contagious matter thrown off from the skin, we know that diseased matter may thus be rendered powerless to infect, and that is probably owing to its powerful oxidizing effects.

In another chapter, reference has been made to

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* *British Medical Journal*, March 10, 1877. See also paper on 'The Uses of Peroxide of Hydrogen,' by C. E. Shelly, M.B., *Practitioner*, March, 1884.

the further fact that septic vibriones are killed by peroxide of hydrogen even when that solution is extremely dilute.

More recent investigations, including those carried out by M. Miguel, of the Observatoire de Montsouris, appear to establish its claim as one of the most potent destroyers of bacterial life. He states that the smallest quantity of each substance capable of preventing fermentation in 1 litre (2·1 pints) of bouillon was as follows :

Hydrogen dioxide water	0·05	gramme.
Iodine	0·25	,,
Bromine	0·60	,,
Zinc chloride	1·90	grammes.
Carbolic acid	3·20	,,
Potassium permanganate	3·50	,,
Boracic acid	7·50	,,
Sodium salicylate	10·00	,,
Borax	70·00	,,
Absolute alcohol	95·00	,,

Careful comparative tests with antiseptics now much in vogue prove it to be sixty times as powerful as carbolic acid, twenty times as strong as salicylic acid and 40 per cent. more potent than the solution of the bichloride of mercury. However extraordinary or incredible this may appear, experiments seem to have placed it beyond a doubt.

So much for peroxide of hydrogen.

Experiments with the Soluble Camphor of the Composition $C_{10}H_{16}O_3$.

Equally striking are the antiseptic effects of this product of the oxidation of turpentine which is obtained as described in the last chapter. The following account of experiments will sufficiently illustrate this fact.

A solution of white of egg* was made by beating up the whites of four eggs with a quantity of water and filtering from membranous parts. Upon examination, the solution was found to contain 3·97 per cent. albumin (dry at 100° C.) Next, a solution of the soluble camphor containing 1·664 per cent. was prepared.

One stoppered bottle was charged with 20 c.c. of the albumin solution and 30 c.c. water : the mixture grew turbid and became putrid on the sixth day. The other bottle was charged with 20 c.c. of the albumin, 25 c.c. water and 5 c.c. of the antiseptic fluid. This mixture kept perfectly sweet for at least thirteen days. That is to say, 0·0832 grm. of the soluble camphor deferred the putrefaction of the albuminous solution at least eight days.

This experiment was repeated, using stronger antiseptic and albuminous solutions, with confirmative results.

In another experiment 0·75 grm. of the soluble

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* Further experience has shown me that it is much better to employ a dilute extract of meat for experiments of this kind, the indications being much sharper.—AUTHOR.

camphor was dissolved in 110 c.c. of the albuminous solution (containing 0·8 grm. solid substance, dry at 100° C.). The mixture kept clear and good from February 10, 1879, till April 21, after which it was no longer observed. At that time the solution contained its albumin in a perfectly unchanged state.

The Volatile Substance $C_{10}H_{14}O$.

Powerful antiseptic properties are also possessed by the thymol-like body constituting the more volatile portion of the solution (to which the odour is chiefly due, and which is obtained on distillation of the fluid). This feature makes 'Sanitas fluid' more valuable, since it is thus better qualified to serve as an air purifier. It is therefore seen that each constituent of the solution in question contributes towards its total effect as an antiseptic and disinfectant. Of course it will be understood that acquaintance had been made with the characters of the solution as a whole, so far as this was possible, long before the experiments on its individual constituents were conducted, and also long before the solution ever became known to the public in commercial form, as 'Sanitas fluid.'

Experiments with 'Sanitas Fluid' and 'Sanitas Oil.'

It is not necessary to reproduce here an account of all the earlier experiments which were made and described in former editions of this work respecting the antiseptic and disinfectant properties of 'Sanitas fluid' and 'Sanitas oil,' but an account is given hereafter of a more recent investigation of a quantitative nature, as also of precise investigations concerning the germicidal properties of both these preparations. 'Sanitas fluid,' even when diluted with eight or ten times its bulk of water, is sufficiently powerful to prevent and arrest putrefactive changes, and when used in a less diluted state, its capacity for work increases accordingly. It does not stain, is perfectly non-poisonous and is without corrosive properties. On the other hand, indeed, it is pleasantly aromatic in character, and is qualified for universal application. For diffusing into the atmosphere of inhabited apartments and sick-rooms it presents a really great advantage, inasmuch as it easily parts with oxygen and thus atones to some extent for that which is used up by human beings, etc.

As regards the uses of 'Sanitas fluid' in surgery, they may be said to be identical in the main with those of peroxide of hydrogen already described in connection with that substance, but, in addition, it possesses the valuable antiseptic properties of its other several constituents.

In four experiments made by Dr. J. W. Miller,* in which lymph was mixed with 'Sanitas fluid' in equal proportions and allowed to stand for eight hours and upwards, the disinfection of the lymph was complete ; that is to say, its infectivity was quite destroyed.

'Sanitas oil' is much more powerful than the fluid, and ranks, indeed, as one of the most potent antiseptics. Its characters in this respect are quite

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* *Practitioner*, October, 1884, p. 264.

apart from, and additional to, its power as an oxidizing agent, and it exhibits, as we shall see later, a correspondingly great germicidal power.

Its power as an oxidizing agent may be judged from the calculation that, assuming its active oxygen could be obtained in the gaseous state, 1 gallon of 'Sanitas oil' would give 25 litres, or between 5 and 6 gallons, of that gas.

'Sanitas oil' is by no means intended to supersede, in any degree, the use of 'Sanitas fluid,' but only to supplement it; indeed, while it is far too powerful in its action to serve the purposes for which the aqueous solution is intended, its physico-chemical properties do not qualify it to meet the same ends. It may be employed for adding to glycerine, oils, or ointments, when these various substances are applied to the body, either during the peeling stages of several infectious diseases, or when any suppurative action or morbid process requires to be arrested. It can also be used for producing a powerful spray for the antiseptic treatment of wounds and the throat in cases of diphtheria. Further, its evaporation forms an excellent expedient for the fumigation of apartments inhabited by persons suffering from communicable diseases. An ordinary-sized room requires about 1 fluid ounce of the oil, which should be evaporated from the surface of water in a saucepan or kettle. Any plane surface, such as is presented by flooring and walls, may be effectually disinfected by simply smearing or wiping it over with a cloth or brush dipped in the oil, and in such operations a very minute amount of the substance goes a long way, by reason of its great spreading qualities. The oil is slowly volatile and hence it is available for use as an aerial disinfectant. Although not appreciably soluble in water, it may readily be made into an emulsion therewith by the agency of gum acacia, and, indeed, such a product is now made and sold for general disinfecting purposes under the name of 'Sanitas emulsion.' This product can be used with advantage for watering streets in times of epidemics, also for the deodorization of wooden pavements and offensive collections of any kind. Other crude and powerful fluids are now also available for washing animals, and as sheep-dips, etc.

'Sanitas oil' is soluble in spirit, and readily mixes with other oils. Sprinkled over sawdust, it forms a most effective deodorant for use in urinals, kennels and other places where a fluid as ordinarily applied is too soon carried away from the scene of action. No doubt many other applications will occur to the minds of readers, but enough has now been said respecting the uses that may be made of this product for antiseptic and disinfecting purposes.

In previous chapters, treating of the relations of micro-organisms to disease and the science of disinfection, I have shown that micro-organisms are rather the indirect than the immediate causes of certain diseases; indeed, it is not going too far to say that at the present time there is a consensus of opinion amongst those who are best entitled to pronounce upon the subject, to the effect that so-called germ diseases are really due to the physiological effects of chemical substances elaborated by or through the agency of micro-organisms. I claim credit for having all along advocated these views,* which have only recently received general adoption.

Our power to control the life of microbes is necessarily very limited, and is based upon our acquaintance with their life-history as ascertained by chemical investigation. We know or can ascertain that they find life possible in certain numerous media, and we also know, or can find out by actual experiment, to what extent their life is destroyed or interfered with by certain chemical substances. To destroy them locally without injury to the human body, to suspend their life-actions by means of suitable chemical substances, until that part of the body which has been diseased through their influence has recovered its normal stage and strength; similarly, so to influence, or to interfere with, the life of these micro-organisms that some particular poisons which they are capable of producing shall be no longer formed, or, if allowed to be formed, shall be instantly destroyed in a chemical sense: these are the legitimate objects of sanitary science.

The germ theory of disease, as still stupidly misunderstood by many, concerns itself alone with the parasite and utterly ignores the host. Bacteria are observed in diseased parts and the various tissues, but in what relation to the disease and the tissues they stand—how the tissues (or rather their cells) are affected by the bacteria (or rather their chemical pro-

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* See *Soc. of Arts Journal*, March 8, 1878.

ducts)—are subjects which still receive scant attention. Virchow has also indicated this defect in current investigations,* and it may be safely predicted that after a time there will be a more or less sudden devotion of scientific attention to the life-history of the cells which build up the human body,† and parasitic micro-organisms will then for a while become the subject of neglect. It is a pity that both subjects should not be dealt with simultaneously.

Until we know more of cell life, it appears to me that progress, of necessity, will have to depend upon investigation conducted in the chemical laboratory; for chemists can construct many mixtures of known composition in which micro-organisms will grow, multiply and flourish, and, similarly, they can both qualitatively and quantitatively ascertain in what ways the chemical molecules are broken down and rearranged by the life agencies of the micro-organisms, and thus they can also place a quantitative value upon the action of so-called antiseptics and disinfectants.

It is in this sense that I, some few years since, conducted an investigation of which an account is given in the following pages.

The details of some later researches in the same direction have been referred to in an earlier place (see Chapter VIII.).

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* *Archiv der Path. Anat.*, Bd. 101, Heft 1.

† These words were originally written by me only a few years since, and already they are becoming verified. (See Chapter VIII., on Phagocytosis and Immunity.)

The Chemical History of Some Micro-organisms.

YEAST AND THE FERMENTATION OF GLUCOSE.

EXPERIMENT I.—A solution of glucose dissolved in water was prepared, containing, as was afterwards ascertained, 1·670 grms. of glucose in each 100 c.c.

A pasty solution of ordinary yeast was then made, containing about 12·10 per cent. by weight in volume. A microscopic examination of the yeast solution revealed the presence of numerous yeast cells of ordinary appearance and many sorts of living micro-organisms.

A quantity (995 c.c.) of the glucose solution was inoculated with 5 c.c. of the yeast solution, and the 'total solid contents' of the mixture was determined and found to be 1·690 per cent.

A mixture (A) of 75 c.c. glucose and yeast solution with 25 c.c. of pure water was placed in one flask, fitted with a cork and bent glass delivery tube, while in a second similar apparatus was placed a mixture (B) of 75 c.c. glucose and yeast solution, 20 c.c. of 'Sanitas fluid' (as sold)* and 5 c.c. water.

After standing at the ordinary temperature of the laboratory during thirty-one days, a chemical examination of the several mixtures was made. That is to say, the total solid contents of each solution was determined, and the amount of alcohol produced by fermentation was ascertained by distilling a known quantity of

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* This solution, upon evaporation to dryness, left a residue = to 2·31 per cent.

each mixture, and taking the specific gravity of the distillates. The results are tabulated as follows :

	Original total solids.	Final total solids.		Loss in weight.	Percentage of loss.	Alcohol produced.	Alcohol calculated.
A.	1·2675	0·486	=	0·7815	61·6	0·4576	0·4000
B.	1·7295	1·700	=	0·0295	2·3	None.	—

The alcohol is calculated upon the basis of the following equation, which represents the fermentation of glucose into alcohol by the agency, as it is supposed, of a soluble zymase, formed by the yeast cells :

$$C_6H_{12}O_6 = 2C_2H_6O \text{ (Alcohol)} + 2CO_2 \text{ (Carbon Dioxide)}.$$

Experiment II.—A fresh solution of glucose was prepared and inoculated with some yeast ; its total solid contents = 8·11 per cent.

A. 75 c.c. of this inoculated solution was mixed with 25 c.c. water.

B. 75 c.c. of the inoculated solution was mixed with 25 c.c. of 'Sanitas fluid' (the total solid residue of which dry at 100° C. = 2·694 per cent.).

The two mixtures were placed in flasks as before, fitted with corks and tubes for the delivery of any gas that might be evolved, and kept during seven days. Mixture A gave off a great deal of gas ; it was not accurately measured, but over 375 c.c. was roughly measured as collected. Mixture B did not give off even a trace of gas.

The chemical examination of the solutions at the termination of the experiment gave results which are here tabulated as follows :

	Original total solids.	Final total solids.	Loss in weight.	Percentage of loss.	Alcohol produced.	Alcohol calculated.
A.	6·0825	3·4950	2·5875	42·5	1·44	1·32
B.	6·7560	6·7560	None.	—	None.	—

A microscopical examination of mixture A showed the presence of many living yeast cells and a great number of micro-organisms (many of which were in active motion) including single cells, association of cells in rods and chains and the *bacterium termo.* A similar examination of mixture B revealed the presence of much fewer yeast cells (not growing) and no moving micro-organisms were to be seen.

One-third of the mixture A was now taken while in active fermentation, and to it was added 10 c.c. of 'Sanitas fluid,' the mixture being replaced in the original flask. The addition of the 'Sanitas fluid' absolutely put an end to the fermentation; not a trace of gas was evolved, and an examination made after seven days, showed that practically no further loss of glucose had occurred, and consequently, also, no further alcohol was produced.

Original total solids.	Final total solids.	Alcohol at start.	Alcohol at end.
1·4344	1·424	0·500	0·525

The trivial change that is noticeable undoubtedly occurred in the interval between the original examination of mixture A and the time when the 'Sanitas fluid' was added.

This result is interesting because it proves that, in addition to its property of preventing the development of yeast cells in glucose solution, together with the resulting chemical changes, 'Sanitas fluid' also arrests their development instantly, even when in the most active stage of growth.

Experiment III.—A further solution of glucose, impregnated with yeast, was prepared, yielding a total solid residue of 8·016 per cent. dry at 100° C. Three mixtures of this solution were prepared as follows:

A. 75 c.c. of inoculated glucose solution + 25 c.c. water.
B. 75 c.c. " " " + 5 c.c. " + 20 c.c. of 'Sanitas fluid.'
C. 75 c.c. of inoculated glucose solution + 25 cc. of a 20 per cent. solution of 'Sanitas emulsion.'*

The 'Sanitas fluid' which was used in mixture B yielded 4·758 per cent. of solid matter, dry at 100° C.

After standing seven days the experiments were brought to a conclusion by a chemical examination of each mixture, and the following tabulated results were obtained:

	Original total solid contents.	Final solid contents.	Loss in grms.	Per cent. of loss.	Alcohol formed.	Alcohol calculated.
A.	6·012	4·2855	1·7265	28·55	0·870	0·882
B.	6·9636	6·9585	0·0051	0·073	None.	—
C.	7·3355	7·287	0·0485	0·633	None.	—

These results are confirmative of those observed in the earlier experiments, and at the same time show that very small quantities of 'Sanitas emulsion' (and 'Sanitas oil,' from which it is made) act like 'Sanitas fluid' in preventing alcoholic fermentation dependent upon the growth of yeast.

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* = 5 c.c. of 'Sanitas emulsion' in the undiluted state, and consequently about 2·5 c.c. of 'Sanitas oil.'

YEAST AND THE FERMENTATION OF STARCH.

I thought it would be of some interest and importance to ascertain if, by the living presence of yeast in a solution of starch, that chemical substance is resolved into alcohol. Such a result, if established by experiment, would be of value, not alone from a chemical and technical point of view, but also as bearing upon the germ theory of disease. It is too often assumed, without ascertained foundation in fact, that each particular micro-organism exhibits only one mode of life, so to say; in other words, that each micro-organism has the property of initiating one chemical change only. Thus, by a habit of mind, we identify the yeast plant strictly with alcoholic fermentation, the *bacterium lactis* only with the souring of milk, and so on. If, however, it can be shown that the yeast plant can split up other chemical substances besides sugar, such, for example, as starch and gum, and produce other products besides alcohol, say, for instance, acetic acid, the field of life-action of minute forms of life is seen to be much larger than was before thought, and we are thereby enabled to understand that, whereas, under one set of circumstances, a micro-organism may give rise to the formation of chemical products which cause disease, under other circumstances merely innocuous products may result and thus no injury to health will ensue.

EXPERIMENT.—A solution of starch containing about 2½ per cent. was made, and to 145 c.c. of it there was added 5 c.c. of a thick mixture of yeast suspended in water. The total solid contents of the inoculated mixture, dry at 100° C., were now estimated, and found to be 2·300 per cent.

100 c.c. of the inoculated mixture was placed in a flask fitted with an indiarubber cork and bent glass tube, the end of which dipped into a bath of mercury. The fermentation of the starch commenced immediately, gas being freely evolved from the 19th of May until June 5, when, although it had slackened, it was still proceeding. On June 16, although the fermentation had not even then ceased, the experiment was brought to a conclusion, and the total solid contents and alcohol present in the fermented mixture were determined. The total solid contents had fallen from 2·300 to 1·326 per cent., showing a loss of 42·34 per cent., and an actual loss of 0·974 grm. in weight. The alcohol present in the fermented mixture amounted to 0·542 grm., as ascertained by the specific gravity of the distillate of an aliquot part.

Now, if we assume the fermentation of starch experienced in this experiment to have taken place in accordance with the following equation :

$$C_6H_{10}O_5 + H_2O = 2C_2H_6O + 2CO_2,$$

then a loss of 0·974 grm. starch should result in the production of 0·552 grm. alcohol, and there was practically obtained 0·542 grm., which is a closely approximating amount.

It was thus established that yeast cells can split up the molecule of starch into alcohol and carbon dioxide, just as it can also split up the molecule of sugar into the same products. Whether or not the starch molecule is first of all converted into glucose by the yeast or a soluble ferment produced from it, in this process of fermentation into alcohol and carbonic anhydride, is unascertained.

YEAST AND THE FERMENTATION OF GUM.

EXPERIMENT.—A solution of East Indian gum in water was prepared and inoculated with 5 c.c. of a pasty mixture of yeast suspended in water. The amount of total solid contents dried at 100° C. was now determined, and found to be 5·460 per cent.

On May 19, 100 c.c. of this prepared mixture was placed in a flask, which was fitted as described in the preceding section dealing with the fermentation of starch. Until May 28 the fermentation, as judged by the evolution of carbonic anhydride, proceeded but slowly; then there was a somewhat sudden change, and fermentation proceeded rapidly. On June 16 the experiment was brought to a conclusion and the fermented mixture was chemically examined, with the results now to be described.

The total solid contents dry at 100° C. had diminished from 5·460 grms. to 4·7355 grms., indicating a loss of 0·7245 grm., or 13·26 per cent.

The fermented solution contained no alcohol, but it was strongly acid in character, and the acidity of the distillate obtained from 130 c.c. of the fermented solution (which had been made up to 150 c.c. by addition of water) was determined, and calculating from the result thus obtained, the total acidity of the whole quantity was equivalent to 54·23 c.c. of decinormal caustic soda solution. This acidity is equal to 0·3253 grm. of pure acetic acid, and the identity of the acid was subsequently established by well-known chemical methods. The chemical constitution of gum is, unfortunately, not yet ascertained, and therefore it is not possible to express with any degree of certainty the stages of decomposition of its molecule by the yeast. If, however, we assume the formula of gum to be $C_6H_{10}O_5$ and the chemical change to be as follows:

$$C_6H_{10}O_5 + H_2O + O_4 = 2CO_2 + 2H_2O + 2C_2H_4O_2,$$

then 0·7245 grm. gum should yield 0·536 grm. acetic acid, whereas there was only found 0·3253 grm. It is possible, of course, that oxidation by other agencies (micro-organisms) had proceeded further, and that part of the acetic acid had been resolved into carbon dioxide and water.

As the product in question contained no alcohol at all, I see no reason for rejecting the idea that the fermentation was of a direct character, and that the immediate products were acetic acid and carbon dioxide.

In any case, the results are interesting, and while they open up a wide field for new investigation, they accentuate the views to which I have called attention in earlier pages of this chapter.

Bacterium Lactis and the Fermentation of Milk and Milk-Sugar.

Experiment I.—A quantity of fresh milk was taken and the milk-sugar present in it was determined by first of all greatly diluting it with water (10 c.c. with 90 c.c. water), and then estimating the sugar by the well-known process which makes use of Fehling's solution volumetrically. It contained 4·422 grms. milk-sugar in each 100 c.c. It was also experimentally proved to be quite free from lactic acid.

Quantities of the milk were now mixed with water and 'Sanitas fluid' respectively, as follows, and placed in flasks loosely covered with filter paper, on July 7 :

A. 50 c.c. milk + 50 c.c. water.
B. 50 c.c. ,, + 30 c.c. ,, + 20 c.c. 'Sanitas fluid.'
C. 50 c.c. ,, + 25 c.c. ,, + 25 c.c. ,, ,,
D. 50 c.c. ,, ... + 50 c.c. ,, ,,

On July 20 the perfect coagulation of each mixture was effected by warming, after which each was filtered ; the filtrate was then made up to a known volume by washing the coagulum with warm water, and the sugar present in each filtrate and its acidity were determined.

In order to understand the table that follows, it must be stated that 'Sanitas fluid' reduces Fehling's solution like sugar, and this capacity was estimated beforehand and calculated into terms of milk-sugar (100 c.c. of this particular sample reduced 540·5 c.c. Fehling's solution = to 3·62 grms. milk-sugar). Similarly, the acidity of the 'Sanitas fluid' was determined volumetrically (100 c.c. of this particular sample required 90 c.c. N/10 NaHO solution).

	Sugar originally present.	Sugar present at end.	Difference due to fermentation.	Original acidity.	Final acidity.
A.	2·211	None.	2·211 grms.	—	28 c.c. N/10 NaHO
B.	2·935	2·935	—	18 c.c.	18 c.c. ,,
C.	3·116	3·116	—	22·5 c.c.	22·5 c.c. ,,
D.	4·021	4·021	—	45·0 c.c.	45·0 c.c. ,,

The first conclusion to be drawn in connection with these results is that 'Sanitas fluid,' when present in sufficient amount (and that is not a large one), wholly prevents the conversion of milk-sugar into lactic acid by the agency of the *bacterium lactis.* A microscopical examination of the fermented mixture A revealed the presence of a great number of the bacteria in question, but none could be observed in the mixtures B, C, D; similarly the *bacterium termo* was seen to be present in A in a very active state, but it was not present at all in B, C, and D.

Now, to look at the results from a quantitative and chemical point of view, the lactic fermentation is expressed by the following equation:

$$C_6H_{12}O_6 = 2C_3H_6O_3,$$

which indicates the splitting up of 1 molecule of milk-sugar into 2 molecules of lactic acid.

From this it is calculated that a loss of 2·211 grms. milk-sugar should yield 2·211 grms. of lactic acid, whereas the acidity of mixture A was only equal to 0·252 grm. lactic acid. How is this difference to be accounted for? In two ways: in the first place, unless the lactic fermentation is stopped precisely when all the milk-sugar has disappeared, the lactic acid is itself resolved by subsequent changes into acetic, butyric, and propionic acids, and finally these acids are split up by oxidation into ultimate products (carbon dioxide and water); in the second place, the lactic fermentation as thus carried out may not be pure in character; that is to say, other ferments are present besides the *bacterium lactis*, and other products are thus produced, perhaps alcohol amongst them.

EXPERIMENT II.—The experiment which has just been described was repeated with another sample of milk containing 3·88 grms. milk-sugar in each 100 c.c., but using the same sample of 'Sanitas fluid.' The mixtures were made up as before, on August 4, and the experiments were brought to an end on August 13.

	Sugar originally present.	Sugar present at end.	Difference due to fermentation.	Original acidity.	Final acidity.
A.	1·940	0·980	0·960	—	37·5
B.	2·664	2·664	—	18 c.c.	18 c.c.
C.	2·845	2·845	—	22·5 c.c.	22·5 c.c.
D.	3·750	3·750	—	45 c.c.	45 c.c.

Here, again, it is seen that fermentation occurred only in the unprotected milk, and inasmuch as the mixtures were not allowed to stand so long as before, the quantity of lactic acid found in A mixture, in comparison with the loss of sugar, is much greater, as was to be expected from the conclusions drawn in respect of the preceding experiment. If the whole of the 0·96 grm. of milk-sugar had been changed into lactic acid, and none of this had been destroyed by other chemical changes, there would have been obtained 0·96 grm. lactic acid instead of 0·3375 grm. actually observed to be present.

Experiment III.—Some 245 c.c. of fresh milk was inoculated with 5 c.c. of very sour milk; then the milk-sugar and acidity of the inoculated mixture were carefully determined, and the following mixtures were then made and placed in glasses as before. On this occasion, however, another sample of 'Sanitas fluid' was used. It contained reducing matter equal to 0·87 grm. of milk-sugar per 100 c.c., and the acidity of the same quantity was equal to 115 c.c. N/10 NaHO solution.

Mixtures.

A. 50 c.c. inoculated milk + 50 c.c. water.
B. 50 c.c. „ „ + 50 c.c. „
C. 50 c.c. „ „ + 25 c.c. „ + 25 c.c. 'Sanitas fluid.'

The mixtures were made on August 20, and were examined on August 24.

	Sugar originally present.	Sugar present at end.	Difference due to fermentation.	Original acidity.	Acidity at end.
A.	2·185	1·675	0·510	0·5 c.c.	44·5
B.	2·185	1·654	0·530	0·5 c.c.	45·7
C.	2·4025	2·4025	—	29·25	29·25

The results of the examination of mixtures A and B are seen to be thoroughly and mutually confirmatory in character. Taking A, the loss of the milk-sugar could produce a maximum of 0·510 grm. lactic acid, whereas the acidity of the ultimate mixture was equal to 0·4005 grm., showing only 0·1095 grm. to be accounted for. It is to be noted that the approximation of the theoretical and actual quantities of lactic acid is much greater than in either of the previous experiments, and doubtless the reason is that the mixtures were only allowed to stand over four days. In order to test the supposition that alcohol might also be found amongst the products, thus accounting for the difference, one half of each mixture A and B was subjected to distillation, and the specific gravity of each distillate after being made up to the original volume was determined, and found to be respectively 0·99977 and 0·99973. Not unlikely, therefore, alcohol was present in the fermented mixtures in more than sufficient amount to fully account for the deficiency in lactic acid produced. Thus, the deficiency of lactose or lactic acid to be accounted for in A is 0·0995 and in B = 0·0887 grm., whereas the alcohol calculable as present in A = 0·27 grm., and in B = 0·28 grm. Now, 0·0995 grm. lactose would only furnish 0·0508 grm. alcohol. The explanation is this: the alcohol which was presumably present was all derived from the fermentation of lactose; whereas a small proportion of the total acidity of mixtures A and B was derived from butyric and other soluble fatty acids which resulted from the rancidity of the cream or fat contained in the milk, thus swelling the amount of acid which is, as explained, not derived solely from the lactose.

Either, then, the *bacterium lactis* performed the double chemical change whereby lactose was resolved into alcohol and lactic acid, or it was accompanied in these experiments with other forms of microscopic life which fermented a part of the lactose into alcohol and carbon dioxide.

Before passing on to other experiments, it should be mentioned that 'Sanitas fluid,' by its acidity, determines more or less the coagulation of milk when mixed therewith, whereas the coagulation of the unprotected milk is of course brought about by the lactic acid produced in the fermentation.

I have ascertained that just as 'Sanitas fluid' protects the milk-sugar which is contained in milk from undergoing lactic fermentation, so also it acts towards pure milk-sugar. In the unprotected samples the milk-sugar solution, when inoculated, steadily decreased in amount, while lactic acid and the other products were formed; whereas when 'Sanitas fluid' was present (even after thirty-seven days in one case), there was no diminution whatever in the amount of milk-sugar, and no products of fermentation were obtained.

Similarly, while the *bacterium lactis* was richly developed in the unprotected mixtures, a microscopic examination failed to detect the presence of the ferment in the mixtures protected by 'Sanitas fluid.'

AMMONIACAL FERMENTATION.

EXPERIMENT I.—Some urine was placed in a warm situation until it had commenced to ferment and formed a deposit. A quantity of freshly-voided urine was then inoculated with some of the deposit from the fermented specimen. The total solid contents of the mixture was then determined and found to be 4·474 per cent. dry at 100° C. The mixture was neutral in character.

On July 15 the following mixtures were made:

A. 50 c.c. inoculated urine + 50 c.c. water.
B. 50 c.c. " " + 25 c.c. " + 25 c.c. 'Sanitas fluid.'
C. 50 c.c. " ... ... " + 50 c.c. " "

The mixtures were placed in loosely corked bottles, and allowed to stand until July 27, when each was made up to a known volume, and the total solid contents and the alkalinity or acidity determined.

Mixture A was dark in colour, and very cloudy, while B and C were perfectly brilliant and sweet.

	Original total solid contents.	Total solid contents at end.	Original acidity.	Final acidity.	Final alkalinity.
A.	2·237	1·782	—	—	21·0 c.c. N/10 H_2SO_4.
B.	3·712	3·712	22·50	22·50	
C.	5·188	5·188	45·00	45·00	

From these results, it is apparent that in B and C the urea present in the urine was entirely protected from ammoniacal fermentation, while in the unprotected (A) mixture there was a loss of 0·455 grm. in solid contents, and ammonium carbonate was formed in consequence.

According to the equation:

CH_4N_2O (urea) + $2H_2O$ (water) = $(NH_4)_2CO_3$ (carb. ammon.),

the ammonium carbonate actually produced in A was only equivalent to 0·0634 grm. urea, as compared with the loss of 0·455 grm. experienced in the solid contents.

Doubtless the *torulaceous* ferment was accompanied with other ferments, and thus the fermentation was mixed in character; but it is evident that, mixed or unmixed, the presence of 'Sanitas fluid' prohibited the fermentation — a fact which affords reasonable hope that this reagent may be used with great advantage in the treatment of those diseases in which the urine is passed from the bladder in an ammoniacal condition.

EXPERIMENT II.—In the next experiment the urine was not inoculated as before.

The following mixtures were made on August 5, and examined on August 17:

A. 50 c.c. urine + 50 c.c. water.
B. 50 c.c. urine + 25 c.c. ,, + 25 c.c. 'Sanitas fluid.'
C. 50 c.c. urine + 50 c.c. ,, ,,

The urine used in this experiment contained 4·147 per cent. matter dry at 100° C., and was acid in character, 100 c.c. requiring 10 c.c. N/10 NaHO.

	Original total solid contents.	Total solid contents at end.	Difference due to fermentation.	Original acidity.	Final acidity.	Final alkalinity.
A.	2·0735	1·5075	0·5660	5 c.c.		112·05
B.	3·5490	3·5490	—	27·5	27·5 c.c.	—
C.	5·0245	5·0245	—	50·0	50·0 c.c.	—

These figures fully confirm the results of the earlier experiment and the protective character of 'Sanitas fluid,' while they show a better accord with a theoretically pure *torulaceous* fermentation.

Thus, in mixture A, the $(NH_4)_2CO_3$ which was produced, not only neutralized the acid urine, but also required further 112·05 c.c. N/10 solution of sulphuric acid, the total alkalinity, therefore, being equal to 117·05 c.c. N/10 H_2SO_4.

Assuming the loss of solid contents to be entirely due to urea, it is expressed as 0·566 grm., whereas the ammonium carbonate which was found present required the conversion of 0·351 grm., thus accounting for 62·01 per cent. of the total quantity.

ACETIC FERMENTATION OF ALCOHOL.

Although I made a great number of experiments, using both chemically prepared alcohol and also white and red wines, upon the general plan already indicated, they resulted in failure. That is to say, the alcohol was not oxidized into acetic acid, nor did the sugar or the total solid contents (of the wines) diminish appreciably in amount. In some few cases the acidity increased somewhat, but in these it appeared to be rather at the expense of some other constituent than sugar or alcohol.

PUTREFACTION.

EXPERIMENT I.—One pound of beef-steak was extracted with water during two hours at a gentle heat, after which the extract was cooled, filtered, and made up to 250 c.c. The total solid contents of this extract amounted to 2·764 grms. in 100 c.c.

The following mixtures were now prepared and then placed in clean stoppered bottles:

A. 75 c.c. extract of meat + 25 c.c. water.
B. 75 c.c. „ „ + 25 c.c. 'Sanitas fluid.'
C. 75 c.c. „ „ + 20 c.c. water + 1 c.c. 'Sanitas emulsion.'

After standing 20 days, the total solid contents of each mixture was again determined and the results are given below:

	Original total solid contents.	Total solid contents after twenty days in closed bottles.	Loss due to putrefaction.
A.	2·073	1·862	0·211 grm., or 10·18 per cent.
B.	2·7465	2·7465	—
C.	2·9975	2·9975	—

A microscopical examination revealed in A the presence of a large number of the micro-organism, *bacterium termo*, in active motion, but none were visible in B and C.

Experiment II.—In the next experiment, the 'Sanitas fluid' which was used gave, upon examination, the following analytical results:

Total solid residue dry at 100° C. = 5·902 per cent.
Acidity of 100 c.c. = to 90 c.c. N/10 NaHO.
Peroxide of hydrogen in 100 c.c. = to 238 c.c. N/10 $Na_2S_2O_3$.

An extract of meat was prepared showing, upon examination, the presence in 100 c.c. of 2·084 grms. dry at 100° C.

The following mixtures were placed in bottles loosely covered with filter paper:

A. 50 c.c. meat extract + 50 c.c. water.
B. 50 c.c. „ + 50 c.c. „
C. 50 c.c. „ + 50 c.c. 'Sanitas fluid.'

Mixtures A and B became putrid upon the second day, and then revealed under microscopic examination the presence of a large number of the *bacterium termo* in very active motion. The mixture C then and thereafter remained quite undecomposed, and contained no micro-organisms in motion.

After standing ten days, an analytical examination of the mixtures was made, and the following are the results which were obtained :

	Original total solid residue, dry at 100° C.	Total solid residue at end.	Loss due to putrefaction.	Original acidity.	Final acidity.
A.	1·0425	0·738	0·3045	—	Neutral.
B.	1·0425	0·735	0·3075	—	Neutral.
C.	3·9935	3·9555	0·0380	45 c.c. N/10 NaHO.	45 c.c. N/10 NaHO.

I regard the insignificant loss of matter experienced by mixture C to be due entirely to the oxidizing action of the peroxide of hydrogen present in the 'Sanitas fluid,' and it may therefore be disregarded. The unprotected mixtures lost respectively 29·20 per cent. and 29·49 per cent. of the dry meat extract by putrefaction ; that is to say, by hydrolysis and oxidation effected by the life action of micro-organisms, among which the *bacterium termo* is one of principal importance.

EXPERIMENT III.—Now, before the chemical examination which has just been reported was made upon the several mixtures A, B and C, they were each made up to 150 c.c. by the addition of water. Of these diluted mixtures there were now taken respectively 100 c.c. (A), 100 c.c. (B), and 90 c.c. (C), and these portions were allowed to stand further twelve days, after which they were again chemically examined. The results are expressed in such a way that the change is at once apparent :

	Total solid residue at commencement.	Total solid residue at end.	Loss due to putrefaction.	Alkalinity or acidity at start.	Alkalinity or acidity at end.
A.	0·492	0·390	0·102	Neutral.	7·77 c.c. N/10 acid.
B.	0·490	0·375	0·115	Neutral.	8·49 c.c. N/10 acid.
C.	2·3733	2·3733	Nil.	27 c.c. N/10 NaHO.	27 c.c. N/10 NaHO.

Expressing these results in words, it may be said that, while the mixtures A and B, during this further period of exposure, lost respectively 20·7 per cent. and 23·4 per cent. of their total solid contents by putrefaction, the mixture C lost no part of its solid contents. Further, it is important to note that, whereas in the earlier stage of the observations no ammoniacal product was formed in A and B (unless, indeed, an acid product able to exactly neutralize it was also formed), in this later stage we have an alkaline product of putrefactive decomposition in mixtures A and B, which required respectively 7·77 and 8·89 c.c. of N/10 sulphuric acid to neutralize.

These facts accord with what was previously known regarding the chemistry of putrefaction, and they also assist in forming an accurate mental appreciation of the stages in which that process is completed.* They further established the antiseptic

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* See also my paper entitled 'Contributions to the History of Putrefaction,' *Journ. Chem. Soc. Trans.*, 1880, p. 15.

properties of 'Sanitas fluid' and its germ-destroying character, for all the mixtures were equally exposed to the attacks of micro-organisms, which flourished in the unprotected mixtures, but were destroyed by the 'Sanitas fluid' present in the protected mixtures.

CHEMICAL ACTIONS OF SOLUBLE FERMENTS.

The question arises: to what extent are the various processes of fermentation with which we are acquainted, the consequences of vital functions of micro-organisms? To this question no satisfactory answer has yet been accorded. That the processes are not due to the mere mechanical presence of the living agents is obvious, although realized by few writers upon this subject. The very essence of a process of fermentation is a change of chemical systems, and this necessitates an acting chemical agency; that is to say, fermentation is the result of a chemical impulse communicated to the fermentable substance by chemical contact with another substance secreted by or resulting otherwise from living organisms, and yet otherwise perfectly independent of them. That the real ferments are independent of the living organisms which produce them is assured by the fact that the organisms themselves do not disappear in the chemical changes which constitute the fermentation proper. It is by such reasoning as this that we arrive at the inference, for example, that before ordinary cane-sugar becomes transformed by fermentation into alcohol, it is split up into glucose and lævulose by a chemical act of hydration, which is initiated by a soluble zymase, which, in its turn, is secreted by yeast.

Similarly, emulsine is known to transform amygdaline into essence of bitter almonds; whilst barley is known to yield by germination and extraction a soluble principle which converts starch into sugar. Well known, also, are the transformations of starch into sugar by the action of ptyalin (the ferment of saliva), and of albuminoids into peptones by the action of pepsin. It is more particularly with these last-named subjects that I shall now occupy some attention.

SALIVA AND THE FERMENTATION OF STARCH.

EXPERIMENT I.—A solution of starch was made and then inoculated with a small quantity of saliva, after which the total solid contents were determined and found to amount to 1·732 per cent. dry at 100° C.

The following mixtures were then prepared, and placed in open test glasses on July 13:

A. 50 c.c. inoculated starch solution + 50 c.c. water.
B. 50 c.c. „ „ „ + 25 c.c. „ + 25 c.c. 'Sanitas fluid.'
C. 50 c.c. „ „ „ + 50 c.c. 'Sanitas fluid.'

The 'Sanitas fluid' which was used in this experiment gave 5·902 per cent. total solid residue dry at 100° C., and contained matter which reduced Fehling's copper solution equal in amount to 2·7025 grms. grape-sugar per 100 c.c.

On July 24 the solutions were made up to a known volume and chemically examined, with the results which are shown in the following synopsis :

	Reducing matter calculated as sugar originally present.	Reducing matter calculated as sugar present at end.	Difference due to action of ptyalin.	Percenaage of starch converted.
A.	None.	0·577 grm.	0·577	60
B.	0·6756	0·700	—	—
C.	1·44	1·3512	—	—

It is seen that in the absence of 'Sanitas fluid' the starch in the unprotected mixture was converted to the extent of 60 per cent. by the chemical change :

$$C_6H_{10}O_5 + H_2O = C_6H_{12}O_6,$$

whereas in the mixtures containing 'Sanitas fluid,' practically no change occurred, the slight differences in the quantity of sugar which were found present before and after being within the limits of error of experiment.

Experiment II.—A further experiment was made with a starch solution inoculated with saliva, containing 4·472 per cent. matter dry at 100° C., and using another sample of 'Sanitas fluid' (containing matter fixed at 100° C. = to 5·975 per cent., and reducing substance, which, calculated as grape-sugar, amounted to 0·6493 per cent.). The total acidity of the 'Sanitas fluid' was per 100 c.c. = to 115 c.c. N/10 caustic soda solution.

Mixtures were prepared as follows on July 30 :

A. 50 c.c. inoculated starch + 50 c.c. water.
B. 50 c.c. ,, ,, + 50 c.c. water.
C. 50 c.c. ,, ,, + 25 c.c. 'Sanitas fluid' and 25 c.c. water.
D. 50 c.c. ,, ,, + 50 c.c. ,, ,,

On August 19th a chemical examination of the mixtures was made, and the results are here appended:

	Sugar or reducing matter found present.	Sugar or reducing matter originally present.	Gain.	Percentage of starch converted.
A.	0·9025	None.	0·9025	18 per cent.
B.	0·8808	None.	0·8808	,,
C.	0·2284	0·1623	0·0661	Trace.
D.	0·3304	0·3247	0·0057	None.

From mixture B a minute drop had been taken each morning for testing purposes, thus accounting for the slight difference between the result as compared with that of A.

Generally, the results fully confirm those of the earlier experiment.

Experiment III. — As 'Sanitas fluid' contains peroxide of hydrogen, and is, in terms of this substance, of about two volumes in strength, it became of interest to ascertain to what extent, if at all, the anti-zymotic character of the 'Sanitas fluid' is due to that constituent. Accordingly, the following experiment was now made.

A fresh solution of starch inoculated with saliva was prepared, containing in each 100 c.c. 3·564 per cent. of substance dry at 100° C.

A solution of pure peroxide of hydrogen was diluted with water, so that it should be in strength about equal to that of 'Sanitas fluid'; it contained peroxide

(H_2O_2) in each 100 c.c. equal to 213 c.c. N/10 solution of hyposulphite of sodium.

Mixtures were prepared on August 5, as follows:

A. 50 c.c. inoculated starch + 50 c.c. water.
B. 50 c.c. ,, ,, + 50 c.c. ,,
C. 50 c.c. ,, ,, + 25 c.c. ,, + 25 c.c. peroxide solution.
D. 50 c.c. ,, ,, + 50 c.c. ,, ,,

On August 18th they were examined as before:

	Sugar found present.	Originally present.	Gain.
A.	0·7874	None.	0·7874
B.	0·6345	None.	0·6345
C.	0·7132	None.	0·7132
D.	0·6564	None.	0·6564

It is apparent from these results that a dilute solution of peroxide of hydrogen is without influence upon ptyalin. This result is not new to science in a general sense, for MM. Bert and Regnard had already pointed out that, while a very dilute solution of oxygenated water arrests and prevents fermentations which depend apparently upon the presence of living organisms, such as *yeast*, *bacterium lactis*, *bacterium termo*, *mycodermi aceti*, etc., it altogether fails to arrest the changes which are induced by soluble ferments or zymases, such as diastase. This fact is now confirmed, and the experiments, therefore, which have been described in this section prove that 'Sanitas fluid' is double-barrelled, so to say—in the sense that it not only acts upon organized or living ferments, but also upon soluble or non-organized ferments. The constituent of 'Sanitas fluid' which acts upon soluble ferments is that which resembles sugar in its reducing properties and extract of hops in its bitterness, viz., so-called 'soluble camphor,' and which is designated by the formula $C_{10}H_{16}O_3$. It forms, indeed, the bulk of the residue which is left upon evaporation of 'Sanitas fluid' to dryness, as this evaporation causes the loss of all the thymol and peroxide of hydrogen which are also contained in the original fluid.

PEPSIN AND ITS ACTION UPON EGG ALBUMIN.

EXPERIMENT I.—A fresh egg was boiled to coagulate the albumin, and then three portions of the white, each weighing 0·324 grm., were cut into thin slices, and placed respectively in 2-oz. wide-mouthed stoppered bottles.

A. To this portion was added 50 c.c. of a solution containing 1 per cent. hydrochloric acid.

B. To this portion was added 25 c.c. of water acidulated to the extent of 1 per cent. with HCl, and 25 c.c. of 'Sanitas fluid' acidulated similarly with HCl.

C. This portion was placed in 50 c.c. of 'Sanitas fluid' containing 1 per cent. added HCl.

After standing overnight, there was added to each portion 0·05 grm. of the prepared pepsin sold by Messrs. Bullock and Co., and the mixtures were then placed in an oven maintained at 38° C.

After three hours and fifty minutes the albumin in A had all disappeared, but some remained in B, and a large quantity was left in C.

EXPERIMENT II.—In the next experiment the proceedings were identical, except that just double the quantity of white of egg was taken in each case. In A all the albumin has disappeared in 4¾ hours; in B some remained even after 6 hours; while in C most of the albumin apparently remained.

EXPERIMENT III.—Being desirous of expressing the results in a more quantitative manner, the following proceedings were adopted: four portions of coagulated white of egg, each weighing 1 grm., were taken, and the first portion was dried at 100° C. and the residue weighed; it amounted to 0·1312 grm., so that 0·8688 grm. of the albumin consisted of water which was lost during the drying. The other portions of albumin were treated as before, and kept in an oven at 38° C. during 3¾ hours, after which the mixtures were filtered through tared papers, and the undissolved portions of white of egg were thus collected and weighed after drying at 100° C.

	Undried albumin at start.	Undried albumin at end.	Quantity dissolved.	Percentage dissolved.
A.	1·000 gramme	0·114	0·886	88·6
B.	1·000 ,,	0·166	0·834	83·4
C.	1·000 ,,	0·722	0·278	27·8

or, taking the albumin dry at 100° C., the following were the results:

	Dry albumin at the start.	Amount undissolved.	Quantity dissolved.
A.	0·1312	0·0150	0·1162
B.	0·1312	0·0218	0·1094
C.	0·1312	0·0948	0·0364

EXPERIMENT IV.—This experiment was made exactly after the same manner as the last, upon a specimen of coagulated white of egg containing 87·06 per cent. water, and yielding 12·94 per cent. of albumin dry at 100° C.

In the case of A, 50 c.c. water, acidulated with pure hydrochloric acid, was employed, and of such a strength that 59·75 c.c. N/10 NaHO was required to neutralize the whole quantity. In the case of B, there was used a mixture of 25 c.c. water acidulated with the same percentage of acid as A, and 25 c.c. 'Sanitas fluid,' to which a corresponding amount of acid had been added, although its acidity was practically double by virtue of its own acid character (25 c.c. = 58 c.c. N/10 NaHO solution). Mixture C consisted of 50 c.c. 'Sanitas fluid,' to which had been added 1 per cent. of pure hydrochloric acid, and the total acidity of the solution was therefore equivalent to 116 c.c. N/10 NaHO solution.

After the mixtures, containing each 1 grm. of the white of egg had stood overnight, there was added to each 0·05 grm. pepsin, and they were all placed in a water-oven maintained at 38° C., during three hours and fifty minutes. The mixtures were then thrown upon previously tared filters, and the undissolved portions were washed, dried, and weighed.

	Dry albumin left =	Original albumin.	Quantity digested =	Percentage.
A.	0·0166	0·128	0·872	87·2
B.	0·0372	0·286	0·714	71·4
C.	0·1146	0·885	0·115	11·5

Experiment V.—Although, from the results which have been described, it is obvious that 'Sanitas fluid,' when present in large amount, seriously interferes with the action of pepsin upon albumin in an acid medium, there was a loss in weight of the original albumin employed in the experiments, and to ascertain the nature of this loss a further investigation became necessary.

In this experiment, therefore, using similar quantities of albumin (containing 14·08 per cent. albumin dry at 100° C. and 85·92 per cent. water), different solutions were used.

A. consisted of 50 c.c. dilute acetic acid; total acidity = 57·5 c.c. N/10 NaHO.
B. consisted of 50 c.c. dilute acetic acid; total acidity = 57·5 c.c. N/10 NaHO.
C. consisted of 50 c.c. 'Sanitas fluid' unmixed; total acidity the same.
D. „ 50 c.c. „ „ „ „

The portions of albumin were allowed, as before, to stand in the several solutions overnight, and the next morning 0·05 grm. pepsin was added to A and C only. Then all four mixtures were digested at 38° C. during five and a half hours, after which the undissolved quantities of albumin were ascertained as before.

	Dry albumin left.	=	Original albumin	Quantity dissolved	=	Percentage dissolved.
A.	0·1310		0·9304	0·0696		6·96
B.	0·1160		0·8238	0·1762		17·62
C.	0·2040		—	—		—
D.	0·1828		—	—		—

These results were unexpected, and are remarkable as affording proof that, in the presence of dilute acetic acid, pepsin is robbed of its digestive function almost entirely. The loss of 17·62 per cent. in B is entirely due to the solvent action of the fluid in contradistinction to digestive action of the pepsin, and is nearly three times as great as the loss experienced in A, where pepsin was present. It almost looks as if the dilute acetic acid in A had precipitated the pepsin into an insoluble condition. The same precipitation apparently occurred in C, but here, as also in D, the albumin evidently entered into combination with some constituent of the 'Sanitas fluid,' thus leading to results which did not lend themselves to the object of the inquiry.

I dwell upon two matters, however, which are proved by these results, viz., the interference of acetic acid with the digestive action of pepsin, and the observation that albumin, when digested in an acid solution in which no pepsin is present, loses weight by being partly dissolved.

Experiment VI.—As hydrochloric acid had been employed in the earlier experiments, the results of which required further elucidation, I now reverted to the use of that acid, using a fresh specimen of white of egg. It contained 86·32 per cent. water and yielded 13·68 per cent. albumin dry at 100° C.

A. consisted of 50 c.c. dilute HCl (1 per cent. in strength).
B. „ 50 c.c. „ „ (1 „ „).
C. „ 50 c.c. 'Sanitas fluid' (contg. added HCl as above).
D. „ 50 c.c. „ („ „ „).

After standing all night with the albumin in the several solutions, 0·05 grm. of pepsin was added to A and C only, and all four mixtures were then digested at 38° C. during three hours.

The undissolved albumin was determined in the usual manner :

	Dry albumin left	= Original albumin.	Loss.	= Percentage.
A.	0·0100	0·0730	0·9270	92·70
B.	0·1112	0·8128	0·1872	18·72
C.	0·0874	0·6530	0·3470	34·70
D.	0·2024	—	—	—

The loss of weight in albumin shown in B proves that of the total loss in weight experienced in A, viz., 0·9270 grm., the proportion due to mere solution in the dilute acid is 0·1872 grm., the difference of 0·7398 grm. (73·98 per cent. upon original white of egg used) alone, is due to the true digestive action of the pepsin.

The loss in weight of albumin in C shows that pepsin loses most of its digestive capacity when present in a solution of 'Sanitas fluid,' but not entirely.

The gain in weight of undissolved matter in D proves that white of egg is insoluble in 'Sanitas fluid,' even when that solution is acidulated with hydrochloric acid, and that the albumin enters into combination with some constituent of the 'Sanitas fluid,' forming an insoluble compound.

The same result was obtained in Experiment V., by which it was also proved that in pure 'Sanitas fluid' (containing, that is to say, no added hydrochloric acid) pepsin is entirely without action upon white of egg. The addition of hydrochloric acid to 'Sanitas fluid,' as proved by the result of mixture C in Experiment VI., permits of the limited action of the pepsin.

'Sanitas fluid,' then, in its pure state, prevents the fermentative change which pepsin can work upon albumin in its absence, and this anti-zymotic power is probably shared by any acetic acid that may be present, the soluble camphor ($C_{10}H_{16}O_3$), the thymol and other substances which are contained in the fluid.

Reviewing the results of this investigation, it has been proved experimentally that *yeast* is destroyed by 'Sanitas fluid' and is prevented thereby from exercising its ordinary functions when contained either in a solution of glucose, or starch, or gum. Similarly, it has been experimentally demonstrated, in a strictly quantitative manner, that 'Sanitas fluid' destroys and prevents the functions of other micro-organisms, including the *bacterium lactis*, the *torulaceous* ferment which changes urea into ammonium carbonate, the *bacterium termo* and the collective living agencies concerned in the putrefactive process.

I have, also, experimentally and quantitatively proved that 'Sanitas fluid,' when present in sufficient quantity, prohibits the action of soluble ferments or zymases such as ptyalin (in saliva) and pepsins.

The results of this investigation will, I hope, also induce any surgeons who may hitherto have hesitated to avail themselves freely of 'Sanitas fluid' in the practice of antiseptic surgery, to take up its unrestricted use in future, for it is pre-eminently qualified above all other chemical reagents for use in that field of science and is perfectly innocuous in itself.

Weighing these facts with the results now widely known to attend the use of 'Sanitas fluid' in the treatment of wounds and as a general disinfectant by medical men, I do not hesitate to say that all the claims which I originally made have been fully justified, and that by its discovery and introduction I provided for a long-felt want. Moreover, it alone, of all substances available for use, possesses those other properties which the highest authorities admit to be necessary for the general use of a disinfectant. In the Thirteenth Annual Report of the Local Government Board, 1883 to 1884, Burdon Sanderson wrote as follows:

'Nor must it be forgotten that, even after the labour of discovery has been got through, and we have joyfully cried Ευρηκα, what are called practical difficulties are sure to come in of such a kind as to render our achievements in a utilitarian sense fruitless. *For an antidote against infection to be of real value, it must be readily procurable, free from poisonous action, and have such physiological relations to the organism that it is capable of remaining in it sufficiently long to exercise its restraining influence on the process which it is intended to counteract. To discover such an agent is indeed a problem of difficulty.*'

I have italicized these words as specially worthy of attention, but I venture to assert that the discovery for which he was then looking had been already made. Not only is 'Sanitas fluid' a natural disinfectant and a mild oxidizing agent capable of readily giving off oxygen when and where required, but it is also as well qualified by its non-poisonous nature for internal administration as for external application, and so it can be used for the treatment of all infectious diseases which are located in the human body, such as cholera, typhoid fever, dysentery, ulcerated bowels and throat complaints, as also for the other contagious diseases which affect more particularly the outside surfaces of the body.

With further reference to the internal use of 'Sanitas fluid,' it may be pointed out that, although, by the experiments described in this chapter, it has been proved that it interferes to some extent with the action of pepsin and presumably, therefore, other digestive ferments, yet the quantity required to wholly arrest their action is considerable, and much greater than that which is sufficient to arrest the action of micro-organisms. That is to say, the amount of 'Sanitas fluid' which could be given in doses for the treatment of such diseases as cholera and enteric fever would not suffice to cause serious interference with the digestive processes.

As to the germicidal action of the 'Sanitas' preparations, several precise investigations have been made, and I give the results in almost the exact words of the respective authors. The sign + signifies growth of the organisms, and the sign – signifies a failure of growth.

INVESTIGATION BY DR. JOHN C. THRESH.

The appended experimental results show that—

1. A 20 per cent. solution of 'Sanitas fluid' kills the typhoid bacillus in from $2\frac{1}{2}$ to 5 minutes.

2. A 40 per cent. solution of 'Sanitas fluid' kills the diphtheria bacillus in 15 to 20 minutes.

3. The pure 'Sanitas fluid' kills the diphtheria bacillus in less than 1 minute.

4. A 50 per cent. 'Sanitas fluid' kills the anthrax bacillus in 10 to 15 minutes.

5. The pure 'Sanitas fluid' kills the anthrax bacillus in 2½ minutes or less.

6. 'Sanitas fluid,' when used as a spray, killed the typhoid bacillus on a papered surface, in between 20 and 30 minutes.

7. A 7½ per cent. 'Sanitas emulsion' kills the typhoid bacillus in less than 2½ minutes.

8. A 5 per cent. 'Sanitas emulsion' kills the diphtheria bacillus in from 20 to 30 minutes, and a 10 per cent. solution in less than 2½ minutes.

9. A 10 per cent. 'Sanitas emulsion' kills the anthrax bacillus in less than 2½ minutes.

BACTERICIDAL POWER OF 'SANITAS FLUID.'

Broth was infected with typhoid bacilli, and at the expiration of forty-eight hours about 3 c.c. of the turbid broth was added to the tubes containing various dilutions of 'Sanitas fluid.' After standing for the requisite time, two or three loopfuls were taken from each and added to sterile broth. The broth tubes were then placed in the incubator, and the results recorded at the end of four, or, on occasions, five days.

Strength of 'Sanitas Fluid.'	Time.						
	2½	5	7½	10	15	20	30 minutes.
20 per cent. ...	–	–	–	–	–	–	–

Experiments with Typhoid Bacilli Repeated, using a more Virulent Culture.

Strength of 'Sanitas Fluid.'	Time.						
	2½	5	7½	10	15	20	30 minutes.
20 per cent. ...	+	–	–	–	–	–	–

Experiments with Diphtheria Bacilli.

The preliminary stages were the same as described for typhoid experiments.

Strength of 'Sanitas Fluid.'	Time.		
	15	20	30 minutes.
40 per cent. ...	+	–	–

Experiments with Anthrax Bacillus (Spore Bearing).

The preliminary stages were the same as in the previously recorded experiments.

Strength of 'Sanitas Fluid.'	Time.						
	2½	5	7½	10	15	20	30 minutes.
50 per cent. ...					–	–	–
Pure 'Sanitas'	–	–	–	–	–	–	–

BACTERICIDAL POWER OF 'SANITAS EMULSION.'

The experiments were made as described under 'Sanitas fluid,' using various dilutions of 'Sanitas emulsion.'

Typhoid Bacilli.

Strength of 'Sanitas Emulsion.'	Time.						
	2½	5	7½	10	15	20	30 minutes.
7½ per cent. ...	–	–	–	–	–	–	–
10 per cent. ...	–	–	–	–	–	–	–

Diphtheria Bacilli.

Preliminaries as before.

Strength of Sanitas Emulsion.'	Time.						
	2½	5	7½	10	15	20	30 minutes.
10 per cent. ...	–	–	–	–	–	–	–

Anthrax Bacilli.

Preliminaries as before.

Strength of Sanitas Emulsion.'	Time.						
	2½	5	7½	10	15	20	30 minutes.
10 per cent. ...	–	–	–	–	–	–	–

EFFECT OF 'SANITAS FLUID' WHEN USED AS A SPRAY.

A papered surface was smeared with broth in which the typhoid bacillus was growing, and allowed to dry. The spray of 'Sanitas fluid' was then directed on the surface until it was fairly uniformly moistened. The surface was protected from the access of bacteria, and at various intervals small portions were detached and placed in broth. The result showed that after being moistened with 'Sanitas fluid' for thirty minutes, the typhoid bacilli had been entirely destroyed.

INVESTIGATION BY MR. C. G. MOOR, M.A., F.I.C., F.C.S.

The following experiments were made to ascertain and establish, if possible, on a scientific basis, the efficiency of the 'Sanitas' preparations and their suitability for the purposes for which they are designed, as indicated by the Sanitas Company's publications and labels giving directions for use.

(*a*) Various disease organisms — namely, those of anthrax, cholera, diphtheria, *staphylococcus pyogenes aureus* and typhoid, were brought into contact with the disinfectant for a given time and in a manner detailed below, and means were taken to ascertain whether the disinfectant employed was sufficiently powerful to determine the death of the organism in a given time.

(*b*) A second series of experiments was undertaken to ascertain the effect when similar cultures were exposed to different strengths of these disinfectants for a standard time.

(*c*) Experiments were also made to ascertain the effect on ordinary air, as regards the removal or extermination of organisms suspended in it, by spraying with 'Sanitas oil' and 'Sanitas fluid.'

(*d*) In the case of 'Sanitas oil,' some experiments were made as to the action of the vapour given off at a temperature not exceeding that of the human body.

(*e*) Finally, Mr. Moor made some experiments to ascertain the action of 'Sanitas oil' and 'Sanitas fluid' on the bacillus of plague.

TABLE I.

Silk threads infected with cultures of the following organisms were exposed in 'Sanitas oil' for the times shown below, and then incubated in broth. Growth is shown by a + sign, no growth by a – sign.

Organisms.	Times of Exposure.		
	1 Second.	10 Seconds.	30 Seconds.
Cholera	–	–	–
Diphtheria	–	–	–
Typhoid	–	–	–

Anthrax and *staphylococcus pyogenes aureus* were also killed in exposures of thirty seconds. Controls all grew well.

TABLE II.

A similar experiment was carried out in the case of 'Sanitas fluid' (Threads).

Organisms.	Times of Exposure.		
	1 Second.	10 Seconds.	30 Seconds.
Anthrax	+	–	–
Cholera	–	–	–
Diphtheria	–	–	–
Staphylococcus pyogenes aureus	+	–	–
Typhoid	–	–	–

Controls all grew well.

He next proceeded to ascertain the *strengths* of these disinfectants required to ensure the death of the above-named bacteria in a given time—and in the following experiments, the time of exposure of the bacteria to the action of the disinfectant was in all cases ten minutes.

In these experiments he used the method of shaking together an actively growing broth culture of the organism to be tested, with such a quantity of disinfectant that the resulting mixture contained the strength of disinfectant specified in the tables below; the exact details of the method of experiment are described in Pearmain and Moor's 'Applied Bacteriology,' second edition, pp. 377-382 (Baillière, Tindall and Cox).

Table III.

'Sanitas oil.' (As the oil is not readily miscible with water, the 'Sanitas emulsion,' which contains 45 per cent. of 'Sanitas oil,' was employed.) Ten minutes' exposure.

Organisms.	Strength employed in terms of 'Sanitas oil.'		
	25 per cent.	10 per cent.	5 per cent.
Anthrax	–	–	+
Cholera	–	–	–
Diphtheria	–	–	–
Staphylococcus pyogenes aureus	–	+	+
Typhoid	–	–	–

Controls all grew well.

Table IV.

'Sanitas fluid' tested against broth cultures, as above. Ten minutes' exposure.

Organisms.	Strength employed.		
	50 per cent.	25 per cent.	10 per cent.
Cholera	–	–	–
Diphtheria	–	–	–
Typhoid	–	–	–

Anthrax and *staphylococcus pyogenes aureus* were also both destroyed by the 50 per cent. mixture in ten minutes' exposure. Controls all grew well.

He also made several experiments as to the destruction of bacteria floating in the air of a room by spraying the air with 'Sanitas oil,' and with 'Sanitas fluid'—testing the air by means of *Hesse's* tube.

The removal of bacteria from air by spraying will doubtless depend very greatly on the mechanical action of the particles of spray, because, as is well known, bacteria are very largely removed from air by a shower of rain, therefore too much importance must not be attached to such experiments.

Taking, however, the mean of several experiments, whereas the air of the room contained a considerable number of bacteria before spraying, the numbers were reduced, after spraying, to under 5 per cent. of those previously found.

'Sanitas fluid' does not give off much vapour at ordinary temperatures; but 'Sanitas oil,' on the other hand, is sensibly volatile at room temperature, and he tested the action of the vapour given off by 'Sanitas oil' at blood-heat on bacteria similar to those used in the broth and thread experiments.

Some of the growth from agar tubes was smeared on filter-paper and suspended in a wide-mouthed jar containing a little 'Sanitas oil.' The whole was placed in the incubator (37° C.), and, after an hour, cultures were made on to nutrient media. The result was that only the two most resistant organisms—namely, anthrax and *staphylococcus pyogenes aureus*—had survived, while cholera, diphtheria, and typhoid failed to grow.

Having a culture of bubonic plague brought by a student from Hong-Kong, Mr. Moor tried the effect of 'Sanitas fluid' and 'Sanitas oil' on it. The bacillus was killed in each case by a ten minutes' exposure to a strength of 33 per cent. of each disinfectant—the only strength tested.

In conclusion, he regarded the results of his investigation as affording ample evidence that the 'Sanitas' preparations are thoroughly reliable, when employed in the strengths and for the purposes specified in the directions issued by the proprietors, while their non-poisonous nature and pleasant character render them applicable in many instances where such substances as carbolic acid or mercuric chloride would be inadmissible or dangerous.

Some observations respecting the germicidal powers of the 'Sanitas' disinfecting fluids have also been published* by J. E. Weeks, M.D. (late instructor in bacteriology at the New York Post-graduate School). He experimented with the *staphylococcus pyogenes aureus* and the typhoid bacillus, and found that

'Sanitas oil'	destroyed their vitality	in exposures	of	20	seconds.
'Sanitas crude fluid'	,,	,,	,,	1½	minutes.
'Sanitas fluid'	,,	,,	,,	4	,,
'Sanitas fluid' of 50 per cent. strength			,,	10	,,

and he classed these liquids very high among the most effective germicides.

Summarizing the evidence concerning the properties of the 'Sanitas' preparations which has been adduced in this chapter, it has been shown (1) that these products were the outcome of a strictly scientific investigation, and really embody the healthful principles which are generated naturally by pine and eucalyptus forests; (2) that their individual con-

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* See *New York Medical Record*, August 3, 1889.

stituents are all possessed of antiseptic or oxidizing properties; (3) that their collective constituents have well-marked characters as chemical antiseptics, thereby inhibiting the processes which bacteria are otherwise capable of initiating; (4) that they are reliable germicides, and therefore act destructively on micro-organisms generally; (5) that they are devoid of all objectionable properties, and are pre-eminently qualified for general employment by the public as disinfectants and sanitary preparations.

CHAPTER XV.

EUCALYPTUS, PINE AND CAMPHOR FORESTS: THEIR EXTENT, DISTRIBUTION AND HYGIENIC INFLUENCES, AND AN ACCOUNT OF THE INDUSTRIES CONNECTED WITH THEM.

I HAVE shown that for all practical purposes, most of the so-called essential oils, of which there are a great number, may be considered as nearly identical in chemical composition. So that what has been demonstrated to be true regarding the changes induced by bringing air into contact with oil of turpentine and water, is also true of oil of eucalyptus, and, as I have more lately ascertained, of camphor oil too.* This is not merely a matter of inference, but one of fact, for I have not only examined the absorptive power of these oils for oxygen, but also determined the fact that peroxide of hydrogen and soluble camphor ($C_{10}H_{16}O_3$) always appear as products of the reaction when it is conducted in the presence of water.

It has also been shown that the sanitary properties

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* Messrs. Faust and Homeyer (*Deut. Chem. Ges. Ber.*, vii., pp. 63-66, and pp. 1429-1430) have shown oil of eucalyptus to consist mainly of terpene ($C_{10}H_{16}$) and cymene ($C_{10}H_{14}$). The oil of eucalyptus also contains an oxidized body, $C_{10}H_{14}O$, or $C_{10}H_{16}O$.

of pine, eucalyptus and camphor forests are undoubtedly due, chiefly, at any rate, to the formation in and around them of the products which result from the atmospheric oxidation of their essential oils when conducted in the presence of moisture. The rapidity and intensity of the process is materially enhanced by the aid of direct sunlight.

In addition to the facts already brought forward in support of this view and of the further elucidation which follows hereafter, there is a fair amount of what may be called negative evidence. In the first place, other fast-growing trees do not possess, so far as is known, the power of freeing vast tracts of country from malarial fever ; hence, this property cannot be due to the mere drainage of the soil. Then, again, both pine-woods and eucalyptus groves are to be found in abundance upon hilly slopes and in mountainous districts, where there can be no waterlogging of the soil, and the hygienic influence of these trees is felt there just as much as in other places. The positive evidence is no doubt, however, the most important, and having already made ourselves acquainted with its nature, we may now proceed to study its extent.

In a lecture* on the *Eucalyptus globulus*, the late Professor Bentley, who made a special study of this tree and the other members of the same genus, said : ' Four years ago I stated my reasons for believing that

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* *Pharm. Journ.*, May 4, 1878. Professor Bentley's former lecture was delivered on March 14, 1874, and printed by order. (Taylor and Francis, 1874.)

the emanations from the leaves of groves of eucalyptus had some influence in destroying marshy miasms, and thus improving the healthiness of the district. Since then the very interesting researches of Kingzett have proved that under the influence of air and moisture, both peroxide of hydrogen and camphoric acid* are formed from volatile oils—the former a powerful disinfectant, and the latter an antiseptic; and hence I think there can now be no doubt that the healthy influence of eucalyptus-trees is, to some extent at least, and probably more than we imagine, due to the volatile emanations from the leaves under the influence of air and moisture, possessing direct disinfectant and antiseptic properties, and thus destroying the injurious effects of paludal miasms.'

In view of the proofs that have been adduced in previous chapters, we may now go even further than this, and say that, if not entirely, then at least mainly, the hygienic influences of eucalyptus, pine and camphor trees are to be attributed to the products of the air-oxidation of their naturally generated essential oils.

The Eucalyptus.

The word 'eucalyptus' is derived from *eu*, 'well,' and *kalypto*, 'to cover,' and is aptly chosen.

The *Eucalyptus globulus* belongs to the order *Myrtaceæ*, which furnishes clove, oil of cajeput and the pimento. The oil smells like oil of cajeput and

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* This should be read as 'soluble camphor' ($C_{10}H_{16}O_3$), not as camphoric acid.

has a mint-like taste. It boils at 144°—177° C. and its Sp. Gr. is 0·917.

Eucalyptus amygdalina. The oil from this species is pale yellow and has a camphoraceous lemon-like odour of a pungent nature. It boils at 165° C. and resinifies on exposure to the air. Sp. Gr. 0·881.

Eucalyptus oleosa. The oil has a camphoraceous odour, reminding at once of mint and turpentine. It boils at 161°—177° C. Sp. Gr. 0·911.

Eucalyptus sideroxylon. The oil boils at 161°—177° C. Sp. Gr. 0·923.

Eucalyptus goniocalyx. The oil boils at 152°—175° C. and has a very penetrating odour and pungent, bitter taste.

Eucalyptus obliqua. Its oil boils at 171°—195° C. Sp. Gr. 0·899.

Eucalyptus odorata. The oil has a very aromatic odour. It boils at 157°—199° C. Sp. Gr. 0·899—0·922.

Eucalyptus rostrata. The oil is very much like *odorata* oil in odour and taste. It boils at 131°—181° C. Sp. Gr. 0·918.

Eucalyptus citriodora. The oil has a variable boiling-point and a Sp. Gr. 0·868.

Eucalyptus corymboza. The oil boils at 174°—199° C., and its Sp. Gr. is 0·880.

Eucalyptus dumoso. The boiling-point of this oil is also said to be variable. Its Sp. Gr. is 0·931.

Eucalyptus fissilis. Sp. Gr. of oil 0·936.

Eucalyptus longifolia. The oil boils at 195°—214° C., and its Sp. Gr. is 0·942.

Eucalyptus viminalis. The oil boils at 167° — 178° C., and its Sp. Gr. is 0·925.

Eucalyptus mannifera yields the peculiar sweet exudation known as Australian manna.*

Writing of the foliage of the *Eucalyptus globulus*, Mr. H. N. Draper says† it is unlike anything seen in these islands. 'It is pendulous, quivering, and evergreen; and the peculiar whitish appearance of one side of the leaves—due to a fatty or resinous secretion—is very characteristic. Till the tree is from three to five years old, the leaves grow horizontally, but afterwards they assume a pendent position. Instead of having one of their surfaces towards the sky and the other towards the earth, they are often placed with their edges in these directions, so that each side is equally exposed to the light.' It has also been suggested that this arrangement of the leaves may have something to do with the large amount of water which these trees exhale into the atmosphere. M. Vallée has shown that a square yard of the leaves of the *Eucalyptus globulus*, weighing about 2¾ lbs., gives off four pints (5 lbs.) in twelve hours. This rapid evaporation of water is greatly assisted by the very numerous *stomata*, or breathing spores, that exist on the under surface of the leaves: each leaf possesses about 350 of these *stomata*.

The flowers resemble those of the myrtle. As for the seeds of the tree, which are contained in the fruit,

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* See paper in *Zeitschr. des oesterr. Apoth. Ver.*, 1878, 402; and *Pharm. Zeitung*, 1879, 220.

† *Chambers's Journal*, March 26, 1881.

they are very minute, and it is said that 160,000 plants can be raised from a single pound weight of them.

The eucalyptus sheds its bark annually, but as this does not take place at one given time of the year, the trunks always present a rough and ragged appearance.

In Australia, the *Eucalyptus globulus* commonly attains a girth of 16 to 80 feet and a height of from 160 to 200 feet, and there are records of trees even 420 feet in height. Such gigantic members are often found without low branches, the tops being capped with radiating branches full of foliage.*

The oils of eucalyptus as obtained from the different species (of which there are more than 135), are, more or less allied in composition, although the odour, which is generally rich and camphoraceous, varies a good deal. The oil is chiefly stored in the pellucid glands which spread throughout the leaves, and which may readily be seen by holding up the leaves to the light. It is, however, to be found more or less throughout the tree.

The following table expresses the results of an examination of some twenty-four samples made by R. H. Davies, F.I.C., and T. H. Pearmain :†

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* *Pharm. Journ.*, vol. xvii., p. 13.

† Communicated to the British Pharmaceutical Conference in 1891. See *Chemist and Druggist*, August 22, 1891, p. 293; also *Pharm. Journ.*, vol. xxii., p. 235, and vol. xxiii., p. 205.

	Specific Gravity.	Specific Rotation.	Solubility of Salicylic Acid.	Phellandrene Reaction.	Solubility in Rectified Spirit.	Acidity as Acetic Acid.
			Acid. Oil.		Oil. Spirit.	%
Average of all the samples..	0·9015	−12·15°	1 to 7·6	—	—	0·09
Lowest ,, ,, ,,	0·8575	−64·72°	1 ,, 3·0	—	5 in 1	0·02
Highest ,, ,, ,,	0·927	+18·09°	1 ,, 17·6	—	5 ,, 50+	0·23
Average of 'heavy' class ..	0·9125	+ 2·65°	1 ,, 4·65	Phellandrene absent.	3·3 ,, 1	0·11
Lowest ,, ,, ,, ..	0·8994	−19·23°	1 ,, 3·0		5 ,, 1	0·02
Highest ,, ,, ,, ..	0·927	+18·09°	1 ,, 8·3		2 ,, 1	0·23
Average of 'light' class ..	0·8721	−53·26°	1 ,, 12·8	Phellandrene present.	—	0·06
Lowest ,, ,, ,, ..	0·8575	−64·72°	1 ,, 7·6		2 ,, 1	0·02
Highest ,, ,, ,, ..	0·8848	−40·20°	1 ,, 17·6		4 ,, 50+	0·09

These results give support to the general conclusions of MacEwan, Squire and others, that there are two more or less distinct classes of commercial eucalyptus oils, which may be termed respectively the 'heavy' and 'light.' The authors concluded from their examination that the oil of *Eucalyptus amygdalina* is the only commercial one that contains phellandrene.

When sodium nitrite is added to a solution of oil of eucalyptus in glacial acetic acid, a solid nitrite is formed if phellandrene be present, and of the samples with which they experimented, the *amygdalina* oil was the only one that gave this reaction. The authors also examined their samples with the view of determining approximately the amount of eucalyptol ($C_{10}H_{18}O$) present in each. That substance (which is said to be identical with cineol and cajuputol) boils at 176° C. to 177° C., is without optical activity, and solidifies when cooled in a freezing mixture.

The amount of the fractions coming over in the distillation of seven oils selected by the authors at from

170° to 175°, and from 175° to 180°, are given in the next table :

	E. globulus.			*E. odorata.*	*E. oleosa.*	*E. amygdalina.*	*E. dumosa.*
Percentage of fraction 170°–175° ..	38·2	28·8	20·0	29·6	38·0	33·0	41·4
Rotation (100 mm.)	+17·63°	−2·36°	+4·70	+16·96°	+1·56°	−43·5°	+7·05
Percentage of fraction 175°–180° ..	21·0	9·8	18·0	26·6	27·4	22·6	22·4
Rotation (100 mm.)	+16·76°	−1·70°	+2·66°	+17·0°	+2·01°	−43·06°	+4·5°

These results can only be regarded as approximate, because the authors did not actually isolate and weigh the eucalyptol from each sample of oil, but only measured the fraction in which it should be contained if present.

It is frequently assumed that the medicinal value of the oils of eucalyptus depends upon the amount of eucalyptol which is contained therein, but there is absolutely no acceptable evidence of the correctness of this view, which I regard as incorrect. Eucalyptol may be a valuable constituent, but I see no reason why the hydrocarbon portion of the oils and the other oxidized constituents should not be equally, or even more, valuable. It is far better to regard the matter as quite undecided and to keep an open view of the subject. In any case, I am sure that the sanitary properties, and therefore probably the medicinal virtues of these oils are, to a considerable extent, dependent upon the hydrocarbon (terpene) constituents, because it is from their oxidation in the presence of moisture that the peroxide of hydrogen which results from that process is undoubtedly and solely derived.

In a further contribution* to the chemistry of eucalyptus oils, Davies and Pearmain obtained eucalyptol from the oils of *E. oleosa*, *E. dumosa,* and *E. globulus.* This substance was found to have a boiling-point of 174·5° C., and a melting-point of 0° C. to 0·5° C.; its specific gravity at 16° C. was determined at 0·927, which is the same as that of cineol.

M. Cloez found† that ten kilos of fresh leaves, taken from the branches of a eucalyptus (species not named) which was killed by frost at the end of 1867, furnished by distillation with water 275 grms., or 2·5 per cent. by weight of oil. In another experiment (species again not named) eight kilos of dry leaves, gathered at Hyères, gave, after keeping them one month, 489 grms., or 6 per cent.† From completely dry leaves, which had been kept five years, he obtained only 1·5 per cent. of oil.

The percentages given in the following table,‡ representing the amount of oil contained in the foliage of different species of the eucalyptus, were, for the most part, determined by Mr. Bosisto for the exhibition of 1862:

Eucalyptus amygdalina (or narrow-leaved peppermint-tree)	3·313
,, oleosa	1·250
,, leucoxylon	1·060
,, goniocalyx	0·914
,, globulus (or blue gum-tree)	0·719
,, obliqua (or stringy-bark-tree)	0·500

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* *Chem. News,* vol. xxvi., p. 63.

† Probably from *Eucalyptus amygdalina,* judging from the quantity.

‡ See *Chem. News,* vol. xxxix., p. 169.

The next table is compiled from the paper of M. Raveret-Wattel,* quoted in a previous chapter:

Eucalyptus amygdalina	5·75
,, oleosa	1·25
,, sideroxylon	1·00
,, goniocalyx	1·00
,, fabrorum	0·50
,, woolsii	0·18
,, rostrata (or red gum-tree)	0·06

It is thus seen that, although the *Eucalyptus globulus* is the best-known species, being a favourite on account of the rapidity of its growth and the luxuriance of its foliage, it is by no means one of the richest oil-yielding trees; therefore this species is not so important from a sanitary point of view as some of the others. Indeed, Mr. R. D. Adams, who obtained his information from Baron von Mueller, writes: 'The respective hygienic value of various eucalypts may, to some extent, be judged from the percentage of oil in their foliage,' which latter also varies in quantity and quality as much as the oil.† Even in the same species the amount of oil varies somewhat, according to the locality and season.

Eucalyptus rostrata, one of the poorest in oils, grows well in periodically inundated places and even in stagnant water which is not saline, and so it is important for planting in malarious districts.

The eucalyptus is indigenous to the temperate

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* *Pharm. Journ.*, New Series, vol. iii., pp. 22 and 43.

† *Chem. News*, vol. xxxix., p. 169.

parts of Australia and Tasmania, where the temperature ranges from 52° to 72° F. Indeed, as Mr. Bosisto has said, 'it ranges over the greater portions' of those countries, but is entirely absent from the other islands of the South, excepting a few species in New Guinea.

It is said that some species grow well in hot and others in colder climates: thus there are eucalypts to suit the tropics of India and the more temperate regions in England. It must, however, be admitted that our climate is, generally speaking, much too rigorous during the winter months for the young plants. Old trees might withstand these climatic influences, but the trees cannot grow old here.

Mr. Draper had at one time twenty-five healthy saplings of the *globulus*, five years of age, of from 10 to 16 feet high, growing near Dublin, and one was 25 feet high, with a stem 22 inches in circumference; but though he kept them during four ordinary winters, they were all killed by the very cold weather experienced in the winter of 1878-79.

At Tre Fontane, Mr. Draper, who personally visited the place, says there are cultivated at least eleven varieties, some of which, such as the *E. viminalis* and *E. botryoïdes*, do best in humid ground, whereas *E. resinifera* and *E. meliodora* flourish best in a dry soil; the *globulus*, however, will adapt itself well to all sorts of conditions.

In a lecture on 'Forest Culture,'* Baron von Mueller

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* *Pharm. Journ.*, New Series, vol. ii., p. 628.

stated that Mr. Joseph Bosisto, a citizen of Melbourne, was at that time largely exporting the oil of eucalyptus and was producing about 700 lbs. a month. Since then, Mr. Bosisto, who has most industriously pursued this business, has given much further attention to the hygienic value of the eucalyptus. He became convinced that its properties have some connection with the essential oil, and set himself to ascertain what he could about the quantity of oil and its probable sanitary effects, supposing it gets into the atmosphere through evaporation aided by warm winds. He writes :*

'The evidence of oil evaporation might thus be stated—that the desert scrub gums, after a winter of average rainfall, supplied the air with a continuous and even quantity of aromatic vapour and kept up a rigorous vitality throughout the summer, and that a short season of rain and a long dry summer diminished the formation of oil and so lessened the exhalation; but, on the other hand, the species tending seaward increased their quantity after a short winter.'

It is said that sometimes the aroma of the volatile oil can be detected in the atmosphere even when travelling in the Bush.

It was in the year 1854 that Mr. Bosisto set up the first still for the preparation of oil of eucalyptus, since which time the industry has attained large dimensions, the factories now comprising, among many others, two stills, each of 5,000 gallons working capacity, and two others of 3,500 gallons. One factory

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[*] *Pharm. Journ.*, New Series, vol. v., p. 270.

is situated about thirty to forty miles east-south-east from Melbourne, at a place known as 'Emerald,' where twenty-two tons of leaves are subjected to distillation every week. Another factory is between Lake Hindmarsh and the town of Dimboola, where about twenty-five tons of twigs and leaves are treated each week for the extraction of the essential oil. The stills are made of wood, duly lined, and are fitted with copper heads.

The production of eucalyptus oil as an article of commerce has become so extensive of late years that the product has almost become a mere 'drug in the market,' and its price has fallen to a comparatively low figure.

'Scrub' covers millions of acres, averaging in height not more than 8 feet, and is so dense that it almost shuts out sun and sky. It is of interest to note that in one kind of scrub there is lodged in the stem about half a pint of almost pure water. Mr. Bosisto reduces the whole tribe of eucalypti to some eight types, namely:

The Viminalis, or manna-yielding eucalyptus.
The Odorata, or sweet-smelling.
The Rostrata, or red gum-tree.
The Obliqua, or stringy-bark.
The Leucoxylon, or iron-bark.
The Globulus, or blue-gum.
The Dumosa, or mallee.
The Amygdalina, or peppermint scented eucalyptus.

These types supply from the maximum to the minimum amount of essential oil, viz., 500 fluid ounces or 25 imperial pints to 7 fluid ounces of essence per 1,000 lbs. of fresh leaves.

As regards the wood of the eucalyptus, a test mentioned by Mr. Bosisto showed that the blue gum-tree wood carried 14 lbs. weight more than English oak, and 17½ lbs. more than Indian teak, to the square inch.

Now, in a previous chapter, attention has been called to the report of Mr. Skene, setting forth the distribution of eucalyptus forestry over Australia, and using these figures, Mr. Bosisto calculated that the mallee scrub in the colony of Victoria would retain in the leaves at one time no less than 4,843,873,000 gallons of oil, and the seaward species 280,891,000 gallons. By another calculation applied to the whole of New South Wales and South Australia, he computed that 96,877,440,000 gallons of oil is held continually at one and the same moment in the leaves of trees massed together and occupying a belt of country over which the hot winds blow. In the face of these figures, none could hesitate to come to the conclusion at which Mr. Bosisto arrived, viz., that the eucalyptus as a fever-destroying tree owes this power to the oil which finds its way into the atmosphere.

As already stated, and as proved again and again, the oil has, of itself, certain antiseptic powers. These, however, are enormously intensified and also become disinfectant and oxidant in character, so soon as the oil is oxidized by the atmospheric oxygen in contact with moisture. This has been fully explained in preceding chapters, and from what is there described, it is probable that every molecule of oil of turpentine, or oil of eucalyptus, or camphor oil, gives rise in this process of oxidation to a molecule of peroxide of hydrogen and one of the soluble camphor which has the approximate formula of $C_{10}H_{16}O_3$. Now, if this be so, then I have calculated that 96,897,440,000 gallons of eucalyptus oil can and must produce in the atmosphere surrounding the forests no less than 92,785,023 tons of peroxide of hydrogen and about 507,587,945 tons of the soluble camphor, not to mention the other products of oxidation.

This quantity of peroxide of hydrogen is capable of oxidizing a correspondingly large amount of organic vegetable matter, rendering it harmless. In this way the peroxide of hydrogen could part with nearly half its weight of nascent oxygen.

Then, again, the antiseptic powers of such an immense quantity of soluble camphor can be appreciated, if we reflect that a solution containing only a few grams to the litre is sufficiently strong to preserve animal matter, almost indefinitely free from decomposition, as demonstrated by my experiments.

I have not met with any figures showing the weight of foliage to the individual trees from which the sanitary value of a single tree could be estimated, but there can be no doubt that the sanitary value of even a single tree must be considerable.

In view of these facts as bearing on the climate of Australia, which is stated to be the finest in the world, it is not surprising to learn* that the death-rate

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* *Brit. Med. Journ.*, September 24, 1887, p. 676.

from phthisis there is less than one-half that of the mother-country, even including the cases of death of persons visiting that continent for the benefit of their health.

The Pine-Tree.

Now, what is true about the eucalyptus and its oil is true also of the pine-tree and its turpentine, but on a much more extensive scale. That this is so is evident from the very great quantity of turpentine which finds its way into commerce, and even this amount, great as it is, represents but a mere fraction of that produced in nature.

Oil of turpentine is contained in the wood, bark, leaves and other parts of the members of the *Coniferæ*, and the method by which it is distilled from the exudations of pines and firs will be referred to hereafter.

According to Planchon,* the French oil of turpentine is produced particularly by the *Pinus maritima* and *P. pinaster;* the German oil is yielded by *P. sylvestris*, L., *Abies pectinata*, and *A. excelsa*, DC.; the Venetian oil is extracted from *Larix Europæa;* and the English oil is a product yielded from the American turpentines produced by *Pinus tæda*, L., and *P. Australis*, Mich.

Dr. R. Godeffroy† has also recorded a similar statement, and adds that the German oil is also obtained from *Pinus vulgaris*, *P. picea*, and *P. rotunda.* He

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* See Paper by Dr. Julius Morel, *Pharm. Journ.*, New Series, January 12, 1878.

† *Pharm. Zeitung*, 1887, No. 81.

says that pine-cone oil (*oleum abietis pini*) is obtained by distilling with water the cones of *Abies pectinata*; dwarf-pine oil by similarly distilling the young tops and cones of *Pinus pumilio*; and pine-leaf oil from the leaves of *Pinus sylvestris* or *P. abies*.

The Russian and Swedish oils of turpentine are obtained more or less by destructive distillation, so that they are characterized by their odour and by the presence of certain empyreumatic substances.

All these different oils are classified as oil of turpentine; they differ, to some extent, in their boiling-points (average 160° C.), their specific gravity and their action on polarized light, but in a more ultimate chemical sense they are identical and merely represent so many different isomeric forms of terpene ($C_{10}H_{16}$). As produced in nature, they are accompanied with certain oxidized products (including the natural resins and gums), which are doubtless formed by the action of atmospheric oxygen upon the terpenes existing in the trees.

The process by which the turpentine is generally obtained from the trees consists in tapping them at regular intervals and collecting the 'crude' or 'brute' turpentine, which constitutes a thick resinous mass, and is afterwards subjected to distillation, either with water, or steam, or otherwise.

It is certain that the hygienic influence of the pine is much greater than that of the eucalyptus, since it has a much wider and more extensive distribution in nature. Thus, Russia alone has 500,000,000 acres of forestry largely consisting of pine-trees; while, as is well known, a large industry is carried on in the turpentine products yielded by the pines and firs of not only Russia, but also France, Switzerland, Germany, Sweden and Austria. The European trade, however, is not nearly so large as the American one, which now furnishes most of the turpentine met with in commerce.

In illustration of the extent of pine forestry in America, it is interesting to notice a remarkable shower of pollen grains which fell in the north-eastern part of Pennsylvania on the morning of March 17, 1879, and covered an area of more than 2,500 square miles. The pollen was that of *Pinus Australis*, from the Southern States, and it was believed to have been carried a distance of over 500 miles.*

Curiously enough, a similar occurrence was recorded† some years since as having been noticed at Windsor, Slough and in that neighbourhood generally. The pollen, which was probably derived from *Pinus sylvestris*, and blown from Windsor Forest, was at first thought by the people residing in the district to be sulphur.

Even in our own country pine-woods abound, not merely in Scotland, but scattered more or less over the entire area; they are to be found so near to London as Bournemouth, Upton and Weybridge.

From this vast extent of pine forestry distributed all over the world, an incalculable quantity of oil of

* *Hardwicke's Science Gossip*, June 2, 1879.

† See *Nature*, June, 1878.

turpentine finds its way into the atmosphere, just in the same manner as does the volatile oil of the eucalyptus. Of course this process of oil-evaporation proceeds far more rapidly in warmer climates, and is much more noticeable in summer than in winter. All who have visited Arcachon, or our own woods at St. George's Hills (Weybridge), in the summer, must have remarked the delicious aromatic perfume of the atmosphere. On a warm day the air is balmy with the odour of the oil and the products which result from its oxidation, all of which are being incessantly poured into it.

That persons suffering from throat and lung diseases derive distinct benefit from residence in such places is beyond cavil. By the natural atmospheric oxidation of the oils of eucalyptus and turpentine there is produced an almost illimitable amount of peroxide of hydrogen and camphoraceous matters which must, perforce, act, according to their chemical natures, upon the pestilence that may be floating in the air and upon the animal and vegetable matters that may be rotting in the soil, as also upon the poison which constitutes the virus of pulmonary disease.

What is done by pine and eucalyptus forests on this grand scale is carried out in miniature by every plant or flower which owes its perfume to the essential oil which it secretes. The importance of essential oils as hygienic agents is well set forth by a report of Dr. Schomburgk* on the progress and condition of

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* *Soc. of Arts Journal*, August 22, 1879.

the Botanic Garden and Government plantations at Adelaide, Australia. In this report it is stated that British India and Europe consume about 150,000 gallons of handkerchief perfume yearly, and the English revenue from eau-de-Cologne alone is about £8,000 a year, while the total annual revenue from imported perfumes is estimated at £40,000. One perfume distillery at Cannes uses no less than 100,000 lbs. of acacia flowers, 140,000 lbs. of rose petals, 32,000 lbs. of jasmine blossoms, 20,000 lbs. of tuberose, besides other fragrant flowers.

Dr. Schomburgk points out that in Australia, mignonette, sweet verbena, jasmine, rose, lavender, *Acacia famesiana*, heliotrope, rosemary, peppermint, violets, wallflower, laurel, orange and the sweet-scented geranium, all grow exceedingly well—indeed, with greater perfection than elsewhere. Australia, then, promises fair to commercially produce vast quantities of essential oils, which by their distribution and use produce hygienic results no less effectually than the eucalyptus, the chemical history of which is studied in this treatise.

Governing bodies and the public alike should never lose sight of the value of eucalyptus and pine plantations. Valleys and swamps may, by their agency, be freed from malarial fever, and in place of a poisonous atmosphere, they substitute a state of balminess and purity, at once enjoyable and health-giving.

There is no necessity to dwell further on this theme, but I hope that enough has been said and sufficient evidence brought forward to conclusively prove that among the processes of Nature's Hygiene there are few more extensive, or more important, than that we have been considering.*

In conclusion, it will be of some interest to glance at the industries that are carried on in a turpentine farm and in connection therewith. It has been well said that the pine of the South Atlantic States is to the dwellers therein what the palm is to the South American and the bamboo to the Chinaman. They build their houses with it, and construct their rude furniture, fences, carts and farming implements with it. They also use it for heating and lighting purposes, and live upon the profits resulting from the extraction of turpentine, resin, pitch and tar from it.

The turpentine industry has gradually extended from the pine forests of North Carolina, southwards from Wilmington, through South Carolina and into Georgia, where it now centres, but it also extends to Florida, where State convicts are employed in 'turpentining.'

Savannah is the principal port in the United States for the exportation of turpentine. In 1885 the quantity exported was 2,800,838 gallons, of the value of £183,402, and in 1886 the quantity was 3,498,244 gallons, worth £229,302. From Wilmington there was shipped during 1886 only £145,714

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* For further evidence concerning the relation of plants, generally, to hygiene, I may refer readers to an interesting article by J. M. Anders, *Pharm. Journ.*, October 18 and 25, 1884. The author of that paper, however, has fallen into the mistake of calling ozone that which has been proved to be peroxide of hydrogen.

worth of spirit of turpentine, illustrating the above-made remark as to the shifting of the centre of this industry.

The extraction of turpentine does not unfit the trees for lumbering, so that large saw-mills are often found in close proximity to turpentine orchards.

The lands are almost worthless, and 'boxing' of the pitch-pine trees for the gum, constitutes the only industry of these districts.

There are several kinds of pine, including the white, spruce, yellow, Roumany and pitch pine, which latter differs a little from the yellow, and is the only valuable one for 'boxing.'

It is said that the owners of these lands generally lease the 'privilege' for the business, and receive about 125 dollars for each crop of 10,000 boxes. These boxes are cavities, of which there may be from one to four, cut into each tree near the ground, and hold about a quart each. Each crop of 10,000 boxes requires the service of one man only, in the season, which lasts from March to September. If the bark of the tree above each box be hacked away a little every fortnight, then about three quarts of pitch or gum is obtained from each box during the season. After successive seasons of hacking, all the bark that can be reached becomes removed, and the quality of the gum gradually depreciates in the sense that it yields less turpentine oil.

A 'still' load of sixteen barrels of this crude gum yields about 80 gallons of turpentine, which fetches 40 cents per gallon, and 10 barrels of residual resin, which sells at from 1½ to 5 dollars per barrel, according to quality. The money produce of the turpentine is said to roughly represent the profit of the industry.

Trees that are unfit for further boxing (which happens in five or six years) and are not suitable for timber, are sometimes used in the manufacture of tar. In that case they are cut up and piled in a large hole in the ground, then covered with earth, and burned in the manner that charcoal-burning is conducted. The gum which is 'sweated' out flows off with the smoke through a channel provided for that purpose. Each 'cord' of wood makes 2 barrels of tar, which fetches 1·5 dollars per barrel, and costs 37½ cents to make: the charcoal is sold for fuel.

It is reported that Mr. E. Koch, of New Orleans, is now extracting turpentine from pine-wood by the following process: the richest pine knots are selected, and charged into iron retorts holding about 2½ 'cords' of wood, which are then fired from below, and at the same time subjected to the passage of superheated steam. After some six hours of this treatment, gas is evolved from the retorts and is utilized as fuel. At the same time, crude turpentine and tar is separated from the wood, and these are discharged through appropriate openings; subsequently, the turpentine is refined by distillation. The heating of the wood is continued until only charcoal remains in the retorts. A 'cord' of wood thus treated yields from 35 to 40 gallons (American measure) of turpentine, about 2 barrels of tar, and from 20 to 25 bushels of charcoal.

Experiments were conducted some time since in

Georgia for treating the sawdust from the mills in the same way as the 'boxed-out' trees, and it is said that each ton yields 14 gallons of turpentine, 3 or 4 barrels of resin and a quantity of tar.

The annual average yield of the State is put down at 175,000 barrels of resin and 35,000 barrels of turpentine, and all this finds a market in the United States.

The distillation of the crude turpentine is carried on in copper stills, and is continued until the proportion of turpentine to water in the distillate sinks to 1 to 9 parts.

The resin left in the still is drawn off and passed through a strainer, to separate it from twigs and other foreign substances.

Virgin dip—that is, the first exudation from a newly boxed tree—yields about 5 gallons turpentine to the barrel of 280 lbs., about 20 per cent. being left in the resin, in order to keep it of a good colour and value. 'Yellow dip,' or that obtained in after-years, yields about 4 gallons to the barrel.

From North Carolina, the turpentine annually exported amounts to about 5,300,000 gallons, and the resin to 550,000 barrels.

Another account, which I believe refers to the industry as practised in France, is given in a paper by Dr. Julius Morel,* from which I have derived some of the following information:

The tapping of turpentine may continue over one hundred and fifty years, and more profitably if, while

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* *Pharm. Journ.*, sec. 3, vol. viii.

the tree is young, it is allowed an occasional period of rest. The process of 'hacking' is carried on during the months from May to September. A vigorous pine standing alone will yield annually twenty to forty kilogrammes (44 lbs. to 88 lbs.) of 'crude turpentine'; but if the trees be massed together, the individual yield amounts only to about five or six kilogrammes. As already stated, the product thus obtained is called crude or brute turpentine. A sample which had been obtained from the Silver and Spanish fir-trees (Strasburg turpentine) was analyzed by Caillot in 1830, with the following results:

Volatile oil - - - - - -	33·50	per cent.
Resin insoluble in alcohol - - -	6·20	,,
Abietine (a kind of resin) - - -	10·85	,,
Abietic acid (resin acid) - - -	46·39	,,
Aqueous extract containing succinic acid	0·85	,,
Loss - - - - - - -	2·21	,,
	100·00	

During the flow of the crude turpentine, there forms upon the bark a concrete mass, consisting of crude turpentine from which the volatile oil has been evaporated by atmospheric influences. This concreted substance is known as 'gum thus,' or 'galipot.' A yet cruder product of the same nature is known as 'barras.'

The pure oil of turpentine is obtained from the crude turpentine containing it, together with certain hydrated and oxidized substances (resins, etc.) by various processes of distillation. The distillation may be conducted in the presence of water, or in a current of steam, or in the dry state. The yield of oil amounts to from 15 to 30 per cent. of the crude product, and averages about 25 per cent.

Strasburg turpentine is very siccative and is furnished by the Pectinate fir-tree, Silver and Spanish fir-trees. This tree inhabits almost all the mountains of Central Europe, the Alps, Pyrenees, etc., and is common on the Vosges and in the Black Forest, where it constitutes high and dense forests.

Venice turpentine is not very siccative, and is yielded by *Larix Europæa*, or common larch. This tree will grow upon almost any soil, but prospers best in a clear, dry atmosphere, or a cold-bottomed soil. It thrives at 1,800 feet above the sea-level, and attains a higher level even than the Scotch pine. A tree of fifty or sixty years of age can yield from three to five kilos of crude turpentine annually, for five or six years.

Canada balsam, or Canadian turpentine, is siccative, and is obtained from *Abies balsamea*. Burgundy pitch is obtained from *A. excelsa*, DC., and contains a large quantity of resinous matter.

Chian turpentine acquired some reputation a few years ago as a cure for cancer, but conflicting testimony as to its value soon followed, and now again it is rarely met with in commerce.

Another branch of chemical industry is carried on with the resin, which is produced as already described. By further destructive distillation it is made to yield resin spirit, resin oils and pitch, which latter substance is left behind in the retorts.

Oil of turpentine is chiefly used in commerce in the manufacture of varnishes, which may be described as solutions of gums or resins, and are made by dissolving them in volatile solvents. When a varnish is spread over the surface of any object, the solvent evaporates and leaves behind a thin layer of the gums previously held in solution. The gums and other substances employed in varnish-making are very numerous, and include copal, shellac, dammar, sandarach, mastic, elemi, benzoin, animi, resin, asphalt, etc. Among the most important varnishes are those made from copal gums. In order to dissolve these in turpentine, they have to be powdered and subjected to dry distillation at a temperature of about 360° C., until a loss of from 20 to 25 per cent. by weight is effected. The residual product can then be dissolved in oil of turpentine and linseed oil, and the product is copal varnish. While, however, the hard gums are quite insoluble in turpentine, I have found that copal, sierra leone and kowrie gums readily dissolve in 'Sanitas oil' without previous distillation, and that product is now used to some extent for this purpose.

The use of 'Sanitas oil' in varnish-making is important, because not only does it avoid the waste of 25 per cent. by weight of the expensive copal gums, but it increases the body of the resulting varnish by the oxidized substances which it contains, and it also avoids the objectionable darkening in colour which results from the distillation of copal. 'Sanitas oil,' which is now manufactured by my process on a large scale, also dissolves shellac, mastic, dammar and resin very readily, and it is said to be of commercial value for bleaching wax and feathers. Its chief employment, however, is as a disinfecting fumigant, and for reproducing (by volatilization over water) an artificial atmosphere resembling in composition that of pine forests.

Mention may here be made of an industry now carried on at Humboldtsan (in Upper Silesia), Remda (Thüringen-Wald), Jonköping (in Sweden), Wageningen (in Holland) and elsewhere, in connection with the acicular leaves of pines, firs and conifers in general. These are exhausted of their oil and then boiled with an alkali (strong solution of carbonate of soda), in order to remove the resinous substances contained in them; after which the leaves are converted into a kind of cotton or wool, termed pine or forest wool. This product is used as a wadding for upholstery purposes and for stuffing mattresses, etc. It is also used to some extent as an absorbent dressing in surgery. It is said to have the pleasant smell of fir-wood and to be repulsive to vermin, but its hygienic value as a pine product is insignificant, seeing that the substances which would give it a value are intentionally removed by the process of its preparation.*

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* Mr. Thomas Greenish has shown, by a carefully conducted investigation, that several articles now being sold in this country under the names of pine wool, fir-tree wool, pine foliage forest wool or flannel, etc., are nothing more or less than stained cotton or sheep's wool, or a combination of the two materials.—*Pharm. Journ.*, November 15, 1884.

We now come to the study of another but allied subject.

The Camphor-Tree.

The crystalline substance, *camphor* ($C_{10}H_{16}O$), and its properties are so well known as hardly to require description. It exists ready formed in the *Laurus camphora* (a plant indigenous in Japan, Java, Sumatra, and Borneo) and other trees, and is known to chemists to possess three several modifications, which are distinguished by their action on polarized light.

Laurel or dextro-camphor ($C_{10}H_{16}O$) exists in the wood and bark of several Lauraceous plants, and can also be produced artificially by the action of nitric acids upon Borneol or Borneo Camphor ($C_{10}H_{18}O$). Camphor is very volatile, and crystallizes upon sublimation.

Everyone is familiar with the fact that camphor is more or less volatile according to the circumstances to which it is exposed; but I am only aware of one experiment[*] to ascertain the amount of loss which it experiences when exposed to the air. Mr. J. C. Folger has ascertained that the percentage of loss in different samples is wide and varied in his observations during ten weeks from 11½ to above 84 per cent., according to the solidity of the substance, the amount of surface which is exposed, and the condition of the atmosphere. During the ten weeks of his observations the temperature ranged from 61° F. to 80° F.

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[*] See the *Druggist's Circular* (America), July, 1885, or *Pharm. Journ.*, July 18, 1885.

Camphor is soluble in alcohol, ether and a number of other liquids, but water only dissolves $\frac{1}{1000}$ part of the substance, acquiring thereby its distinctive taste and odour. It melts at 175° C., and boils at 204° C.; its specific gravity ranges from 0·986 to 0·996, and it burns in the air with a smoky flame.

The striking rotations which are exhibited by small pieces of camphor when thrown on to the surface of water are supposed to be caused by the movement of the vapour of the substance which is gradually given off therefrom, but the phenomenon is really ill-understood.

According to Proust, a substance resembling camphor may be obtained from the essential oils of rosemary, marjoram, lavender and sage by deposition; whilst by the action of nitric acid on the essential oils of pansy, semen-contra, valerian and sage, other substances supposed to be modifications of camphor have also been obtained.

The manufacture of camphor is quite an important industry in the Island of Kio Shui (Kew Shew), there having been exported from the Port of Nagasaki in 1882 no less than 15186·18 piculs of $133\frac{1}{3}$ lbs. each, valued at 227,792 dollars,* in addition to that sent from other ports not accessible to foreign trade. It is said that the annual export of camphor from Japan amounts to about 5,000,000 lbs., of which quantity three-fourths come to Europe.

The camphor-tree, or *Kusonoki*, as it is called in

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* From a report by Consul Jones, of Nagasaki, printed in the *St. Louis Druggist*, August 18, 1883.

Japan, grows most abundantly in those provinces of the Islands of Shikoko and Kinshin which have the southern sea-coast, being found alike on high elevations and in low valleys; it also grows abundantly in the province of Kishu. It is a hardy, vigorous, slow-growing, but long-lived tree, which flourishes in all situations and often attains an enormous size, many in the vicinity of Nagasaki measuring 10 to 12 feet in diameter, while at other places there are said to be some as much as 20 feet in diameter. The ancient temple of Osuwa at Nagasaki is situated in a magnificent grove of camphor-trees of great age and size. They usually run up 20 and 30 feet without limbs, and then branch out in all directions, forming well-proportioned beautiful trees, evergreen and very ornamental. Many are said to live for more than three centuries.

The leaf is small, elliptical in shape, slightly serrated and of a vivid dark green colour, except in the early spring, when for a few weeks the young leaves are of a delicate tender green. They bear seeds or berries, which grow in clusters, resembling black currants in appearance. The wood is valuable for many purposes, such as shipbuilding, the roots being also used for making ships' *knees*, while the fine grain of the wood makes it specially suitable for cabinet work.

According to H. Oishi,* the amount of contained camphor varies according to the age of the tree, that of one hundred years old being tolerably rich in the

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* *Journ. Soc. Chem. Industry*, vol. iii. (1884), p. 353.

substance. To extract the camphor, the tree has to be cut down, and by a stringent law of the land, Mr. Jones reports that another tree has always to be planted in its stead.

The trunk and large stems of the selected trees are cut into small pieces, and by means of a simple apparatus are then subjected to distillation with steam. A metal pot is charged with water and placed over a slow fire, and a wooden tub having a perforated bottom is placed over the pot. In this the broken camphor wood is placed, and a clean light cover is then placed over the tub, from which a bamboo pipe leads into another tub, through which the steam, camphor and generated oil flow. The second tub is connected with a third, which is divided by a floor into two compartments, one above the other; the oil and water pass on to the lower floor, while the upper one is provided with a layer of straw, which catches and holds the crystals of camphor as they are deposited by cooling. The camphor is afterwards packed in tubs of 1 picul, or 133⅓ lbs., ready for the market.

The water is afterwards separated from the oil by means of a faucet, and the oil is said to be used by the natives partly for illuminating purposes, while the exhausted wood is dried and used as fuel. The yield of camphor and oil varies greatly with the season, much more solid being obtained in winter than in summer, while the reverse holds good of the oil. In summer, from 120 kilos of wood, 2·4 kilos, or 2 per cent., of camphor is obtained in one day, whilst in winter, 3 kilos, or 2·5 per cent., is obtainable in the same time.

The amount of oil obtained in ten days, *i.e.*, from ten charges of 120 kilos each, is in summer about 18 litres (4 gallons), and in winter it amounts to about 5 to 7 litres (1 to 2 gallons). Mr. Oishi reported the then price of camphor to be at 1s. 1d. per kilo (1,000 grammes, or 2·2 lbs.). The price in this country to-day is about 230s. per cwt., or over 2s. per lb. The camphor oil contains a considerable quantity of camphor, and by means of distillation and cooling about 20 per cent. of it can be removed.

By the fractional distillation of some original oil Mr. Oishi obtained between 180° C. and 185° C. a distillate which, after a number of redistillations, was analyzed and found to have the composition of camphor. Another fraction which came over between 178° C. and 180° C. after three distillations was analyzed, and gave 86·95 per cent. carbon and 12·28 per cent. hydrogen =99·23 per cent. This substance was, therefore, in the main a hydrocarbon, probably of the terpene series. The original camphor oil may, therefore, be described as a solution of camphor dissolved in this hydrocarbon and an oxidized modification of it.

The probability of the hydrocarbon being a terpene, thus bringing it into distinct family relationship with turpentine and oil of eucalyptus, I have since established by proving that when exposed to oxidation by air or oxygen in the presence of water, it yields, in common with those essential oils and all others which contain terpenes, a large amount of peroxide of hydrogen and soluble camphor ($C_{10}H_{16}O_3$) in the manner explained in previous chapters. Indeed, I have conducted this process on a manufacturing scale.

Japanese camphor oil has been studied with some care by Mr. K. Yoshida,* who also observed that it has the property of absorbing oxygen. By subjecting a sample of the oil to fractional distillation he finally separated it into five portions, of which the chief ones were as follows :

(1) Terebenthene ($C_{10}H_{16}$) boiling at 156° C.; a hydrocarbon, probably isomeric with ordinary turpentine, of specific gravity 0·8641, and forming 7 per cent. of the oil which was distilled.

(2) A terpene of pleasant lemon odour, said to be probably identical with the citrene of lemon oil and like hesperidene of the orange. When oxidized with chromic acid it yielded a camphor-like substance. It formed some 20 per cent. of the oil and its boiling-point was 172° C.

(3) Camphor, boiling-point 205° C., forming some 23 per cent. of the total oil.

(4) An oxygenated oil boiling at 212° to 213° C., and forming 50 per cent. of the whole.

This last-named constituent is of the greater interest, as Mr. Yoshida considers it to be connected with the formation of camphor, since by repeated distillations he obtained from this portion a quantity of camphor. This was supposed to be formed during boiling (a temperature of 100° C. was insufficient to produce any camphor) from a substance which he has

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* *Journ. Chem. Soc. Trans.*, 1885, p. 779.

named camphorogenol, with the assumed formula $C_{10}H_{16}O, H_2O$. That is to say, he regards the substance as a hydrate of camphor, which upon continued boiling is resolved into ordinary camphor and a dark coloured oil supposed to be polymerized camphorogenol.

This so-called camphorogenol is a colourless heavy oil of sp. gr. 0·9794 at 20° C., having a pleasant camphoraceous odour, milder, however, than that of pure camphor. Mr. Yoshida supposes that the camphor which is believed to be produced in camphor oil by the process of ageing (oxidation) is likewise formed by the agency of this peculiar camphor hydrate. Probably this substance has but a hypothetical existence, and that the camphor which he obtained in the way described was pre-existent. I have ascertained that when camphor is dissolved in oxidized camphor oil, even to the (added) extent of 20 per cent., none of it can be removed therefrom by freezing; thus rendering it probable that the camphor which Yoshida obtained from his oxidized oil (which had been previously subjected to freezing) was pre-existent and resulted merely from the concentration which ensued upon repeated distillations.

I have shown that the active principles obtained by oxidizing the oils of turpentine, eucalyptus and camphor are identical, and that they give rise to the production of peroxide of hydrogen in the same way.

Like turpentine, camphor oil dissolves many resins, and is therefore suitable for varnish and paint-making.

The following report by Mr. Oishi shows the annual production of camphor in the province of Tosa up to 1880:

1877—504,000 kins (of 1⅓ lbs. each) of total cost 65,520 yen (2s. 9d.)
1878—519,000 „ „ „ 72,660 „
1879—292,890 „ „ „ 74,481 „
1880—192,837 „ „ „ 58,302 „

As distinct from the statement of Mr. Consul Jones, respecting the replacement of trees cut down, Mr. Consul Hall, reporting on the trade of Nagasaki, states that the destruction of the camphor forests still goes on and that no effort is made to replace the trees, for the reason that the tree is so slow-growing that none but large capitalists can afford to wait during the many years that would have to elapse before a new plantation could become a source of profit. He adds that seven-eighths of the camphor exported from Japan goes into the Hong-Kong market, where it has to compete with the supply from the Island of Formosa (China).

According to Flückiger and Hanbury, camphor oil is used by the Chinese in the treatment of rheumatism. Japanese camphor oil as it comes to this country is not of constant quality, for while some tins of it contain a mass of deposited camphor crystals, I have bought many barrels quite free from any crystalline deposit, although smelling strongly of camphor and containing a large percentage of terpenes.

The camphor trade in Formosa, which had almost become extinct, is said to have been recently taken under the protection of the Chinese authorities as a Government monopoly. Hitherto, the collection has been too scattered to make the trade very remunerative, but now the Government has undertaken the establishment of fixed depots for receiving the scattered supplies, which are paid for at a certain rate and resold for exportation at a great profit.

Borneo camphor, or *Borneol* (as it is also known to chemists), is somewhat different from ordinary camphor, its formula being $C_{10}H_{18}O$, but it yields the ordinary variety when subjected to the action of nitric acid. It can also be produced artificially from common camphor, whilst in odour and many properties it resembles the ordinary article. It is extracted from the *Dryabalanops camphora* or *aromatica*, being found in cavities in the trunks of old trees, and it is also present in small quantity in moist oil of valerian.

I have gathered some useful notes respecting Borneol from a paper written by Mr. Peter MacEwan.[*] He points out that from an early date it has been sought after by the inhabitants of the Malay archipelago, and that the tree which furnishes it is found in Johore as well as in Borneo, while in the state of Perak there is known to be a vast forest of camphor-trees. This tree is known by the natives as the 'Kayo Kapur' and its product as 'Kapur baroos.' The wood of the tree is of the colour of cinnamon, and is as durable as, and stronger than oak, and weighs 48 lbs. per cubic foot. It is a handsome tree, frequently running up to 150 feet in height, with a diameter of six or seven feet at five feet from the ground.

The Labuan export in 1863 was valued at 5,168

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[*] *Pharm. Journ.*, vol. xv., p. 793.

dollars; in 1864, at 11,156 dollars and in 1865, at 2,587 dollars.

The wood of the *Dryabalanops camphora* yields, upon distillation, an oil much resembling that obtained from the Laurel camphor previously described.

Borneol camphor oil is said to consist chiefly of Borneene (an isomer of turpentine) holding in solution a quantity of Borneo camphor. It varies in specific gravity (averaging ·882) according to the amount of oxidized matters which are contained in it. The oil undergoes oxidation when exposed to the air, resembling in this respect the Japanese camphor oil and ordinary turpentine, and as in those cases, an organic peroxide is formed which produces peroxide of hydrogen when placed in contact with water.

In conclusion, it may be remarked that the natural history of camphor forests affords another and remarkable illustration of Nature's Hygiene. In them, as in those of pine and eucalyptus-trees which we have previously considered, atmospheric oxygen is constantly being absorbed by the essential oils that are continuously evolved into the air, and this simple process gives rise to the production of a number of active chemical principles, including peroxide of hydrogen, a thymol-like substance and soluble camphor, all of which purify the air and enhance the healthful character of the climate. In these respects nature may be said to be independent of the efforts which have to be made by man in densely populated cities and districts, to maintain the health of the locality.

INDEX.

THE END

BAILLIÈRE, TINDALL AND [illegible], 8, HENRIETTA [illegible]EET, COVENT GARDEN

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PARIS - LONDON - MADRID
MENS SANA
CORPORE SANO