THE INDIAN

MANUAL OF HYGIENE

BEING

KING'S MADRAS MANUAL OF HYGIENE

REVISED, REARRANGED AND IN GREAT PART REWRITTEN

BY

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VOLUME I.

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PREFACE.

To the medical officer but lately arrived in the tropics, one of the earliest and most important matters of concern is, naturally, the ascertaining of the special sources of information that exist upon Disease in India and its Prevention. Before he has been long resident in the country it must become evident to him that things in general are in many ways different from what they are in Great Britain, that he has to unlearn a little and to learn a great deal. It is not merely that the population is different from that of Great Britain but that it is composed of elements differing essentially in themselves; that some invariably wear one kind of dress and some another, and that by many clothing is looked upon as a luxury rather than a necessity; that to some the eating or even the thought of meat, especially beef, is pollution, whilst others have no objection to beef but look upon pork as a thing of abhorrence; that some eat little but rice all their days, whilst others rarely see rice; that some live in a climate in which the annual range of temperature is more than 100° F., whilst others spend their days in a climate with an annual temperature range of about 25° F. Clearly, then, he has much to study and much to see ere he can gain even a rough and incomplete idea of the social conditions and vital surroundings, the demography, in fact, of the 300,000,000 inhabitants of the Indian Empire.

Further, a little reflection and observation will soon convince him that of the numerous subjects he has studied there are some which are identical in all important respects with what he has already learnt, *e.g.*, Anatomy, Physiology, Obstetrics, Materia Medica, etc., whilst others, typically Surgery and Medicine, retain their essential features but require important alterations and additions in many points, and, finally, that there are three great subjects, *viz.*, Pathology, Medical Jurisprudence and Hygiene, which differ so much in India and present so many entirely new features that he is almost helpless without special works to guide him. In the case of Medical Jurisprudence there need be no difficulty, for there are in existence two standard books in which is contained all that is necessary*. In addition, there are several excellent books dealing with the Practice of Medicine and its various subdivisions. such as Fevers. There is, unfortunately, no text book of Indian Surgery, as yet, though there are many excellent monographs on its special branches. Still more remarkable and regretable, however, is the non-existence of standard works upon either Indian

* *A text book of Med. Jur. for India*, by Bde.-Surgeon Lt.-Colonel J. B. Lyon, C.I.E., F.C.S., F.I.C., and *Med. Jur. for India*, by the late Norman Chevers. The latter is now out of print, but a new edition is in preparation.

Pathology or Hygiene. It seems almost incredible that it should be so after years of British occupation and generations of medical officers, including men of world-wide fame and unsurpassed ability. It is not here intended to discuss the reasons for such a state of matters, but some of them will be alluded to incidentally hereafter.

Though, as has been said, there is no standard work on hygiene in India, there have been written three books of moderate size and completeness, and many elementary books and pamphlets dealing superficially with the subject or in a very simple form for the use of schools. The oldest work of any size is that by Sir William Moore, entitled 'Health in the Tropics; or Sanitary Art Applied to Europeans in India,'* an excellent work, which serves to illustrate, as do Miss Nightingale's writings, how many years ahead of sanitary reform a sanitary reformer may be, and how slowly is the lesson of cleanliness appreciated or applied. In 1875 was published 'The Madras Manual of Hygiene', compiled under the orders of Government, by Surgeon-Major H. King, the first and only attempt at a systematic text book for students of medicine and others. In 1880 the second edition of this book was published. In 1888 Mr. J. A. Jones, M.I.C.E., at the present time Sanitary Engineer to the Government of Madras, published, under official approval, his well-known 'Manual for District and Municipal Boards', which contains a large amount of information relative to sanitary work and construction. Finally, in 1889

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* Published by Churchill, London, 1862.

the late talented and much-lamented Surgeon-Major C. J. McNally, formerly Professor of Hygiene at the Madras Medical College and at that time Acting Deputy Sanitary Commissioner, brought out his excellent book, 'The Elements of Sanitary Science: a Hand-book for District, Municipal, Local, Medical and Sanitary Officers, Members of Local Boards and Municipal Councils and Others.' In many ways this book is the best yet published in India on the subject, and is very well suited to all who wish to gain a clear idea of the leading facts and principles of hygiene, but whose scientific and technical knowledge is limited. It is by no means, however, comprehensive or systematic, and makes no claim to be considered as a text book for advanced students, medical officers and others. Of the smaller works, the more important are the clear and thoughtful *brochure* of Surgeon-Major S. J. Thomson, at present Deputy Sanitary Commissioner, N. W. Provinces, 'Sanitary Principles, more especially as applied to India,'* the 'Sanitary Primer' by Surgeon-General J. M. Cunningham, and, quite lately, the Sanitary Primers for Schools by Surgeon-Captains A. E. Roberts and P. Hehir. In addition, several excellent pamphlets on 'Water,' 'Precautions against Cholera,' etc., have been issued.†

It was originally intended by the author to write a small and compact text book, principally for the use of students of medicine, to whom many of the terms and examples contained in English works are unintelligible. At the same time material was to

* Brown & Co., Calcutta, 1883.

† *e.g.* 'Cholera and Water in India,' by Surgeon-General M. C. Furnell, M.D., C.I.E., and 'Simple Sanitary Rules,' by Surgeon-Major W. G. King, M.B., etc., etc.

be sought for, gathered and arranged, for a large and, as far as possible, complete Manual of Indian Hygiene, to be issued in the course of several years. The second edition of the Madras Manual of Hygiene being out of print, Messrs. Higginbotham and Co., in 1892, applied for and obtained permission to reissue a new and revised edition, as a purely private publication, and at their request the present writer undertook the work. At first it was believed that thorough revision and a few alterations were all that were necessary, but, as the work proceeded, it soon became clear that most of the information was out of date and that the book was in other ways unsuitable for present requirements. It was therefore determined to rearrange, rewrite and enlarge it, to illustrate it, where necessary, and to make it applicable to the whole of India.

Owing to its being the first work of its kind there has been great trouble in even ascertaining the various sources of information. It would have been both interesting and instructive to have illustrated each individual point with examples drawn from local sources, but besides the fact that this would have rendered the present work too bulky, there remains the important condition of its practical impossibility owing to the limitation of all sanitary officials to certain particular presidencies or districts; the one exception being the Surgeon-General with the Government of India, who, obviously, could not possibly undertake the particular work required. Before any text book of Indian hygiene can have the fully representative character and intrinsic value it should possess, there must be available the records and observations of a capable and carefully-selected sanitary officer who, untrammelled by official burdens or restrictions, has travelled through the length and breadth of India; who has personally inspected the numerous sanitary systems and institutions; who has spent days in the bazaars and streets of the towns and villages, and has made himself familiar with the customs, appearances, food supplies, habitations, etc., of the various peoples; who has studied the important influence of climatic and physical surroundings in modifying their health and general well-being; and whose opinion may thereby carry the weight and conviction his great experience would justify. Certain it is that work thus carried out, and knowledge thus gained, if embodied in a text book or separately issued in explanation and amplification of the same, would very materially help the onward progress of hygiene in India and be of immense use to all local workers in the field of sanitary science. It is sometimes asserted that nothing of any value is to be thus gained, some boldly declaring that the climate, customs, food supply, etc., are practically the same for all India, whilst others declare that they are so different in different places that no good can come of an attempt at a general survey. To both classes the answer is—let the experiment be fairly tried once; the expense would be very small, the results, it is not doubted, of great and lasting importance. The author has many times sought in vain for a comprehensive and detailed survey by one worker as here sketched out, the need of which becomes at once apparent to any one desiring systematic information on this vast subject. But for such a task the individual selected must not only possess a wide general knowledge, coupled with the training of a specialist in hygiene; he must be ready to go into the highways and hedges, to bear the burden and heat of the day, and, above all, be in true and thorough sympathy with his fellow-subjects, the toiling and ailing millions of India.

In the absence of any systematic text book on Indian hygiene it is evident that the want of the same is felt not merely by one class of persons but by all concerned with the subject. So far as possible, then, the aim of the writer has been to supply a book which will be neither too superficial nor too comprehensive, and which, whilst containing all, and more, than is required by students of medicine, will yet serve as a useful guide and means of information to military and civil medical officers, assistant surgeons, candidates for a degree in sanitary science, and others. It is obvious, of course, that anyone holding a purely sanitary appointment should be acquainted with all the original books, memoirs, reports, etc., dealing directly or indirectly with the subject, but this, owing to the isolation of Indian stations and the want of scientific libraries, is by no means easy. It is intended, therefore, to insert at the end of the second volume a short descriptive list of the chief books and other publications connected with modern, and especially Indian, hygiene, and it is further intended, if found feasible, to separately publish an as nearly as possible complete index or digest* of the numerous memoirs, papers, reports, etc., on hygiene and sanitation which have appeared in India,

* Now in preparation.

with the exception of those dealing purely with statistics.

If to any reader it should appear that in places one subject receives disproportionately full treatment, to the detriment of others, let him remember the varied nature of the audience for whom the book is written and the extreme difficulty of pleasing all alike. Let him remember also that what may seem a simple and unnecessary explanation to one who has studied hygiene in England, may be difficult and new to an Indian student, and *vice versâ*, allusions may be made to habits and customs with which the student has been familiar since his youth, but which are novel to the fresh arrival from Europe. And there is still another important aspect of this question. If the teaching of hygiene to students is to bear any fruit in their after career it is necessary that they should be presented with a broad and attractive view of the subject. How common it is to meet medical officers upon whom the sole effect of their brief and purely lecture-room training has been the strengthening of their opinion that hygiene is a synonym for sanitation, and that sanitation is summed up as the "looking after drains and bad smells, and all that sort of thing." It should, therefore, be clearly brought home to the student, in order for the prevention of so limited a conception, that hygiene is a science which has only of late years become a science, that in its application it is termed sanitation, that it requires a most varied and extensive knowledge, that it is intimately connected with other sciences that bear upon the moral and physical health of mankind, and that its good effects are soon felt and increase in geometrical ratio. True, mistakes have occurred and will occur from obstinacy, timidity or misguided enthusiasm, but the central fact remains that on moral, political, financial and purely personal grounds, the study of hygiene and the spread and progress of sanitation amongst the people are to be earnestly desired and encouraged. It is hoped, therefore, that the student who honestly peruses the contents of this book may not only gain therefrom the special information necessary for examination purposes, but may be led to see the wide, and at the same time intimate, relation of hygiene to other important matters, and may also be enabled to realise, as noted above, the essentially practical nature of the subject.

One great difficulty in inducing students to take a real and lasting interest in hygiene is the fact that, as yet, there are extremely few, if any, purely sanitary posts open to them. It is only a matter of time till the larger towns* have each their health officer, and for such posts there are a few men to be found in the Indian Medical Schools who have every qualification save the special training after graduation.†

Year by year the duties of District Medical Officers are increasing in number and complexity, and some day it will become thoroughly apparent that one man cannot be the sanitary officer of a large town, sanitary officer of a district of 10,000 square

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* According to the latest census (1891) there are 30 towns with a population of over 100,000, 48 with a population of over 50,000, and 149 with a population of over 20,000.

† Even now there is one medical graduate trying, in the absence of all proper facilities, to take the L. San. Sc. degree of the Madras University, and others are writing or have written to know how it can be managed.

miles or more, the medical officer in *executive* charge of one or more hospitals, and possibly of a jail as well, and in *administrative* charge of numerous smaller hospitals, dispensaries, vaccination stations, etc., etc., without some portion of his work receiving but very nominal attention.* Such a state of matters is good neither for the official nor for the district in which his sphere of labour lies. If sanitation is to make solid progress in India, it is necessary either to appoint special and purely sanitary officials, who shall be resident in their districts, or to largely increase the number of District Medical Officers.† The statement that in the present state of affairs occasional inspections by the District Medical Officer, with an annual or biannual visit of the Sanitary Commissioner or his Deputy, is all that is required, is untrue and shows complete failure to realise the

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* The point that seems to require special emphasis is the fact that so large a portion of *medical* work is executive and not merely administrative, and that to an amount of the former which would be considered ample work for an ordinary practitioner in England, is added a very large amount of administrative labour in connection with returns, reports, communications from all other departments, inspections, etc., etc. In addition, most people fail to realise the peculiarly wearing effect of the continuous and unremitting responsibility inseparable from the conscientious treatment of the sick, and the severity of the punishment invariably meted out for any real or supposed carelessness in such work.

† "It may be urged that the civil surgeon is a stationary officer, or at any rate is supposed to be so, and will not be able to visit personally all the villages of the district; it will be taking him away from his legitimate work of treating the sick in the station [which is just what does happen continually under present arrangements]. Suggesting rules and measures in writing from his office, he may do; but travelling into the district from village to village will be practically a physical impossibility, having regard to his urgent daily station work, as also to the extent of the district. That is a reasonable argument and a real difficulty. Then have a regular sanitary office for each collectorate distinct from the deputy sanitary commissioner." *v.* Trans. VIIth San. Sci. Cong., Vol. XI., p. 117. In England, this matter, *viz.*, the appointment of Medical Officers of Health, absolutely distinct from ordinary practitioners and debarred from practice, has at length, after years of fighting and much waste of time and money, been finally settled in the affirmative, with corresponding and speedy benefit to the health of the general public.

necessity for continuous supervision and attention to details. By all means introduce pure water supplies and good drainage schemes into the larger towns as rapidly as possible. They are of inestimable value, but they do not constitute the sanitation of India.

The whole subject of the expansion and development of sanitary science that must needs take place in India is considered in several papers contributed to the Seventh International Sanitary Congress.* Two points are of especial importance, the spread of a knowledge of sanitary principles and practice, and the education of purely sanitary officials. With reference, firstly, to the latter point, it may, possibly, be necessary, or strongly advisable, to send selected engineering students to Europe, as advocated by many; it is certainly quite unnecessary to send medical graduates there. There is nothing now wanting in Madras for the complete instruction and training of sanitary officers save time and the proper facilities. The means are there,† from a laboratory of hygiene completely equipped, far more so than many in England, to a town presenting almost every possible sanitary or insanitary feature of interest. Given properly-arranged courses on the special subjects, practical and theoretical, a good student after seeing, perhaps, the other presidency towns, would be in all points fitted to take his L. San. Sc. degree and to become the health officer of a town or district—always supposing that he possessed the high qualities essential to success in this profession. It is not asserted that

* *v.* Vol. XI of the Transactions.

† Save a Museum of Hygiene, the building of which, however, is being considered.

"trained Indian sanitarians will [or should for many years] perform the duties which now devolve upon the higher sanitary officers of the Presidency." "They have not," says one writer,* "the same education [as English students], though it may be good of its kind and very creditable, considering the educational and instructional appliances of Indian Medical Colleges."* * * "The Indian student, to be a practical scientific sanitarian, will have to be practically educated to appreciate the practical difficulties of carrying out sanitary measures." This question of furnishing trained sanitary officers to the larger towns and to the districts is of such importance and, though its solution in the affirmative is only a matter of time, is likely to meet with so much opposition on financial grounds, that it is extremely important to consider it from the stand-point of expense and to see whether the Indian student does really labour under such disabilities as compared with the same class in England. The writer can only speak of Madras and, so far as Madras is concerned, he states most emphatically that it is not so. For years the course of lectures in hygiene delivered to M.B., L.M.&S., and Government 'warrant grade pupils,' has been longer and more complete than that required for M.B. Students at the British universities. Instead of three months with lectures on alternate days of the week, the course at Madras Medical College continues for six months, during which there are, on the average, more than sixty meetings, including over fifty lectures, eight oral and two

* Surgeon-Major K. R. Kirtikar, I. M. S., *v.* Trans. VIIth San. Sci. Cong., Vol. XI.

written examinations. The subject is far more fully gone into than at most English Colleges, and it is impossible for a student to take his degree without attending such a course, whereas, until quite lately, there were many officers to whom the subject of hygiene was a closed book before attending the course on Military Hygiene at Netley. For any one intending to become a specialist in research it is certainly, and most regretably, still necessary for him to proceed to Europe. But for the thorough post graduate training of sanitary officers, Madras, as before stated, possesses everything that is necessary and, given proper development of the facilities available, there is not the slightest necessity to go to the expense of sending home those intended for future sanitary officers. The average Indian medical student or graduate would certainly not make a good sanitary officer, for various reasons, but there are quite enough exceptional men who combine an intimate knowledge of the country and its customs with the high qualities necessary for the sanitarian.

As regards the other great sanitary need of India already alluded to, *viz.*, the popularisation of an elementary knowledge of hygiene, it is pleasing to see that the question is being earnestly taken up by the educated natives of India themselves, backed by the able advocacy and exertions of Miss Florence Nightingale and others.* There is no doubt that a great deal could be at once accomplished in this direction by means of lectures illustrated by diagrams, lantern slides, and practical demonstrations, but at present no one who has the requisite skill and know-

* *v.* Several papers in Trans. VIIth San. Sci. Cong., Vol. XI.

ledge has also the necessary leisure. Such lectures, adapted to the capacity of the various audiences, would naturally form part of the work of the special Sanitary Officers who must ultimately be appointed for all large towns and districts, in place of the already over-worked District Medical Officers.

So far the discussion has been limited purely to the question of the sanitary needs of Indian towns and districts. But what about the work of enquiry into the various disease-scourges of this great country? What about the patient and careful study of the countless unsolved problems which confront all engaged in sanitary work in India? What about the systematic investigation of the food-stuffs, as to composition, purity, etc., upon which 300,000,000 persons depend for food? What about malaria, which kills its millions and disables its tens of millions? What about cholera, elephantiasis, beri-beri, enteric fever, dysentery, jail-diarrhœa, anæmia and the whole gamut of Indian disease? What about the study of Hygiene in fact? Nothing! or next to nothing, save what a few earnest and un-thanked workers are able to accomplish in the intervals of arduous routine duties. In the whole of the Indian Empire not one institution where half-a-dozen trained investigators are constantly engaged in studying the questions of disease causation and prevention. Everything is considered of greater importance than this. *One* bacteriologist and the promise of *one* officer if the public subscribe the money for a Pasteur Institute! The British race is avowedly afraid of the word scientific because, owing to a total misconception, 'science' is supposed never to pay. Even by many medical officers, who have been or are 'sanitary officers' as well, the pursuit of scientific investigation is looked upon as something quite apart from ordinary teaching and ordinary sanitary work. Disregarding for the present the inaccuracy of this view, it must be pointed out that they also forget the fact that nothing is so stimulating to the student and nothing is so qualified to make him an earnest, useful man in after-life as the sight of others engaged in enquiries into the actual causes of disease. All that he learns in the wards of a hospital he can read of in his books, but there is something new and strange in a research laboratory, enabling him to realise how little is known, how much remains to be done, and that he himself, like the workers he saw, may hereafter do something, not merely to lessen misery and relieve the sick, but to break the power of disease. As to the question 'Does it pay'? there are signs that the British public is beginning to find out for themselves, as they have gradually found out in the case of sanitation, that it certainly *does* pay. Once they realise this, there is no fear for the future and then, instead of India having no Hygienic Institute and every European country one or two, India will probably have one in every presidency and independent province till there are as many as in all Europe.* At present the small French Colony of

* Nothing lately has given the writer greater pleasure than the reading of a review of the *Official Catalogue of the German Empire*, at the Chicago Exhibition (*v. Nature*, 22nd June, 1893), in which is set forth the enormous industries which have grown up in that country as the direct result of pure scientific investigation. "Side by side with the military forces, the scientific forces of the country have been carefully and patiently organised. At the instigation of Liebig, great state laboratories for pure scientific research were erected all over the country, and from these have issued an army of highly-trained workers." * * * "Firms with 40 workmen sometimes employ as many as 5 or 6 chemists and three great colour firms

Tonkin is better equipped in this respect than the Indian Empire. It is frequently urged by the timid or sceptical that quite as much is being done for Indian sanitation as is advisable in the present state of education. Without for one moment admitting the truth of such assertion, it may be pointed out that the study of hygiene is not subject to any such disadvantage, and since the refusal to do more is ascribed purely to a desire not to 'push matters,' it should be pointed out that now is the time to pursue the study of hygiene, to elucidate the causation and means of prevention of disease, so that when public opinion reaches the wished-for degree of development, advantage may be taken at once of the discoveries of the workers in hygiene.*

With the exception, then, of the three presidency towns, the purely sanitary workers in India are a mere handful, willing and capable enough, but unable to work miracles and to multiply themselves

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employ 178." * * * "In our own humble opinion the days of *laissez faire* have gone never to return, and the time has come when the Government of the country, backed by the country, must take as is the case in Germany—a larger share than it has done hitherto in the systematic organisation of our scientific and industrial forces." It should be noted also that it is not merely in chemical products that Germany is taking or has taken the lead, but also in scientific instruments, engraving, hardware and countless other directions. Truly we are paying dearly for our slavish fear of 'science' and of anything which does not 'pay' at once.

* The utter absence of any true research work in hygiene in India, is rendered painfully evident by the fact that amongst the whole of the papers contributed to the Indian Section of the Seventh International Congress of Hygiene and Demography, there was not one single paper giving the results of scientific investigation into the problems of Indian Hygiene. This, of course, is not due to the want of trained scientists amongst the officers of the Indian Medical Service, for there are many such; but the facilities and encouragement for the work are so entirely wanting that it is almost impossible for any one to attempt it. So also there was not a single scientific paper from Indian Engineers. Why? It has been left to a private individual—Mr. John Wallace, C.E.,—to publish the first work on Sanitary Engineering in India. So little is the term hygiene understood, even by some medical officers, that a remark of the author's as to the absence of hygienic research in India, was understood to mean that no one in India knew anything about sanitation!

indefinitely. Madras, with an area of 141,189 miles, in which are 214 towns, 56,867 villages, and a population of 35,630,440 persons, possesses one Sanitary Commissioner and one Deputy Sanitary Commissioner, whilst the District Medical Officers are supposed, in their rambles of inspection over the 10,000 square miles or more of country which is under their charge, to exercise their additional function of 'Sanitary Officers.' As to the *value* of the work done under such conditions of hurried and intermittent inspection let the Reports of the Sanitary Commissioners issued year after year testify. The amount of routine work is enormous, the tables are endless, but the nett results are small indeed compared with what they would be had each district its own sanitary officer constantly at work amongst its towns and villages, stimulating the indolent, helping those in doubt, lecturing, etc., etc., and evidencing, by his presence, the keen interest of the State in the salvation and betterment of the lives of its subjects.

Of the work done by past and present generations of Indian sanitary officials, in the face of much opposition and scepticism, no one has or can have a higher opinion than the writer. There can be few things more disheartening than the sanitary charge of a district in which the inhabitants are sunk in apathy, surrounded by filth, and kept, by grinding poverty, on the borderland of starvation; where the European officials too often say "What's the use, you *can't* make these people clean"! and the educated natives say, or imply, that it is isn't worth while doing so if one could, for there are always enough of these people to till the land and do the manual labour, which is all they are good for; where in reply to complaints to the higher authorities, it is acknowledged, indirectly, that one is expected to make bricks without straw, but that in the present dearth of the latter article the sanitary department cannot possibly receive more, and so on. Truly it needs great faith and endurance to go on steadily, as many have done, in the face of all this, and to accomplish as much, or as little, as is permitted. As a result of the present system, the District Medical Officers in India fall into two divisions—those who by habit and training are accomplished and earnest sanitarians, and those who are not so, either from want of interest or from a perfectly legitimate desire to devote their time and energies to the over abundance of purely medical and surgical work lying to their hands.* Surely it is time that the idea that a medical officer is *ipso facto* capable or desirous of the duties of sanitary officer as well, was given up,

* With reference to this point, Sir Mountstuart Grant Duff, in his opening address as Chairman of the Indian Section, at the Seventh International Congress of Hygiene and Demography, made the following remarks. "We made, in my time [as Governor of Madras], the civil surgeon of each district a sanitary officer, and imposed upon him the duty of advising the presidents of municipalities and local fund boards in every thing that relates to medical and sanitary affairs; providing him at the same time with a second in command to undertake some of his former duties. I hope that change is working well." That change, so far as sanitation is concerned, is working well just where the district medical officer takes a keen personal interest in the subject, and in these cases it is equally certain that the purely medical work must suffer. The 'second in command' was an absolutely necessary addition owing to continued expansion of the executive and administrative medical duties of the districts, and cannot be regarded as a means by which the medical officer is perforce transformed into a trained and willing sanitary officer. Once more, a man cannot possibly look after the entire medical and sanitary work of a district of many thousand square miles. This point is strongly insisted on by Surgeon-Major Kirtikar in his paper, *Our Sanitary Wants in the Bombay Presidency*, communicated to the VIIth San. Sci. Congress, and, indeed, its urgent claim to immediate attention must impress all who have the sanitary and medical welfare of India at heart.

and the acknowledgment honestly made that the two classes should be kept distinct, and that proof of special training and aptitude will invariably be required from those selected for the latter class of appointments. Of the leading sanitary officials in India, one thoroughly competent to speak* has lately said, "His extensive connection with various sanitary workers in this country and the continent had brought him in contact with a large number of medical men, but he could say, without hesitation, that the Sanitary Commissioners and Medical officers of Health of India were most devoted to the prosecution of sanitary work, and possessed a vast amount of information as to the causes and the prevention of disease in that country, and that they would compare favourably with like officers in other countries." It is not the men so much as the system which is at fault.

It is a commonly observable, though much-to-be-regretted, fact that long residence in India seems to blunt the æsthetic sense of many officials, medical and otherwise, so that the filthy smells and unspeakably offensive sights common to towns in the tropics no longer cause a feeling of active disgust within the observer. Years of daily contact with a people, the mass of whom, rich and poor, educated and uneducated, regard such matters with perfect composure or indifference, have inoculated these officers with the fatalistic virus to such a degree that they have even been known to imply by their remarks that the attempt to sanitate Indian towns

* Mr. Baldwin Latham, M.I.C.E., of world-wide fame and experience as a Sanitary Engineer.

and their inhabitants is a mistake, an interference with the laws of Nature! Others, it must be confessed, never started even with any enthusiasm for the true cleanliness of men and cities. Their being of British origin entitled them to the credit of a love of cleanliness for its own sake, but their subsequent lack of interest in the matter, and entire acquiescence in the insanitary conditions around them, have made it obvious that their cleanliness was only superficial, and the result of a favourable environment in early life. If there is one thing in which the British dweller in India should set a constant good example, it is in this matter of scrupulous cleanliness in person *and surroundings*, even at the cost of considerable trouble and a little expense.* The plea of ignorance is not allowable; in this matter ignorance is culpable. It is well to remove the beams in our own eyes, and then shall we see clearly to cast out the motes in those of our brethren.

The present book may be said to retain but few of its original features. A considerable amount of matter has been omitted or altered, and a very large amount added. The introduction is entirely new and is intended, primarily, to give the student a bird's eye view of the subject, and to enable him to trace the gradual evolution of hygiene from the simple idea of self-preservation, up to its modern high degree of development and organisation, under which the State orders and controls the measures to

* The mere fact that in a presidency town, like Madras, there is no proper market in the year of grace 1893, and that the English residents, as a class, are still content to allow their daily food to be exposed to chance contamination from loathsome practices and impurities, betokens a grievous amount of 'tropical languor,' or an extraordinary degree of callousness.

be adopted for the Public Health, and in doing so enlists the aid of its educated and humane subjects, either individually or in theform of local and municipal bodies.

In the First Chapter the original arrangement has been slightly altered and the whole carefully revised; the Second and Third Chapters are largely altered and added to; the Fourth, Fifth and Sixth Chapters, with the exception of a few paragraphs, are entirely new. In the Second Volume by far the greater part of the book will be new. The numerous tables and formulæ for calculating the humidity, atmospheric pressure, etc., formerly given in the Madras Manual, have been omitted, both because they were chiefly applicable to Madras only and because special tables, issued officially by the Government of India, are now available for any one wishing to pursue the subject further. It is hoped that the tabular statements of Indian climates, the source of which is acknowledged below, will prove of general interest and encourage the reader to peruse the original work in which they are contained along with many others. A very large number of works have been consulted in the preparation of this book, including those of Wilson, Murphy and Stevenson, E. A. Parkes, L. Parkes, Whitelegge, Galton, Simon, Hirsch, Boulnois, Denton, Crimp, Sykes, Longstaff, Newsholme, Creighton, Kingsley, Mill, Scott, Burdett, Miss Nightingale, and many others too numerous to mention, and, in addition, many works relating to India, by McNally, Moore, Jones, Clark, Wallace, Blandford, Medlicott and Blandford, Fayrer, etc., and numerous reports and memoirs.

The author's special thanks are due to Messrs. Churchill, London, and to Bde-Surgeon Lieutenant-Colonel Notter, A.M.S., Professor of Hygiene at the Army Medical School, Netley, for permission to use the table of the Qualitative Examination of Dissolved Solids from Parkes' Hygiene, and to Messrs. Crosby Lockwood and Sons for the use of the drawing in plate IX., and for two other figures. He has also to acknowledge his great indebtedness to the works of Stevenson and Murphy, Sir Douglas Galton, Louis Parkes, Whitelegge, Denton and others, in England, for figures and drawings; to Mr. A. M. Jones, M.I.C.E., Sanitary Engineer to the Government of Madras, for figures in plates III. and IX.; to Surgeon-Major W. G. King, Acting Sanitary Commissioner to the Government of Madras, for two figures in plate IX.; to Miss E. Isis Pogson, F.R.MET.S., Meteorological Reporter to the Government of Madras, for permission to use the drawings from which plates XVII. and XVIII. are taken; to Mr. Henry Irwin, C.I.E., Consulting Architect to the Government of Madras, for the drawings in plate XV.; to Mr. John Wallace, C.E., for an advance copy of his 'Sanitary Engineering in India,' to Mr. B. R. Harrington, for plans and explanations of his incinerator and patent hydraulic sewer. He is specially indebted, as acknowledged elsewhere, to the works of the late Henry F. Blandford, F.R.S., F.R.MET.S., the well-known Meteorologist to the Government of India, for much of the information in the Sixth Chapter, for the drawings in several of the plates, and for most of the tables in the same chapter.

Personally, he has received much help and assistance from various friends, amongst whom Mr. C. Michie Smith, B.Sc., F.R.S.E., Acting Astronomer to the Government of Madras, has rendered invaluable aid in suggestion and revision during the preparation of the Sixth Chapter and at other times. His thanks are also due to Surgeon-Captain C. L. Williams, I.M.S., Acting Resident Medical Officer, General Hospital, Madras, for revision of proofs; to Mr. R. Ll. Jones, B.A., Professor of Physics at the Presidency College, Madras, for the explanation on page 338, and for revision of proofs; and to Mr. W. H. Cook, Deputy Superintendent, Madras Revenue Survey, for the trouble he has taken in the preparation of the frontispiece. From M.R.Ry. M. C. Nanjunda Row, B.A., M.B., the Assistant to the Professor of Hygiene, he has received, since the commencement of the work, continual and efficient assistance in ways too numerous to mention, but which the author gratefully acknowledges here. Lastly, but by no means least, he acknowledges with thanks the great interest taken in the progress of the work by the members of the Madras Government, by the present Surgeon-General with the Government of Madras, W. de Fabeck, M.D., by Mr. H. B. Grigg, C.I.E., I.C.S., formerly Director of Public Instruction, Madras, and now British Resident at Travancore, and by many of his brother officers in the Indian Medical Service. It is probable that the names of some to whom he is indebted have escaped his memory and he hopes that they will believe that such omission is entirely unintentional. Of faults and blunders there are doubtless many, for the work has been carried on coincidently with arduous and unremitting official duties. It is hoped that all such will be pointed out, and the author assures his readers that he is only too anxious to receive advice, suggestions, and friendly criticism from all who are engaged in sanitary work. He also hopes that to no one has offence been given, as certainly none was intended, but in writing on matters sanitary the importance of the issues involved renders it necessary that the language shall be clear and to the point. Lastly, it should be remembered that, the work being entirely unofficial, the opinions expressed are to be regarded as purely private. The difficulties connected with the publication, and especially the illustration, of a book in India are so great, that those at least who have essayed a similar venture will fully understand and readily pardon all shortcomings in this direction.

Hygiene Laboratory,
Madras Medical College.
November, 1893.

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Page 2, line 16, *for* 'names' *read* 'name.'
,, 7, ,, 6, ,, 'of' *read* 'or.'
,, 19, ,, 20, ,, 'retatively' *read* 'relatively.'
,, 32, ,, 9 & 10, *delete* 'per head.'
,, 41, ,, 9, *for* 'Ellinson's' *read* 'Ellison's
,, 57, ,, 11, ,, 'follows' *read* 'follow.'
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,, 68, line 7, *for* '15°' *read* '15° C.'
,, 88, ,, 11, ,, 'calcare' *read* 'calcaire.'
,, ,, ,, 15, ,, 'fruit' *read* 'seed,'
,, 119, lines 16 & 17, *transpose* 'warmer' and 'colder.'
,, 120, line 3, *footnote* *, *for* 'previous' *read* 'pervious.'
,, 122, ,, 2 from bottom, *insert* '(4) Cholera;'
,, 137, *footnote*, *for* 'Wilson' *read* 'Wilson's.'
,, 138, lines 15 & 20, *for* 'deoderant' *read* 'deodorant.'
,, 157, *Transpose* the sentences beginning, respectively, "The former are often called" etc., and "Careful Distinction" etc.

Page 171, line 24, *delete* '(*v.* pl. ix.).'
,, 179, *footnote* †, *for* 'pl. vii.' *read* 'pl. ix.'
,, 192, line 24, *delete* 'to.'
,, 214, ,, 6 from bottom, *for* 'temporary' *read* 'temporarily.'
,, 216, *Footnote* †, line 6 from bottom, *for* 'Chindevin *read* 'Chindwin.'
,, 226, line 4, *for* 'deoderant' *read* 'deodorant.'
,, 301, *foot note* †, *for* 'p.' *read* 'p. 288.'
, 303, ,, †, ,, 'p.' *read*, p. 293.'
,, 349, line 3 from bottom, *for* 'a five hundredth' *read* 'five hundredths.'
,, ,, ,, 1 ,, ,, 'a two thousandth' *read* 'two thousandths.'
,, 351, line 3, *for* 'pl. xix.' *read* 'pl. xvi.'
,, 368, ,, 12, ,, 'per hour' ,, 'respectively.'
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INTRODUCTION.

Non est vivere, sed valere, vita, wrote the Roman poet* many years ago—"Not merely to live, but to be well, that is life"—for without good health, living is mere existence and the capacity for true enjoyment extremely limited. Though many realise this important fact in its more obvious sense, as evidenced by the common form of greeting, "I hope you are quite well?" it is only those who have devoted special thought and attention to the subject that are enabled to grasp the full significance and meaning of the phrase 'good health.'

From such a stand-point, the whole of the human race might be classified or arranged under two headings—The Healthy and the Unhealthy. In the latter class would come all who are not possessed of the *mens sana in corpore sano,* the healthy mind in a healthy body, and that this would include the larger portion of mankind there is little doubt. Now, the aim of the hygienist, put shortly, is to so influence the vital conditions and environment of the living amongst men, as to bring about the transfer of as large a number as possible from the latter to the former class. Note, also, that whilst doing this, he ensures that the coming generation, as the offspring of healthier parents and the inheritors of improved conditions of life, shall go to swell the

* Martial.

numbers of the truly healthy, to whom life will, in the best sense, prove enjoyable, and not a weariness of the flesh.

This view is sometimes disputed, and it is argued that one effect of improved hygiene is to keep alive the weakly and diseased who would otherwise have died early, these in turn propagating a puny and unhealthy offspring: an artificial and unwarrantable interference, so to speak, with the natural laws resulting in the 'survival of the fittest.' This rather plausible fallacy will be disposed of later on.

Having defined, in very general terms, the scope of hygienic reform, it remains to go a little more into detail as to the origin of this science—for such it is—and as to what was originally indicated by the word 'hygiene,' compared with what is now, and in the future will be, included under this extremely comprehensive title. In its simplest meaning it signifies 'health' and is derived from the Greek word *ὑγίεια* (Hygieia), which was the name given to the Goddess supposed to preside over the bodily well-being of mankind. Amongst all nations not advanced in the scale of civilisation the belief is strongly held that disease is simply the concrete expression of the anger of offended or evil deities. This belief is naturally fostered by the priests of the various religions, who find therein a means of filling their coffers and reducing the supplicants to a proper degree of submission. It is, in truth, one of their most powerful weapons, and is used in many ways, for purposes of offence or merely of defence. Thus, amongst the very ignorant and superstitious, this belief forms a most convenient way of extorting money or of exciting fear, whilst with the more enlightened, whom the priest is unable to threaten directly with plagues and other discomforts if they do not obey his commands, advantage is taken of an epidemic of disease or of a prolonged drought to indicate the evident displeasure of the Deity; the profit accruing from such a proceeding being a demonstration of the superior perception of the feelings and wishes of the Supreme Being possessed by the priestly adviser.* In the minds of some there thus arises an extraordinary confusion of ideas, occasioned, on the one hand, by the knowledge resulting from practical experience that certain acts will induce certain diseases, whilst on the other hand, illnesses of an obscure and insidious character are firmly believed to be the result of Divine displeasure. In proportion, however, as the mode of origin and intimate nature of the various diseases to which the human frame is liable have been, bit by bit, and one by one, demonstrated, so has the education of mankind progressed steadily, till many thousands among the enlightened of the nations have been brought to understand clearly that disease, while partly due to the mortal nature of the human body, is also largely due to the direct violation, through ignorance or otherwise, of the simplest laws of health. This may seem a small matter to those educated in a country like England, but in India its sufficient recognition by the people is nothing less than the foundation which must be laid ere any scheme for the prevention of disease can be satisfactorily carried out on the large scale. In the education of the young there is no matter of greater importance than the inculcation of the general methods by which diseases arise, and of the simple rules relating to bodily health, cleanliness, purity of air and water, etc., by which the occurrence of the former can be largely prevented.

* "That the Deity is normally absent, and not present; that he works on the world by interference and not by continuous laws; that it is the privilege of the priesthood to assign causes for these "judgments" and "visitations" of the Almighty, and to tell mankind why he is angry with them, and has broken the laws of nature to punish them—this, in every age, has seemed to the majority of priests a doctrine to be defended at all hazards; for without it, so they hold, their occupation were gone at once". Written thirty-five years ago by Charles Kingsley, a clergyman of the church of England, at a period when sanitary reform was looked at askance by the ultra-religious and viewed as a foolhardy interference with the workings of the Creator. All honour then to the 'priest' and man who, in the largeness of his humanity, did not hesitate to say what had to be said in no uncertain voice. Since then there has been truly a wonderful change, and no body of men now realises more thoroughly than the clergymen of the Established Church of England the power of clean and healthy surroundings to raise a man to a higher level—bodily, mentally and spiritually. It would be well for India could her own leaders, spiritual or otherwise, be brought to tell the truth in the same outspoken fashion.

Looking back on the history of the nations which have in turn led the civilisation of the world it will be found that there are invariably two points which stand out clearly. Firstly, the value of personal cleanliness was understood by the learned and wealthy classes and was practised by them, but it was chiefly a selfish knowledge, made use of for their personal safety and comfort, whilst all beneath them socially were allowed to exist in a condition infinitely inferior to that of the dumb animals belonging to their masters. Amongst the Egyptians, Medes and Persians, the priests and upper classes used friction and inunction of the body, abstained from certain kinds of food at specified seasons, practised gymnastic exercises, wore linen as being the cleanliest covering for the body, and attempted during epidemics to purify the air by fumigations. Secondly, in addition to this attention to personal cleanliness, was the fervent belief of all, from the highest to the lowest, that epidemics were visitations of the Divine anger, and being so, were to be subdued by endless propitiatory prayers and offerings. Amongst the Jews the same ideas prevailed to a large extent, but their priests had a clearly defined code of laws and regulations,* which will repay study by the thoughtful student, and is especially interesting as being the earliest known collection of rules relating to general sanitation. Their regulations dealt with the leprosy (so-called) of men, houses and clothing, with bathing, pollutions, the marriage of near relations, the situations of cemeteries, the isolation of the sick and the cleansing of vessels employed by them, the nature and mode of preparation of animal and other food, the disposal of excreta, etc. Many hundreds of years later, the careful observance of these rules by the conservative Jews, saved countless of their lives during the dread pestilences of the middle ages, whilst those around them were dying by thousands.

* Contained in the book of Leviticus, in the Bible. "It corresponds to the reality, in both the actual and chronological points of view, to consider the Jews (under Moses) as the creators of the science of Public Hygiene". Baas, *op. cit.*

To the fact that in their early days the Greeks and Romans lived up to the ideal of "plain living and high thinking" inculcated by the best of their philosophers, was due much of their success in all things, from bodily supremacy to the production of many of the world's masterpieces in philosophy, poetry and art. In later times, when luxury and immorality had first corrupted the Greeks and afterwards had sapped alike the health and independence of their Roman imitators, they became a fitting prey at once to epidemic disease and to the hardy northern tribes they had previously held in check. The essentially practical nature of the Romans showed itself in the elaborate and costly works they executed for the conveyance of pure water to the city of Rome and for the carriage of their sewage to the river Tiber, works of which large portions still remain more or less intact. With them, also, the place of the Jewish Levite or priest was taken by the Ædile, a public functionary upon whom fell the duties connected with the sanitary inspection of drains, streets and buildings, of baths, of food, etc., and in whom a considerable degree of authority was vested. As is well known, they carried the construction and use of baths to a high degree of perfection; to too high a degree in fact, for these latter became, ultimately, a mere excuse for luxury and idleness; true hygiene was neglected, and the people were attacked again and again with epidemics of disease that devastated the population and laid them at the mercy of their foes.

Corresponding to the Greek goddess Hygieia, before alluded to, was the Roman Dea Salus but, like many other nations in whose religion polytheism is a prominent feature, they could manufacture a deity on the shortest notice. Whenever, therefore, any evil particularly troubled them, they speedily elevated it to the rank of a divinity and worshipped it. Such were the goddess of fever, Febris; of foul smells, Mephitis; of itch, Scabies; etc., and when their drains or *cloacæ* were more than usually offensive, they created a goddess, Cloacina, and worshipped her devoutly!

Indian students can doubtless furnish many local examples of the same practice for themselves.

From the early years of the Christian era onward to the end of the fifteenth century is embraced a period of history unique in many ways, but in none more so than in the extraordinary number and severity of the epidemics of disease, amounting, by their universal distribution in many cases, to pandemics. The information obtainable is exceedingly scanty and frequently unreliable, but enough is known with certainty to convince all who read that never before*, or since, in the history of the human race, has the neglect of the commonest details of personal cleanliness and public hygiene been so universal and complete and, as a consequence, been followed by such fearful and wholesale destruction of human beings.†

For the first ten centuries or so the sickness chiefly took the form of the so-called 'plagues,' to be followed later by the dire 'epidemics' of the later middle ages. Of these plagues there are many historical accounts extant, but it is impossible to give them in any detail. One such visitation, known as the Justinian Plague, occurred at the beginning of the 6th century A.D. and was considered, as usual, to be associated with numerous Divine portents and threatenings, such as earthquakes, comets, volcanic outbreaks, peculiar-coloured markings on houses and food‡, and many other signs. In the year 542 the plague, which originated in lower Egypt, spread up the Nile and from thence to Asia Minor. "Constantinople was speedily attacked and (according to the almost incredible accounts) in the time of its greatest severity 5,000,—10,000 human beings perished there daily. In the next year, however, the plague striding over Greece to the west reached Italy. In 545 it extended to Gaul,

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* So far, of course, as can be ascertained from historical records.

† For much that follows the author is largely indebted to the *History of Medicine* by Joh. H. Baas, M.D., as translated and enlarged by H. E. Handerson, M.A., M.D., of Cleveland, Ohio, U.S.A., to the excellent, though brief, historical summary in Dr. George Wilson's *Hand book of Hygiene*, and to Dr. Charles Creighton's *History of Epidemics in Great Britain*.

‡ Caused by the presence and growth of coloured fungi and micro-organisms.

and in 546 it reached the Rhine, whose bordering cities (at that time in the bloom of prosperity), from Bingen-over-Mayence, the Metropolis, to Schlettstadt, it depopulated with its ravages. After its first period of fifteen years (which it is said to have afterwards almost uniformly maintained), the disease became milder, though it did not entirely disappear, until in 558 it visited Constantinople for the second time, with horrors only heightened by comparison with its first assault. So fiercely did it rage that the towers upon the walls were unroofed, filled to the brim with corpses, and then again covered in, since hands were wanting to assist in their burial; while many of those who lent aid in this horrible labour of heaping up the dead fell down themselves and expired in the midst of their task. Thus new causes of death in the form of the horrible gases of decomposition were pent up, as it were, in these fearful store-houses. In other cases the dead were treated more judiciously and hygienically by sinking the corpses in the open sea with the aid of a ship specially appointed for that purpose, though some bodies were carried back by the waves to the shore—dreadful tokens of warning to those who yet survived. In this plague, however, the general imminence of death broke down all the barriers of custom and shame to such a degree that only the worst of mankind seem to have survived. In the year 565 this unprecedented plague visited Italy a second time so severely that the Romans could not advance against their enemies. For long years it endured, intermixed at the close with the small-pox, sweeping away in its devastating course the bloom of manhood and youth, and destroying the greater part of women, maidens and children in all the then known world. It loosened, too, almost all the rootlets of the ancient civilisation, so that the withered stem was able to maintain for centuries, only a feeble and sickly existence."*

* It is impossible to gain even an approximately correct idea of the mortality resulting from this great plague, but that it was enormous there is no doubt. Concerning this Justinian plague, Creighton has some pertinent remarks. "The historian Hallam includes a thousand years in the

From these early centuries onward the same state of things continued to a great extent. Civilisation and its resulting comforts may be said to have been limited to the very few who could afford them, but even in these cases it was but a superficial gloss. Their general mode of life and their personal habits alike were in the main filthy and coarse, far worse than those of many nations who preceded them in this world's history. Under the name of religion most extraordinary things were done, *e.g.*, the extremely meritorious and pious practice of kissing leprous ulcers. Immorality in its grossest forms was the rule and was a most fruitful cause of disease. In fact, that the "Middle Ages were socially and hygienically a most degraded period" will be very thoroughly realised by any earnest and unbiassed student of history.*

As to the factors which aided in spreading disease far and wide it is written, "The causes of this phenomenon were in part prolonged in their effect from the last ages of Antiquity. In this connection we must mention first of all the wandering and restless migration of peoples (including the Crusades) and of individuals. From this arose,

mediæval period, from the invasion of France by Clovis to the invasion of Italy by Charles VIII., in 1494. We begin, he says, in darkness and calamity, and we break off as morning breathes upon us and the twilight reddens into the lustre of day. To the epidemiologist the mediæval period is rounded more definitely. At the one end comes the Great Plague in the reign of Justinian, and at the other end the Black Death. Those are the two greatest pestilences in recorded history; each has no parallel except in the other. They were in the march of events and should not be fixed upon as doing more than their share in shaping the course of history. But no single thing stands out more clearly as the stroke of fate in bringing the ancient civilization to an end than the vast depopulation and solitude made by the plague which came with the corn-ships from Egypt to Byzantium in the year 543; and nothing marks so definitely the emergence of Europe from the middle period of stagnation as the other depopulation and social upheaval made by the plague which came in the overland track of Genoese and Venetian traders from China in the year 1347. While many other influences were in the air to determine the oncoming and the offgoing of the middle darkness, those two world-wide pestilences were singular in their respective effects: of the one, we may say that it turned the key of the mediæval prison-house; and of the other, that it unlocked the door after eight hundred years."

* A statement, the truth of which is in no way controverted by the fact that amongst the rich or amongst those living in cloistered retirement it was by no means rare to find pure and high-souled devotion to the culture of religion, art, literature, or even to the claims of humanity.

gradually, complete insecurity of property with its lack of employment, idleness, and their result, imperfect cultivation of the land. The latter brought about a failure of crops, which again, united with the utter want of good roads and commercial facilities, * * * created dearth and famine, continual poverty, and generally insufficient, bad and coarse means of subsistence. Personal uncleanliness was the rule and the clothing worn, of leather or rough wool, was seldom changed day or night. Immoderate quantities of wine and strong ale were consumed, and gluttony and intemperance were prominent failings of the mediæval Britain. * * * The towns and villages were composed for the most part of hovels with mud walls and thatched roofs." The floors of the houses were unpaved, damp and usually covered with rushes underneath which lay the collected filth of ages. The streets were dark, narrow and tortuous and no attempt to pave or drain them was made. The dead, from whatever cause they died, were generally buried in vaults beneath the churches or in defective graves in the churchyards, which latter were situated inside the towns and villages. The small population on the other hand were scattered in slight hovels over wild woods, dreary wastes, and undrained marshes, so that ague and rheumatism were always rife amongst them, and in times of scarcity, etc., they were sure to suffer from famine. Famines indeed, were terribly common in the middle ages and alternated with the devastating plagues. It has been computed that from the 11th to the 15th century there were thirty-two great plagues, whilst famine occurred about every fourteen years. None but those of the strongest constitutions survived and the population remained almost stationary. Such were some of the evils which favoured not only the origin, but the wholesale and repeated spreading of the various pandemics.*

* The description of mediæval England, above given, can hardly be considered exaggerated by the most sceptical, though some are of opinion that Erasmus and others who wrote about the conditions of life in England saw the darkest side of things. Beyond all question the people of early England suffered very severely from famine and pestilence,

Leprosy, Ergotism or St. Anthony's fire, Scurvy, the Black Death, the Sweating Sickness, and Syphilis killed and mutilated their hundreds of thousands. To enable

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sometimes separately and sometimes together, as happens at the present time in India; and not only so, but their domestic animals, the sheep, cows, pigs, etc., which, to the then rural population, meant food and money, were frequently destroyed in thousands by various plagues and 'murrains.' Creighton (*op. cit.*, p. 15), gives a list of the authenticated 'Famine-Pestilences' occurring in England between the years 679 and 1322, amounting to 42 in number and extending, sometimes, over several years. In England, and in other countries, the priesthood sought to show its power by forbidding the rite of burial, etc. "It was the papal method of checkmating the kingdoms of this world; that it was subversive of traditional decency and immemorial sanitary precaution was a small matter beside the assertion of the authority of Peter." The population, as mentioned before, was essentially rural and agricultural. "It would be within the mark to say that less than one-tenth of the population of England was urban in any distinctive sense of the term. After London, Norwich, York, and Lincoln, there were probably no towns with five thousand inhabitants." Any thing approaching the immense aggregations of human beings contained in the towns of Modern England, would have been impossible under those early conditions. "If there was 'rude plenty' in England, it was for a sparse population, and it was dependent upon the clemency of the skies. A bad season brought scarcity and murrain, and two bad seasons in succession brought famine and pestilence." Of one year, 1069, when the county of Yorkshire was 'harried', the historian, Simeon of Durham (quoted by Creighton), writes, "There was such hunger that men ate the flesh of their own kind, of horses, of dogs, and of cats. Others sold themselves into perpetual slavery in order that they might be able to sustain their miserable lives (like the Chinese in later times). Others setting out in exile from their country perished before their journey was ended. It was horrible to look into the houses and farm-yards, or by the wayside, and see the human corpses dissolved in corruption and crawling with worms. There was no one to bury them, for all were gone, either in flight or dead by the sword and famine. The country was one wide solitude and remained so for nine years." Of the famine in 1143, another writer (quoted by Creighton) observes, "There was the most dire famine in all England; the people ate the flesh of dogs and horses or the raw garbage of herbs and roots. * * * As autumn drew near and the fields whitened for the harvest, there was no one to reap them, for the cultivators were cut off by the pestilent hunger which had come between." In this case, as often in India, the harvest came too late to save the people; with this difference, however, that there was no thought of a million pounds sterling, or its then equivalent, being subscribed at a few days notice as a 'Famine Fund' for the starving. Then, as now, the wealthy few were apt to forget the starving many, though there were, and are, honourable exceptions. "In the year of great scarcity and mortality, 1322, there was such a crowd for a funeral dole at Blackfriars that fifty-five persons, children and adults, were crushed to death in the scramble. At the same time the prior of Christ Church, Canterbury, was sitting down to dinners of seventeen dishes, the cellarer had thirty-eight servants under him, the chamberlain and sacrist had large numbers of people employed as tailors, farriers, launderers and the like, and the servants and equipages of the one hundred and forty brethren were numerous and splendid." For detailed accounts of the Plague, Leprosy, Sweating Sickness, Small-pox, Influenza, etc., in the words of the various contemporaneous chroniclers, *v.* Creighton, *op. cit.*

the reader to grasp the appalling nature of these outbreaks the original descriptions must be read, but some idea of the mortality may be gathered from the fact that about two-thirds of the entire inhabitants of the known world are supposed to have perished, including about 25,000,000 in Europe alone.*

Towards the end of the middle ages (1300—1500 A. D.) the frequency and magnitude of these outbreaks compelled attention to two points, *viz.*, the necessity for isolation of the sick and the establishment of 'quarantine'† to prevent infection. Various attempts were made to keep the sick separate from the healthy, occasionally with success, but more often uselessly. So also, the attempts to prevent the introduction of disease by keeping ships arriving from foreign ports in quarantine for forty days, generally ended in failure. As will be seen later, to prevent or stamp out an epidemic in a place where the sanitary conditions are entirely defective, is almost invariably a hopeless attempt, and further, it is beginning the wrong way about. *Prevention* is the watchword of modern hygiene, and it is only by constantly keeping a place in a condition of scrupulous cleanliness that any effectual resistance can be offered to the attacks of epidemic disease. It is worthy of note, however, with reference to the gradual evolution of hygienic measures, that a 'Board of Supervision', which gradually became a model for all Italy, was established in Venice in 1348, a 'Sanitary Commission' in Paris in 1350, and similar attempts to cope with epidemics were made in other cities.

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* Towards which London is said to have contributed 100,000 human victims to the Black Death in 1349. These figures are probably much in excess of the reality, but it should be remembered that the population of London at that time was little more than 100,000. The whole subject is clearly and ably discussed by Creighton, *op. cit.*, who certainly does not err on the side of exaggeration.

† Derived from the Italian numeral *quaranta* meaning 40. The reason for the selection of a term of forty days is disputed, the selection being made on medical grounds according to some, owing to the teachings of Hippocrates, and on religious grounds according to others. Lepers were really the first diseased people isolated and placed in quarantine, and the name *lazaretto*, meaning 'leper-hospital', is still applied in Europe to quarantine establishments.

Coming now to the never-to-be-forgotten sixteenth century, we begin to leave behind us the superstitions and follies of the dark period preceding and can trace the beginning of that marvellous awakening in all directions of human thought and ingenuity, from which, with occasional and temporary relapses, has resulted the enormous improvement in the moral and social condition of the leading European nations and has spread or is spreading from thence to America, to Asia, to Africa, and the farthest portions of the world.

It was a veritable awakening from the sleep of death. "Not only the lofty, in a social and intellectual sense, often hazarded their all for the attainment of higher intellectual and moral objects, but the common people likewise took part with enthusiasm in the reformation. * * * The fundamental chord of the whole century was thoroughly idealistic and its result was an astonishing creative activity towards every point of the intellectual compass—in religion, the arts, the sciences, technics and social life. * * * The 16th century ripened free investigation, and in medicine too was peculiarly the century of reformation, of struggle and of protest against all medicine which had abandoned the * * * principles which placed the observation of nature, not the letter of tradition, in the forefront of knowledge." But all was not plain sailing. "Beside an earnest effort to advance, a retrograde impulse of almost equal strength exerted itself; beside the clearest discernment appeared the darkest superstition; beside poor dupes stood the grandest impostors; beside philanthropic efforts were deeds of the most terrible delusion; in short, we observe a collection of revelations and riddles of the human mind * * * such as no other period can offer." Yet many wise and excellent laws were enacted in Europe, relating, more especially, to the prevalent plagues, and which were known as the 'Pest-Ordinances'. They were wise in that they showed a power of observation and recognition of causes hitherto almost entirely latent, but failed to a large extent in their effect, like many modern regulations, from a variety of reasons, *e.g.*, imperfect knowledge, want of thoroughness, and a general absence of personal hygiene. "With a view to disinfection, horn, gunpowder, arsenic with sulphur, or straw moistened with wine, etc., were burned in the streets, so that the statement "They are burning horn" signified at that time "The plague is there and we can do nothing against it", a condition which we now express euphemistically by the odour of carbolic acid. The administration of preventive doses of disinfectants was also customary at that period. The Pest Medici anointed the uncovered portions of their bodies with oil, etc., or wore special 'plague-dresses' and 'plague-masks', 'plague-gloves,' etc. The plague-dresses were red and black; the masks were made of leather, had openings fitted with glass for the eyes and a beak-like prolongation for the reception of disinfecting substances." Certain epidemic diseases such as the plague still raged with great violence, others such as leprosy and the sweating sickness almost entirely disappeared, whilst yet others such as spotted typhus (intermediate between the plague and typhus), small-pox, influenza and diphtheria put in their first historical European appearance. Influenza, indeed, became pandemic in Europe at least four times in this century, *viz.*, in 1510, 1557, 1580, and 1593, and smaller outbreaks occurred between. As in this country, the evils wrought by centuries of filth and the neglect of the simplest rules of hygiene could not be even partially controlled for many a long year.

In Germany, especially, the first earnest endeavours were made to grapple with preventable disease by the issue of ordinances of medical police relating to the sale of food, popular amusements, adulteration of wine, etc. In Frankfort-on-the-Main the medical ordinance of 1577 directed: "1. In order to improve the air the streets shall be cleaned Wednesday and Saturday of each week after the closing of the market; 2. The passing of urine in the streets is prohibited*; 3. Privies shall be erected in all houses;

* *cf.* Indian towns, in 1898, A.D.

4. The knacker shall transact business only during cold weather; 5. The shops of butchers, tanners, fishermen and farriers shall be removed. 6. Hog-pens, goose-pens and wells shall be cleaned," etc., etc. In England, too, interest in these and allied matters, *e.g.*, the more humane treatment of the insane, was aroused amongst the intelligent, but the progress made was "slow, tedious and tentative," and it was not till the great fire of London in 1666, following close on the plague,* swept away the whole town from Temple Bar to the Tower that the people as a whole began to be aroused. Thirty-two years previous to this, however, the Royal College of Physicians presented to the Council in London a "Report on all such annoyances as they conceive likely to increase the sickness in this populous city. 1. The increase of buildings by which multitudes are drawn hither to inhabit. 2. Inmates by whom houses are so pestered that they become unwholesome. 3. Neglect of cleansing the common sewers and town ditches, and permitting standing ponds† in inns. 4. The uncleanness of the streets. 5. Laystalls so near the city especially on the north side. 6. Slaughter-houses. 7. Burying of infected persons in churches and churchyards in the city. Overlaying the churches with burials, so that many times they take up bodies to make way for more burials. 8. Carrying up funnels to the tops of houses from privies and vaults. 9. Selling musty corn, and baking bread thereof, and brewers using unsound malt. 10. Butchers selling unsound cattle. 11. Tainted fish." In this most sensible and practical report the formation of a "Commission or Office of Health" was suggested but, as too frequently happens, no attempt seems to have been made by the Council to give effect to the suggestions offered.

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* The following table, from Creighton, *op. cit.*, will give an idea of the mortality in London during the so-called 'Great Plague,' though it was not much more severe than those of 1603 and 1625 had been for the London of their generation.

Year.	Estimated Population.	Total Deaths.	Plague Deaths.	Highest Mortality in a week.
1603	250,000	42,940	33,347	3,385
1625	320,000	63,001	41,313	5,205
1665	460,000	97,306	68,596	8,297

† Comparable to the filthy tanks which still abound in Indian cities.

Amongst the people of England, also, the general conditions of life were becoming more healthy. "The gradual improvements in agriculture, manufactures and commerce were adding steadily to the comforts of life. Food was becoming more plentiful and the diet less coarse. Vegetables, and more especially the potato, were becoming much more generally used; fresh meat was taking the place of salted meat, which had hitherto constituted such a large part of the English dietary; while tea and coffee were to some extent replacing the strong ale and ardent spirits which had formerly proved such a baneful source of disease. People, too, were beginning to recognise the value of cleanliness of person and home. The introduction of soap and soda made washing easier, and cotton and linen articles of clothing were gradually coming into more general use." In fact, a gradual emancipation from the 'thraldom of filth' had begun and the benefit resulting therefrom soon began to be apparent. That is to say it is easily apparent when looked at from this distance of time, but it must not be imagined that any great effect was produced in the direction of checking epidemic disease till very near the end of the 17th century. The plague, which, as we have seen, appeared in London for the last time in 1665, lost its predominance in Europe by the end of the century, but till then it ran through country after country, *e.g.*, Italy was attacked in the years 1630, 1656, 1669, 1683 and 1691. During one epidemic in that country more than quarter of a million people perished in four cities alone. In Milan, two unfortunate people, one a Health Commissioner, were accused of rubbing plague salve on the walls of the houses, and, after various other tortures, had their hands cut off, were broken on the wheel and finally burned. In Germany, where the mass of people were much more enlightened, energetic precautions to prevent the introduction and spread of the disease were frequently taken.* In Magdeburg, in 1680, a physician,

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* As illustrating the fact that there were even then, in the seventeenth century, wise and thoughtful persons, who studied the public health and

surgeon, minister, nurses, 24 inspectors of the streets, 24 corpse-bearers, and 12 grave-diggers for the plague were appointed by the magistrates in anticipation of its appearance, a plague-hospital was erected, and the house in which the first case of plague occurred was burnt down. In addition to this disease, malaria, dysentery, typhus fever, influenza, diphtheria and scarlet fever (accurately described for the first time) and numerous other diseases still continued to prevail. Malarial disease, owing to the still-defective drainage of the country, was terribly prevalent and included amongst its victims James I and Oliver Cromwell. From 1661—65 it was the most fatal disease in England.

By the commencement of the 18th century several of the more important plague-scourges had disappeared from England and the neighbouring countries, never, let us hope, to return. But other diseases, almost, if not equally deadly, remained, *e.g.*, small-pox, typhus, malaria, dysentery, influenza, scurvy and many others, and these had still to be attacked. In the case of small-pox, the very ancient practice of 'inoculation' was first introduced to England and the Western Continent from the East during this century, and later on was followed by Jenner's immortal discovery of vaccination. Typhus fever, known at that time as 'jail-fever', was rife, and to the lessening of that disease and the general improvement of the conditions of life of prisoners, John Howard, the Quaker philanthropist, devoted his means, energies and, ultimately, his life. For nearly eighteen years this man travelled throughout all parts of Europe, living in great discomfort and in frequent danger of his life both from disease and from the numerous enemies which his reforms created for him. Within one year after

well-being, the following quotation from a German writer (Ludwig) will shew. "No one should without necessity remain in the dwellings of patients suffering from dysentery, especially in the place where the discharges are placed. The latter should be taken to remote places and covered with lime or ashes. The beds, linen and clothing used by such patients should all be carefully washed. Before the dwellings in which such patients have been living are again occupied, we should not neglect to fumigate and clean them thoroughly."

he had begun his work in England and given his preliminary evidence before the House of Commons, Bills were passed for the reform not only of jail-routine, but also directing the construction of suitable jails, with hospitals for sick prisoners attached to them, and that all the buildings should be properly cleaned and ventilated. Two or three years later he published his classical work *The State of Prisons*, and later on added two important appendices. In 1789 he started, in further prosecution of his researches on jail-fever, on what proved to be his last journey, for at Cherson, in Russian Tartary, he caught the 'bubo-plague' which was there prevalent and died. Of him, and the results of his work, one writer has said, "His influence did not die with him, for it has continued to influence not only the legislation of England but of all civilised nations down to the present time," whilst another has written, "The outcome of his self-sacrificing labours is simply this that for years back the prisons of this country have been proved by the most rigid statistics to be far healthier than our homes, and that so-called preventable disease of any kind is of such rare occurrence within their walls, that when any isolated cases do appear they at once give rise to surprise, and are sure to call for inquiry." All through the 18th century, wherever dirt and over-crowding prevailed, this dreaded disease, known variously as spotted fever, famine typhus, war-fever, putrid fever, etc., made its appearance. At Prague, in 1742, more than 30,000 of the French troops were carried off by it. Another disease, scurvy or scorbutus, which had frequently destroyed almost the entire crews of ships, so that the latter could not be navigated, and which constantly broke out amongst and decimated besiegers or besieged in continental wars, was successfully attacked and subdued by Captain Cook, that dauntless but humane sailor. He showed that its occurrence could be entirely prevented by the use of fresh vegetables or acid fruit juices, coupled with ordinary hygienic precautions. Within thirty years of the time when 600 men out of 900 died, mostly of scurvy, on Anson's disastrous expedition, Captain Cook brought back 114 out of a total crew of 118 after three years continuous voyaging, and without a single death from scurvy.* Malaria and dysentery still prevailed, also, to a great extent in Europe during the last century, as well as Influenza or *La Grippe*, and Diphtheria, both of which latter diseases spread through almost the entire known world, including America.

In the early part of the century that terrible disease known as the 'bubo-plague', from the fact that the glands in the armpit and elsewhere were specially affected, the 'disease of barbarism' as it has been called, started from its then habitat the S. W. of Europe and, favoured in its spread by the Russo-Swedish war, travelled northwards and westwards, carrying off 300,000 persons in E. Prussia alone. Later on it again broke out several times, killing John Howard the prison-reformer as before mentioned, and causing terrible havoc in Russia. In that semi-civilised country a panic seized the inhabitants from highest to lowest, and Queen Catherine II. promptly beheaded the doctor who first correctly diagnosed the disease! This example was speedily followed by the densely ignorant people, and a regular insurrection, which necessitated the use of physical force to quell it, took place. In Moscow more than 52,000 people, or about one quarter of the entire population, died, the disease being increased by the number of concealed and putrefying corpses in the houses. It is a disease of particular interest to us in India, for it is

* With reference to the use of lime-juice as a preventive to scurvy, it should be noted that the valuable properties of the former in this direction had been known and made use of for a long time before Captain Cook's three years voyage, from 1772–75. At the end of the sixteenth and beginning of the seventeenth centuries, when the English trade with the East Indies was opened up, the commanders of the fleets, especially Hawkins and Lancaster, were in the habit of carrying lemons, etc., on board their ships. In addition, John Woodall, a well-known English surgeon of that date, who wrote a book called *The Surgeon's Mate*, "chiefly for the benefit of young sea surgions imployed in the East India Companie's affairs," alludes to the importance of giving lime-juice to the ship's company regularly, and advises various additional precautions regarding change of clothing, diet, sufficient exercise, etc. What Captain Cook did was to insist upon the necessity for precautions being invariably taken in this matter, and he also demonstrated, practically and convincingly, the great success of such preventive measures when properly carried out.

possibly identical with the plague which, under various names, has broken out at intervals in India, during the present century.*

General Hygiene received a large share of attention during the 18th century, and such subjects as dietetics or the systematic study of food-stuffs and beverages, the hygienic management of children, the influence of climate on health, etc., were freely written about. One notable German physician† even delivered simple lectures on hygiene to boys and girls over ten years of age. Military hygiene, hitherto merely conspicuous by its absence, was also studied to a certain extent, especially by British army surgeons, and the health and comfort of the unfortunate sick and wounded thereby increased and money saved to the State. About 1784 was published what was probably the most notable book on the subject of Public Health of that century, *viz.*, Frank's System of Medical Police, which has been considered by some to be the 'cornerstone of our modern public and private hygiene.' Amongst other things, the author of this book, a German physician, first pointedly drew the attention of those in authority to their duties as regards the health of their ignorant fellow men. Regular inquests on the dead were first established in this century, as also *morgues* (*i.e.*, special buildings where the unclaimed bodies of the dead were exposed to view), and institutions for the rescue and treatment of the apparently drowned, etc., etc. It is thus evident that hygiene in a general sense received a considerable share of attention during the last century, but the science of preventive medicine as applied to epidemic disease, owing doubtless to the general ignorance regarding the causation of these diseases, was still very imperfectly developed.

We have now brought our brief historical summary to a point at which we may profitably pause for a little while

* *v. Trans. Med. Phys. Soc.*, of Bombay, and Chevers' *Diseases of India*, and references given therein. The 'Black Death' was a similar, if not identical, complaint, and both were eminently 'filth-diseases.'

† Fr. Ant. May, of Heidelberg: *v.* Baas, *op. cit.*, p. 715.

and take a backward glance to see what lessons are derivable from the study of the gradual development of the art of hygiene—for it was still merely an art and not a science. Of the earliest nations of whom there is historical record not much more can be learnt than the fact that the rich and learned knew and appreciated the value of personal cleanliness, but at best it was an imperfect and eminently selfish knowledge. With the Jews came a strict code of priestly ordinances applicable to all, rich and poor alike, thoroughly suited to their mode of life and stage of civilisation, and by means of which they may with accuracy claim to have *prevented* to a considerable extent an otherwise certain and large mortality. So too the early Romans, self-disciplined and law-abiding, gave evidence, by their laws and enactments, their special officials, their baths, aqueducts and cloacæ, of their recognition of the extremely important position occupied by sanitation in any thorough scheme of government, and later, when scepticism and luxury held chief sway, found to their cost that an enemy infinitely more powerful and untiring than the Goths and Huns was clamouring for admittance, and that gates and walls alike were powerless to oppose or prevent its entrance.

Then came the long period of the Middle Ages when the old civilisation was giving place to the new, when war, famine, and pestilence stalked the land, when everyone was too busy cutting his neighbour's throat with one hand and protecting his own with the other to pay much attention to such matters as health and cleanliness. The monk in his cell, the courtier surrounded by every luxury, and, possibly, the inhabitants of isolated and thinly-populated districts, escaped to a certain extent, but the mass of the people, *i.e.*, those of them who escaped death in battle, were frequently attacked by infectious diseases of a most virulent type and rotted and died like sheep.

Still later, and chiefly in the sixteenth and seventeenth centuries, there were signs that men were at length beginning to realise, though ever so faintly, that these horrors of disease and famine were—if not actually caused by —at all events increased by their own carelessness and filthy habits, and from this recognition resulted attempts to cope with the evils, earnest enough, perhaps, but predestined to failure, partly from ignorance and partly from want of the co-operation of others.

From the commencement of the eighteenth century the improvements in manners and the mode of living began to tell favourably, and certain diseases disappeared from England. Small-pox, Scurvy and Typhus Fever still held the field, however, but each in turn was attacked and routed by the stout-hearted philanthropists—Jenner, Cook and Howard—who achieved in their fights a measure of success unknown to any of their predecessors from the fact that they were enabled, by their brilliant discoveries, to *prevent* the occurrence of these diseases by rendering human beings proof against their power.

Coming now to the commencement of the present century we find ourselves confronted by such an immense degree of activity and progress in the direction of hygienic reform, that it is necessary to confine our attention to the general course of events in England, and even of this only the merest outline can be given. During the early years of the nineteenth century the thoughts of the people were principally concentrated on British battles by land and sea and on the increase of the country's possessions and commercial prosperity. Though the drain on the population from the continuous demand for recruits* and from disease was still excessive, the increased healthiness resulting from improved conditions of life had reduced the mean annual death-rate from 80 per 1,000 in the seventeenth century to 22 per 1,000; an enormous reduction,

* "War is without doubt the most hideous physical curse which fallen man inflicts upon himself; and for the simple reason that it reverses the very laws of nature, and is more cruel even than pestilence. For instead of issuing in the survival of the fittest [?], it issues in the survival of the less fit, and therefore, if protracted, must deteriorate generations yet unborn."—Chas. Kingsley.

representing a saving of 17,000 lives annually in a population of 300,000. So that in spite of all, the population of England was increasing.

From the discovery and application of steam power there resulted an enormous impetus to trade, and following this there took place a change in the habits and surroundings of the English people the full consequences of which cannot be determined even yet. This was nothing more nor less than the rapid centralisation in a few great towns of a population which had hitherto been characteristically rural and agricultural. A few figures may help to render the subject clearer. As stated above, the population of England, since the latter part of the eighteenth century had been steadily increasing, but this increase had taken place almost entirely in the country districts. Outside London there was no town of 100,000 inhabitants and only 5 with more than 50,000. There are now 7 towns with a population of over 250,000 inhabitants, 15 towns with about 100,000 inhabitants, and very numerous other towns with 50,000 inhabitants or more. All these are situated in England alone, excluding Scotland and Ireland, *i.e.*, in a country with a total area of about 50,000 square miles, or about $\frac{1}{3}$ of the size of the Madras Presidency. Just at the time, then, when it seemed as if the increase of population in England would continue unchecked and in increasing ratio, the whole condition of things was reversed or rather, tended to be reversed; for, as will be seen, in spite of this enormous centralisation of the population in towns in place of its former rural distribution, the numerical increase has been steadily maintained. In 1810, the population of England (including Wales) was about 10,000,000; in eighty years it has just trebled itself, so that now it is about 30,000,000. Great, then, and serious, as were the errors made by the early pioneers of hygiene in England, it may be confidently asserted that such an immense numerical increase in the population of a country in face of the countless evils and drawbacks inseparable from rapid concentration in towns, would have been absolutely impossible under any conditions approximating to those that obtained throughout Europe up to the end of the fifteenth century or even later.

From the commencement of the nineteenth century to the battle of Waterloo (1815) was indeed a most important period in the social history of England. "English exports had nearly doubled since the opening of the century. Manufactures profited by the discoveries of Watt and Arkwright; and the consumption of raw cotton in the mills of Lancashire rose during the same period from fifty to a hundred millions of pounds. The vast accumulation of capital, as well as the vast increase of the population at this time, told upon the land, and forced agriculture into a feverish and unhealthy prosperity. Wheat rose to famine prices, and the value of land rose in proportion with the price of wheat. Inclosures went on with prodigious rapidity; the income of every landowner was doubled, while the farmers were able to introduce improvements into the processes of agriculture which changed the whole face of the country. But if the increase of wealth was enormous, its distribution was partial. During the fifteen years which preceded Waterloo, the number of the population rose from ten to thirteen millions, and this rapid increase kept down the rate of wages, which would naturally have advanced in a corresponding degree with the increase in the national wealth. Even manufactures, though destined in the long run to benefit the labouring classes, seemed at first rather to depress them; for one of the earliest results of the introduction of machinery was the ruin of a number of small trades which were carried on at home, and the pauperization of families who relied on them for support. In the winter of 1811 the terrible pressure of this transition from handicraft to machinery was seen in the Luddite, or machine-breaking, riots which broke out over the northern and midland counties; and which were only suppressed by military force. While labour was thus thrown out of its older grooves, and the rate of wages kept down at an artificially low figure by the rapid increase of population, the rise in the price of wheat, which brought wealth to the landowner and the farmer, brought famine and death to the poor, for England was cut off by the war from the vast corn-fields of the Continent or of America, which now-a-days redress from their abundance the results of a bad harvest. Scarcity was followed by a terrible pauperization of the labouring classes. The amount of the poor-rate rose fifty per cent.; and with the increase of poverty followed its inevitable result, the increase of crime. The natural relation of trade and commerce to the general wealth of the people at large was thus disturbed by the peculiar circumstances of the time. The war enriched the landowner, the farmer, the merchant, the manufacturer; but it impoverished the poor."* It will be seen, then, that sanitary reformers had indeed a difficult task before them, with a population rapidly increasing and becoming more and more concentrated in towns made up of hastily-built and imperfect houses; with wealth unevenly distributed, and therefore difficult of just and sufficient taxation; and with the minds of men concentrated on wars abroad and class factions at home.

With reference to the rapid increase in population, the following able summary† of the then existing conditions, and their pernicious effects on future generations, may help the reader to realise the state of matters. "But under what conditions [had this increase in population taken place] ? For the most part in the dust and din of factories; the vitiated air of mines; the stifling atmosphere of workshops; the bustle of busy warehouses; and, when the day's work was done, in overcrowded houses or underground cellars, heaped together in filthy, narrow, and unventilated streets or reeking back slums. Even in the construction of better class houses the veriest rudiments of sanitation were

* Green, *A Short History of the English People*, pp. 828—9.
† Wilson, *op. cit.*

neglected, because they were still but little understood and less appreciated. Instead of Municipal control there was general apathy. Sewers had to be constructed, but they were of the worst possible description, uneven, leaky, unventilated and incapable of being flushed, while the house drains leading into them were quite as faulty and imperfect. Scavenging was neglected, filth accumulated everywhere, cess-pits multiplied and wells became polluted. But why fill up the disgusting details of the picture? The mischief was done, and in spite of recent improvements and legislative enactments it will take years of steady, earnest, sanitary work and millions of money to undo it. The money no doubt will be forthcoming and the cleansing of the Augean stables may be accomplished in time, but the squalor, the misery, the disease, the physical deterioration, and the moral degradation engendered have imposed a load of vitiated heritage which will tell on generations yet unborn and which at the present day is crushing thousands of children into an early grave." For a number of years, then, instead of any real progress being made in practical sanitation, careful examination of the facts of the case shows that it was really the other way; for bad or defective sanitation is far worse than no sanitation, as hasty or careless legislation is worst than none at all, and only creates evils instead of mitigating them. Beyond the fact that the ruling bodies of some few towns asked for Parliamentary powers to enable them to provide drainage and water supply, nothing much was done.

In 1831 Cholera made its dreaded appearance for the first time on English soil and this fact coupled with the earnest and unceasing labours and writings of the rising generation of sanitary pioneers forcibly directed the attention of Government to the state of affairs. In 1832 a most important move was made, by the establishment of a Statistical Office in the Department of the Board of Trade, for the purpose of collecting, arranging and publishing statements relating to the conditions and various interests of the British Empire. In 1837 the Registration Act was passed, and the first Annual Report of the Registrar-General, by the distinguished Dr. Farr, was issued in 1839; so that from the year 1838 onwards there is an unbroken series of statistical reports dealing with the public health of England, which now forms a vast and increasingly valuable storehouse of facts bearing upon Hygiene. In 1833 a Factory Act* dealing with the ages of children and women working in the great factories, and kindred matters, was passed, and in the following year the Poor Law Amendment Act, but these were more or less of an imperfect and permissive nature.

Nothing further of any magnitude was attempted for ten years, but the gradually accumulating evidence in the returns of the Registrar-General, and the persistence of the sanitarians before mentioned, at length induced Parliament to appoint the celebrated Health of Towns Commission. To every town of any size in England a long list of queries was sent, having reference to the most important points in connection with the sanitary question, and from every large town there came back, with for little variation, the same "terrible series of replies—bad drainage, polluted water, unhealthy houses, overcrowding, filth everywhere; and, as a consequence, an excessive death-rate, with fever and filth-diseases of every description adding enormously to the death-roll. But so powerful were vested interests, and so strong the opposition to interference with the liberty of the subject or of corporate bodies, that it was not till the country was threatened with a second visitation of cholera as severe as the epidemic of 1831, that Parliament became alarmed and passed the Public Health Act of 1848. Under this Act, the General Board of Health was constituted, with a staff of inspectors who were empowered to hold public inquiries and report on the sanitary condition of towns which according to the returns of the Registrar-General showed an excessive rate of mortality. From the passing of this Act, that is less

* Other Factory Acts was passed in 1844, '56, '71, and '74.

than fifty years ago, the sanitary legislation of England may be said to date, but this act unfortunately was, like too many later acts, of a permissive nature, and as a consequence, the beneficial results which might have been expected to accrue from it were long in appearing, and were by no means general. Nevertheless, it originated an era of active sanitary improvement in most of our large towns, and it merits special notice as the first outspoken recognition on the part of the legislature, that the health of the State concerns the statesman. By enabling town authorities to borrow money and spread the expense of public works over a number of years, it removed one of the greatest obstacles of sanitation, and as a consequence, extensive schemes of sewerage and water supply were soon undertaken in many parts of the country." But the art of sanitary engineering was unhappily still in its infancy, and the result was the construction of numerous and extensive systems of sewerage which only removed the sewage, and that imperfectly, from one town, to discharge it into the nearest river, where it speedily became a nuisance and a danger of the gravest order to the towns situated lower down on the river.

The first move having thus been made in the direction of sanitary legislation was speedily followed by further action, and during the next twenty-five years or so, *i.e.*, between 1849 and 1874, a large number of Acts were passed dealing with various branches of sanitary reform. Amongst these Acts, the names of which sufficiently indicate their purpose, were the Common Lodging Houses Act, 1851, the Labouring Classes Lodging Houses Act, 1852, the Metropolis Amendment Act, the Nuisances Removal Act, the Diseases Prevention Act, all of 1855. In 1858 the powers of the General Board of Health were transferred to the Privy Council, and in the same year the Local Government Board Act, which consolidated to a large degree the previous sanitary Acts, was passed. Mr., now Sir John, Simon, K.C.B., was appointed Medical Officer to the Privy Council, and had placed under his control a staff of able and efficient medical inspectors.

The work done by these men in the face of much doubt and opposition is simply invaluable. One experienced writer in alluding to this subject has said, "The material causes of disease were investigated with a minuteness and completeness of detail which could not fail to influence the most sceptical, and the series of reports in which these investigations are embodied and commented on have become the classics of sanitary literature. To any one who takes the trouble to read these reports*, it becomes at once apparent that whatever of purely beneficial sanitary legislation which has subsequently come into force has all along been largely indebted to Mr. Simon's foresight and advocacy, based on the inquiries of such able co-adjutors as, Seaton, Greenhow, Buchanan, Hunter, Thorne, Nelten-Radcliffe, Ballard and others." The reports deal with the nature and spread of typhoid fever and cholera; with the huge subject of injurious trades and occupations; with overcrowding in houses, adulteration of food, the sale of impure drugs, the adulteration of milk, impure water supply; with the leading part played by filth in the distribution of disease; with diseases of animals; with small-pox and vaccination; and with a host of other important questions. As a result of these labours, further measures, which it is unnecessary to describe in detail, were passed by Parliament, culminating, in 1875,† in the important Public Health Act which consolidated the previous Acts and led to the repeal of 19 of these and affected 16 others. Since then numerous Acts have been passed, the following being the more important; the Sale of Food and Drugs Act, 1875; Contagious Diseases (Animals) Act, and Rivers Pollution Act, 1876; Factory Acts, 1878 and 1883; Public Health Amendment Act, 1890; and, finally,

* The study of these reports by all who pretend to a knowledge of hygiene is absolutely essential, and many of them form models for sanitary investigation which it would be hard to improve upon. They can be studied in their original form, or in the *Public Health Reports* by John Simon, Vol. II., published by the San. Institute.

† A few years previously, the divided powers of the Poor Law Board and Privy Council were vested in the Local Government Board, which latter henceforth became the Central and Governing Body in matters sanitary.

the very important Public Health (London) Act, 1891, the latest and most advanced in ideas, upon which the next Public Health Act for the country (England) in general must be more or less modelled. It is thus apparent that an enormous amount of thought and attention has been given to sanitary matters during the last fifty years, and it follows that, in England, hygiene has assumed a position of great importance, and that the duties of the health department are of the most varied and extensive nature. For many years English laws have formed the basis of sanitary legislation in other countries.*

At this point, and before considering the effect upon the general health of the community of the various sanitary reforms of the century, attention may be very shortly directed to the important changes made in regard to the hygiene of the army. In olden times it was the invariable rule that an invading army lost by far the greater number of its soldiers from disease and not from battle. The short Austro-Prussian campaign of 1866 is said to have been the first war in which the number of those killed in battle exceeded that of those killed by disease. In 1854 came the Crimean war, a war carried on with a base of operations maintained at the sea coast, between which and England there was at all times free communication. Yet, in spite of this, the amount of disease and misery, of easily-preventable disease and misery, endured by our troops was appalling. It was due chiefly to a faulty commissariat, *i.e.*, the issue and passing of bad or rotten stores by English army contractors and their supervisors, and also to an utter neglect of scavenging and cleanliness, coupled with an incredible disregard of the most rudimentary conditions of health. At a later period in the same campaign, when the English nation made one of those stupendous and unequalled efforts to redeem its past mistakes, the mortality was very greatly reduced

* *v.* Speeches of foreign delegates at VIIth Internat. San. Sci. Congress, Vol. I. of the *Transactions*. For further details regarding sanitary legislation, *v.* Vol. II., Part V. of this book.

and the healthiness of the troops in the Crimea compared favourably with that of the regiments quartered in England. In the China war, where great attention was paid to health, the mortality was just one-tenth of that in the Crimea during the early part of the latter campaign. As a result of official enquiry, and the heroic labours of Florence Nightingale, Edmund Parkes, and others, the Royal Commission on the Health of the Army was ordered in 1857. Following the most valuable work of this Commission came the Report of the Barracks and Hospitals Commission, and the Commission on the Health of the Army in India. "All these demonstrated," says one authority, "in the most complete manner that the sick-rate and death-rate of the army were culpably excessive; while the adoption of their recommendations, under the able teaching of the late lamented Dr. Parkes, afforded such conclusive proofs of the grand policy of prevention, that a stimulus to sanitary reform began to permeate the more intelligent classes among the general community which has continued to increase ever since."

The Royal Commission appointed to inquire into the Sanitary State of the Indian Army assembled on 31st May 1859, and directed that attention should be paid to the following points: 1. The rate of sickness and mortality; 2. The cause of such sickness and mortality; 3. The comparative healthiness of the different existing stations; 4. The subject of healthy positions generally; 5. The best construction of barracks, huts, hospitals and tents for India; 6. The present regulations for preserving the health of troops and enforcing medical and sanitary police; 7. The organisation of the army sanitary and medical service; 8. The practicability of establishing a general system of military statistics throughout India, and what changes it might be considered expedient to make in present practise on the above mentioned subjects. The voluminous report on this subject was forwarded to England in 1863 and considered at Home by the Royal Commission sitting there; after which the latter made the following recommendations to the Government of India. 1. The appointment of a Sanitary Commission at each of the Presidencies. 2. A careful consideration of the changes that may be necessary in the present distribution of the European troops. 3. The selection of sites for new barracks and hospitals, the construction of those buildings on approved principles, and the application, as far as possible, of those principles to existing buildings. 4. The regulation of the diet of the European troops, and the prevention, if possible, of the use by them of ardent spirits. 5. The provision of means for the innocent recreation and healthy occupation of the men. 6. The measures to be adopted to prevent the spread of venereal disease. A lengthy dispute took place between the Home and Indian Governments, the latter feeling itself aggrieved, and with some show of justice,* that its previous labours for the health of the Indian Army had not been more fully recognised by the Home Commission. The Home Commission however stuck to its guns and proved ultimately that the principle cantonments of the English Army were on some of the unhealthiest sites in India, that the mortality of the European force in India had been on an average at the rate of 69 per thousand down to the year 1856 and was higher in the excluded mutiny years, that such waste of life was unnecessary and could be reduced by careful

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* "The announcement of the Commission that the death-rate of European soldiers in India averaged 69 per 1,000 annually, was received with astonishment and indignation. It was said in the House of Commons that this report had disclosed a state of things which no one had believed to exist. Yet that statement ought not to have been possible, because previous to the appearance of the Commission's report there had passed through the press such works as Colonel Sykes' *Statistical Tables;* Macpherson's *Statistics;* Ewart's *Vital Statistics of the Anglo-Indian Armies;* Chevers' *On the Means of Preserving the Health of the European Army in India;* and my [Moore's] *Health in the Tropics or the Sanitary Art applied to Europeans in India;* all reiterating the fact of Europeans *disappearing* at the rate of 69 per 1,000." Sir W. Moore, *San. Progress in India, v.* Trans. viith San. Sci. Congress. There is but little reason to believe that the House of Commons, as a body, is even now well-informed as to the work done by the pioneers of sanitation in India, and the imperative need for the encouragement of Hygiene in all its branches in that country.

attention to sanitation, etc., etc. In the report of the Indian Commission, the greatest pains were taken to secure accuracy : "Three series of questions were sent to 175 stations in the three Presidencies and the answers received in time from the commanding, engineering and medical officers of 117 stations are printed in an appendix to the evidence; with observations on the said returns by Miss Nightingale; with statistics of the East India Company's army, extending nearly from its origin, down to the latest date, by Dr. Farr; with statistics of Her Majesty's troops in India by Dr. Balfour; and statistics of regiments which had served in India by their commanding officers.

To give an idea of the amount of sickness amongst troops the following is quoted from official sources. "Some of the heaviest losses occurred in time of peace and to regiments when they were not in action. The following is an example :—All the Bengal regiments enter India at the stations about Calcutta, Fort William, Dum Dum, Barrackpore, and Chinsura. The 29th Regiment of foot arrived 1,004 strong in India, on 29th July, 1842; at Chinsura it lost 106 men in eight months; at Ghazipore and Meerut 418 men in the two next years, before it had seen an enemy: its valour was not extinguished, for 141 of the men were killed or died of their wounds in the Sutlej campaign and 48 in the Punjab. It lost 1661 men in all by death in India, and sent home 461 invalids, etc., before it embarked with a strength of 824 for England on 30th September 1859." But the authorities* in India had in reality been far from idle for years before the Royal Commission was appointed, and the interesting fact comes out clearly that the reduction in the mortality which was hoped for by the Commission, namely from 69 per thousand to 20 per thousand, was almost attained by the time that the Indian

* *i.e.*, The leading medical officers, backed by some few of the more enlightened commanding officers, such as Hodgson and Peel. As a rule, however, but little attention was paid to their warnings, their reports being conveniently pigeon-holed—a practice by no means extinct in official circles yet; *v.*, also, Trans. VIIth San. Sci. Cong., Vol. XI., p. 21.

Commission was assembled. "The hope of the Sanitary Commission," says the report, "that by improved sanitary arrangements the death-rate may be reduced to 20 per thousand, and thus only 1,460 recruits be needed annually to replace death vacancies in India, was practically realised before the publication of their Report."

A later Sanitary Despatch, dated 23rd April 1868, dealing with the whole question of the future sanitation of India, concluded thus: "Practically it would be impossible to introduce into India a complete cut and dried system of sanitary administration. Our ultimate success depends on carefully obtained experience. We know everything that requires to be done but we do not know the best way of doing it over so great a continent: we shall arrive at this only by experience, but the result will be the civilization of India. These remarks of course apply to the civil question only. There is no difficulty whatever in completing at once the organization for ensuring the health of troops, if only it can be provided at the same time that the measures recommended by commanding officers under advice of their medical sanitary officers, are promptly and efficiently carried out." And, as a matter of fact, the measures recommended by commanding officers, under advice of military medical officers, have been, since that time, efficiently and promptly carried out to a considerable extent, for the former have been led to realise by practical experience that upon the healthiness of a regiment depends very largely its discipline and effectiveness, whether in peace or war.

The Victorian Era has rightly been called the "Age of Sanitation."* Up to the commencement of the present century the subject of sanitation can hardly be said to have attracted attention except amongst a few military surgeons and thoughtful civilians. The books dealing with it were few and imperfect, whereas now there is such a vast and

* "The Victorian Era is the age of sanitary and social reforms—of diminished sickness, of increased longevity." Sir Chas. Cameron.

ever-increasing array of reports, blue-books, magazines and text-books, dealing solely with hygiene, that it is extremely difficult for any one to keep themselves fully informed of the latest discoveries or methods. Then again, as before stated, the early sanitary acts were largely of a permissive nature, and therefore almost inoperative, whilst the later ones have been, as far as possible, compulsory, and have accordingly exercised a most beneficial influence upon the public health and well-being. Thirdly, at the commencement of this century the public health was nobody's concern in particular. Now every town of any size, and every rural district, has its own Medical Officer of Health and a large number of other officials concerned with sanitation; whilst the central and governing organisation—the Local Government Board—has a most complete and efficient staff of Medical Inspectors and others for routine and expert duties. One thing is still wanting and that is a direct representative of the health of Great Britain in the person of a Minister of Health, with a seat in the Cabinet, but it is only a matter of time till such an appointment is made. So also, at all universities and other centres of medical training the teaching of hygiene has of late years received great attention; though in one respect, the means for research into the causes and methods of prevention of diseases, Great Britain is far behind her European neighbours. In addition, the youth of both sexes are being trained whilst at school to a simple understanding of the construction of their bodies and of the laws which govern the preservation of health. It is, of course, too soon to try and estimate the great and lasting benefits that have followed, and are still following, from this immense expenditure of time, labour and money, but there are one or two points to which the student's attention may be shortly directed ere taking up the discussion of the full meaning and tendency of modern hygiene and its future influence on India.

In 1850, the medical officer of the General Board of Health laid before the President of that Board a most careful and elaborately exact paper by Dr. Greenhow, on the Distribution of Disease in England. In this paper it was shown that the diseases chiefly causing the annual mortality were as follows :—(1.) Bowel complaints, including cholera (a disease new to England), dysentery and diarrhœa, (2.) Fevers, including especially typhus and typhoid or enteric, (3.) Pulmonary or lung affections, especially those included under the generic term of 'phthisis', and (4.) In the case of children, measles, whooping cough, scarlatina and small-pox. An examination of this list will show how changed the types of fatal disease had become from those that characterised the earlier centuries. Small-pox was still prevalent it is true, but to a much less degree, and chiefly amongst unvaccinated children. Cholera had appeared, apparently for the first time, in Europe, spreading from India.* Typhoid or enteric fever, our present dreaded foe in India, if not occurring for the first time, was only distinguished from typhus in the year 1846†. Commenting on the immense loss of life due to almost entirely preventable causes, Sir John Simon says, "Looking at the last eight or nine years for which materials are before me," 1848—'55 or '56, "I find that the annual average of deaths by the three diarrhœal diseases has amounted to 26,388; by fevers (typhus, typhoid, infantile and remittent) to 18,616; by small-pox to 4,587; by tubercular diseases to 57,982; by non-tubercular respiratory diseases to 50,273; by the common infectious disorders to more than 32,000; by the nervous disorders of childhood, to nearly 37,000. Here altogether are 227,000 deaths annually distributed with utmost inequality. After reasonably estimating the degrees in which they severally are preventable, it can no longer

* This is denied by some, *e.g.*, Sir William Moore, but the point is immaterial to our present purpose. *v*, however, *post.*, Vol. II., Part III.

† The following interesting note on this matter occurs in Baas, *op. cit.*, p. 728. "The first description of typhoid fever—under the designation of 'Schleimfieber' (mucous fever)—appeared in the 18th century, and was due substantially to Roederer * * * and his pupil Karl Wagler. * * * As regards its etiology, these two observers already mention the contamination of the springs with filthy water. The disease was subsequently described by Sarcone in Naples, Armstrong, Campbell, Grant and Stoll."

seem so difficult to make a very large beginning towards striking off the annual 100,000 deaths against which the Registrar-General protests as deaths of artificial production." To give weight to this statement, there are here appended two tables from Dr. Greenhow's Report, illustrating how enormously the death-rate for the same diseases varies at different times and in different localities; and which go to prove that, to a large extent, the excessive mortality in certain districts is distinctly preventable.

I.—Annual death-rates from diseases which are either wholly, or almost wholly, preventable under good sanitary arrangements.

Cholera.	Diarrhœa and dysentery.	Continued fevers.	Small-pox.
From 0 to 403	From 4 to 345	From 21 to 209	From 0 to 146

II.—Annual death-rates from diseases which, to some extent, are inevitable, but of which the severity or frequency may be controlled by good sanitary arrangements.

Tubercular phthisis in women.	Non-tubercular lung diseases in men.	Common infectious disorders of childhood.	Convulsive disorders of childhood.
From 229 to 588	From 66 to 869	From 694 to 2,194	From 280 to 3,832

Twenty years later, Sir John Simon, in considering the same subject, and after an enormous amount of additional careful investigation in this direction had been carried on, wrote as follows in the Thirteenth Report to the Privy Council. "It seems certain that the deaths which occur in this country are fully a third more numerous than they would be if our existing knowledge of the chief causes of disease were reasonably well applied throughout the country; that of deaths which in this sense may be called preventable, the average yearly number is now about 120,000; and that of the 120,000 cases of preventable suffering which thus in every year attain their final place in the death-register, each unit represents a larger or smaller group of other cases in which preventable disease, not ending in death, though often of far-reaching ill effects on life, has been suffered. And while these vast quantities of needless animal suffering, if regarded merely as such, would be matter for indignant human protest, it further has to be remembered as of legislative concern, that the physical strength of a people is an essential and main factor of national prosperity; that disease, so far as it affects the workers of the population, is in direct antagonism to industry; and that disease which affects the growing and reproductive part of a population must also be regarded as tending to the deterioration of the human race. . . There are also some indirect relations of this subject which seem to me scarcely less important than the direct. For, where that grievous excess of physical suffering is bred, large parts of the same soil yield, side by side with it, equal evils of another kind; and you will often have seen illustrated in my reports, that in some of the largest regions of insanitary influence, civilisation and morals suffer almost equally with health. At the present time, when popular education (which indeed in itself would be some security for better physical conditions of human life) has its importance fully recognised by the legislature, it may be opportune to remember that throughout the large area to which these observations apply, education is little likely to penetrate unless with amended sanitary law, nor human life to be morally raised, while physically it is so degraded and squandered." These are weighty words indeed, and carry with them a grave responsibility on the part of all legislators and statesmen.

It is certainly extremely difficult to estimate the actual amount of good resulting up to the present time from all that has been done in the name of sanitary reform in England. As has before been pointed out, the peculiar and quite exceptional growth of population which has taken place during this century, and the immigration of that population into enormous towns, have not only increased the complexity of the problem of successful hygiene but, owing to general carelessness and crude and hasty efforts, have actually exercised a strong retarding influence, so that it has been said that the sanitation of the latter half of this century has consisted chiefly in the undoing of the mistakes made in earlier portions. With regard to the actual reduction in the death-rate since the early part of this century, it must be carefully remembered under what adverse conditions of poverty and over-crowding the mass of the people were forced to live.* The statistics for the years prior to 1838 are somewhat doubtful and even those from 1838 up to 1854 are probably defective. Still, it must be confessed that the death-rate which was undoubtedly greatly reduced towards the end of the eighteenth century, remained almost stationary through the period of over-crowding, poverty, and crude and hasty attempts at sanitation. Under those conditions, however, a stationary death-rate must be considered decidedly favourable, and it is certain that had these great and radical alterations in the distribution and habits of the English people taken place a century or two earlier the result would have an appalling outbreak of epidemic disease and probably of dire famine as well.† Instead of that, however, the population has steadily increased. From the passing of the Public Health Act in 1872 and the appointment of Medical Officers of Health, a steady

* *v. ante*, p. lxiv. † *v. footnote*, p. L.

decrease in the death-rate has taken place. The following extract may help to make this clearer.* "There is nothing in the series of annual reports issued by this office that comes out more distinctly and unmistakably than the wonderful effect which the sanitary operations of the last decade have had in saving life. The Public Health Act came into operation in 1872. The average annual death-rate for the immediately preceding ten years (1862—71) had been 22·6, and there were no indications whatsoever of any tendency of the rate to fall lower. Indeed in 1871, the final year of this period, the rate was exactly the average, *viz.*, 22·6. The Act came into force, and at once the rate began to fall, and continued to fall year by year with almost unbroken regularity, until in 1881 it was no more than 18·9. Once only in the ten years that had elapsed since the Act came into operation was the rate as high as the average of the previous decade. That was in 1875, when the rate was 22·7. In that year a second Public Health Act, of more stringent character, came into operation; and from that date down to 1881 the death-rate did not once reach 22·0, and averaged no more than 20·5.

"Had the fall in the death-rate been limited to a single year, or to two years, or even to three, it might have been argued by sceptical persons that the improvement was due to a succession of seasons favourable to health, or to other causes unconnected with sanitary administration, and that the setting in of the fall coincidently with the coming into operation of public health measures was no more than casual; but in face of a fall lasting for ten years in succession and increasing each year in amount, no one can seriously maintain such a position. There can be no real doubt that the saving effected in life was the direct product of the money and labour expended in sanitary improvements. Doubtless the money thus expended

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* *v. Annual Report* of the Registrar-General for the year 1881. The whole subject is fully discussed by Dr. Newsholme in his *Elements of Vital Statistics*, 3rd ed., 1892, (*q.v.*). *v.* also Vol. II., Part V., of this work.

was enormous in amount; and it will be well, therefore, to consider what return it has brought in. If, then, the death-rate in 1881 had been only equal to the average death-rate in the decade preceding the Public Health Act of 1872, there would have died in the course of that one year 96,917 persons who, as it was, survived. From this total, however, a deduction must be made of some 5,000 for the following reason:—The birth-rate in 1881 and in each of the two immediately preceding years was considerably below the average annual birth-rate in 1862—71. Consequently, there was a smaller than average proportion of children in the first three years of life in the population of 1881. But the death-rate at this early period of life is always very high. Had the birth-rate in 1879, 1880, 1881 been equal to the average birth-rate in 1862—71, there would have been so many more young children living in 1881 as to have increased the deaths in that year by a number close upon 5,000. Instead, therefore, of 96,917 lives saved, we have only about 92,000.

"Now we shall probably be well within the mark if we assume that for every fatal case of illness there are from four to five more cases which end in recovery. This is about the proportion in enteric fever, which is a more fatal disease than the average of diseases. The result, therefore, on this assumption, would be that, speaking in round numbers, there were 500,000 fewer cases of illness, and 92,000 fewer deaths in England and Wales in 1881 than would have been the case had the population been living under the conditions that existed in 1862—71. It may perhaps, be objected, and not unreasonably, that the year 1881, with its extraordinarily low death-rate, was so exceptional that it can hardly be taken as a fair sample by which to measure the annual return in life and health from the money spent in sanitary improvements. Let us then take the entire period of ten years that elapsed between the first Public Health Act and the close of 1881. Had the death-rate remained during that period at its mean level in the preceding decade, the total deaths from 1872 to 1881 inclusively would have been 5,548,116; whereas they were actually no more than 5,155,367. Thus no less than 392,749 persons who, under the old *régime,* would have died, were, as a matter of fact, still living at the close of 1881. (The mean birth-rates in the two decades 1862—71 and 1872—81 were almost exactly the same, so that no correction need be made in this case). Add to these saved lives the avoidance of at least four times as many attacks of non-fatal illness, and we have the total profits as yet received from our sanitary expenditure. Moreover, it is important to note that these profits were not equally spread over the ten years, but that there was a manifest tendency to progressive increase throughout the period. This is what might be anticipated; for the full effect of sanitary improvements requires time for development."*

Beyond all doubt, then, and in spite of many errors, enormous progress has been made, progress which has raised England, with its present population of nearly 500 per square mile as against 149 per square mile in 1801, to the very forefront of nations in the scale of health.

Having thus completed a brief historical review of the development of the subject, from early times to the present century, it is necessary to consider what is now meant by

* If the death-rates between 1881 and 1888 are included, the improvement realized becomes even more striking (Newsholme). Thus—

	Period of Years.	Mean Annual Death-Rate per 1,000 Living.
	Ten Years, 1862—71	22·6
Public Health Act, 1872—	Four Years, 1872—75	21·8
Public Health Act, 1875—	Five Years, 1876—80	20·79
	Five Years, 1881—85	19·30
	1886	19·28
	1887	18·79
	1888	17·83

the sanitary progress of that country by half a century, and India can but ill afford to neglect the dearly-bought experience of the richer and healthier country in this matter.*

Of man in relation of Self, as a sentient and rational being, but little need be said here save to note the extreme importance of impressing upon every member of the human race, while still young, the respect of his own body in all matters relating to health and the regulation of the desires. For such education youth is the proper time, before evil habits have corrupted the mind and weakened the body.

Next, as regards man in relation to his Surroundings, there are many things included under the latter term, such as the Air he breathes, the Water he drinks, the Food† he eats, the Clothing† he wears, the Dwelling he inhabits, the Soil he dwells upon, the Climate he lives in, the Disposal of the Waste Matter he gives rise to, etc., and it is the aim of the hygienist to ensure that men shall have pure air, water, food and soil, suitable clothing, dwellings and climate (as far as possible), and that all waste matter shall be speedily removed or rendered inoccuous. "But," say the ignorant, "why talk about pure air, pure water, suitable clothing and so on? Is not all water pure, is not the air the same everywhere, is not one sort of clothing as good as another, what is the harm of a little waste matter, as you call it"? To which questions the answer must be "No! all water is not pure—far from it—neither is air necessarily pure, nor all clothing suitable, and the waste matter that you would allow to accumulate around your dwelling is the worst of all, for it renders the air, the water and the soil impure, and I will prove what I say by showing you how diseases arise and spread, and how they may be prevented."

* If a man is to be called 'Sanitary Engineer' or 'Sanitary Officer', he should be one in deed and in fact. The idea that any engineer will make a competent Sanitary Engineer, and any medical officer a trained and earnest Sanitary Officer, let alone a specialist in hygiene, is still far too prevalent, and is a most costly and far-reaching error. *v.* also, Trans. VIIth Internat. San. Sci. Cong., Vol. XI., p. 160, *f. note*.

† Conveniently considered under Individual Hygiene, as they vary so much according to custom, climate, nationality, religion, etc.

Scurvy used to be a most deadly disease. Its cause was not known and therefore it could not be prevented. Now we know that it is due to hardship, exposure, etc., in conjunction with a defective dietary. It can therefore be prevented, and this prevention is brought about, chiefly by the provision of suitable food. Again, guinea-worm was, and is, still prevalent in many parts of this country. For a long time no one knew how or where the miniature form of the parasite gained admission to the human body. Now it is known to do so by means of impure water that is drunk. It can, therefore, be prevented by the use of pure water. Yet again, workers in match factories formerly suffered terribly from disease of the jaw bones. This was found to be due to the action of the phosphorus used in making the matches, upon teeth which had begun to decay. It can, therefore, be prevented by taking care that the air is not rendered impure by the fumes of the phosphorus, and this is done by using another form, the so-called red or amorphous phosphorus, which does not give off any injurious products.

Granted then that a man is cleanly and temperate, that his food, clothing, etc., are sufficient and suitable, that he takes trouble to ensure the purity of the water he drinks and of the air he breathes in his own house; is he properly safe-guarded at all points? By no means, and for this reason, that he may find it impossible to prevent his exposure to the risk of accident or disease from the ignorance, carelessness or greed of others. But what remedy is it possible to apply and who is to apply it, for it is evident that one man by himself would be quite unable to avoid or remove all sources of danger? In a rudimentary stage of civilisation, a man's health, and even his life, is no one's concern but his own; under more settled conditions he is protected from bodily violence; whilst only amongst the really civilised nations is it held to be the duty of the State to step in between its subjects and those who intentionally or even unintentionally might injure their health. Of instances where such interference is necessary there are many which will occur to any thoughtful person. The danger of phosphorus poisoning have already been alluded to. Here it was found necessary for the authorities to intervene between employer and the employed, and order that the amorphous form of phosphorus should always be used in match making. And so with very many injurious trades, special laws, regulating the age, hours of work, means of protection, etc., of the workers, have been passed, one of the most noteworthy being the Employers' Liability Act of England, by which a workman killed or injured through defective provision for his safety, or his heirs, can obtain pecuniary compensation for the injury from the employer, if it be shown that the former did not contribute to the accident by his own negligence. It must not be imagined, however, that the persons for whose benefit the State has framed the laws are always ready to appreciate them or even to conform to the conditions imposed; on the contrary, through ignorance or a false idea of the liberty of the subject, they will frequently go out of their way to nullify the protection offered them. Therefore it is that early education in the elementary laws of physiology and hygiene is of such extreme importance, as enabling those taught to understand and value the restrictions placed upon the cupidity of employers or upon the licence of the ignorant or depraved.

Out of these three important relationships of man,—to self, to his surroundings, and to his fellowmen—has slowly and by degrees grown the modern science of Hygiene. Of its supreme importance there is no question, and the statesman or economist who fails to recognise this has no just claim to be considered either far-sighted or enlightened. Prominent as is the position now occupied by this question of the Public Health in all civilised countries, it may be safely prophesied that it will year by year receive still greater advancement, till by general consent it is acknowledged—*Salus Populi Suprema Lex.*

It remains, however, to examine a little closely into the causes of the obstruction, active or passive, with which sanitary reformers of all nations have been opposed. Such obstruction will be found to be due to one of the following, *viz.*, Simple Ignorance, Religious Superstition, Indolence (Bodily apathy), Fatalism (Spiritual apathy), Pecuniary Considerations, or Scientific Objections (so-called).

Under the heading of Simple Ignorance come two great classes of opponents to the progress of hygiene. In both defective education is at the root of the matter, but with the one class, which includes the majority of the unlearned, the opposition is the result of sincere ignorance of all matters in general save those relating to the bare necessities of daily existence. For these the greatest patience and consideration must be shown, the reasons for any sanitary measure explained in clear and easily-understood terms and, above all, they must not be frightened or coerced, save only, perhaps, when the matter is extremely urgent and of national importance. The second and smaller, but infinitely more harmful, class is composed of persons* who have received an education complete in many directions, but seriously defective in one important point—the training of the mind to the accurate and logical methods of thought which alone, save in rare instances, result from a scientific education. Amongst this class must be included many eminent persons in nearly every profession and occupation who have never, unfortunately, accustomed themselves to see how small a place they occupy in the scheme of the universe, nor have been shewn how infinitely valueless are their so-called 'opinions', compared with the lessons daily spread before them by the workings of nature, but which are hidden from their limited and partial mental vision. They receive mention here simply because of the fact that owing partly to their social position or distinction in a particular profession, and partly to the persistency with which they advocate their own peculiar craze or superstition,

* Most numerous in Great Britain, but not unknown in India.

they are able to command an amount of public attention entirely incommensurate with their real importance, and may thereby delay or hinder valuable and much-needed reforms. With such persons arguments and demonstrations are alike fruitless, and the only consolation derivable is the remembrance of the fact that the gradual spread of scientific knowledge amongst all classes is steadily lessening their numbers, and may even at some future date lead to their complete extermination.

To the opposition resulting from Religious Belief, or Superstition, allusion has already been made, and it has been shewn why it is that the priesthood of so many nations is jealous of a science which declares that disease is most frequently the natural consequence of man's imprudence or laziness, and is only rightly called a 'divine visitation' in that limited sense. Of particular religious customs it is unnecessary to speak here, save to emphasise the fact that many are essentially insanitary. At any place possessing a reputation of being particularly sacred and where, accordingly, enormous crowds of devotees assemble periodically, it is the primary duty of those who receive the revenues therefrom accruing to devote a sufficient portion of the latter for the efficient sanitation of the spot, and that not by feeble and spasmodic attempts after the appearance of disease, but by careful and thorough preparation for all emergencies beforehand. If, after proper warning, no attention is paid to this matter locally, it is the bounden duty of the authorities, with a view to the welfare of the population generally, to prohibit the holding of the religious festival or ceremony till their orders have been complied with. In this respect considerable improvement has taken place of late years in this country, but a great deal remains to be done.*

* At the present time the want of sanitary precautions and supervision in connection with the annual *Hadj* to Mecca is a disgrace to all concerned, and it is to be hoped that enlightened Muhammadans will insist on a complete reform in this matter and thus remove an evil which directly causes the death of many thousands of pilgrims, and is a standing menace to the health of the nations. It is reported that the Sultan has

Of passive obstruction, the result of Indolence or Fatalism, it must be confessed that whilst in all countries it is an important bar to sanitary progress it is pre-eminently so in the East. To a certain extent the existence of caste distinctions must be held responsible, for under this social code, so rigidly enforced for many generations, the lower orders are not encouraged to rise nor to improve their surroundings, and occupy therefore, a position in many respects similar to the serf in early England. There is no doubt that it is difficult for any one trained in the light and learning of western science, and accustomed to the general education and independence of the masses in Britain, to understand the mental attitude of the ordinary uneducated native of India who looks upon all disease as he looks upon the rainfall—"It may or may not come; if it is going to come it will come, if not it will not come: it is all a matter of fate and a man cannot alter that!" Years' of experience have taught him to take some little trouble in husbanding the supply of water, else how will he get food? But not so as regards the simplest provisions for warding off disease. And indeed the bodily circumstances of many millions in India are so straitened, and their surroundings so unhealthy through malaria and other diseases, that they may be said to continually dwell on the borderland between life and death, and thus a feeling of callousness, fatal to all self-respect and self-endeavour, is produced. Sanitation amongst the millions of India scattered throughout the land in small villages must for years be confined to the simplest measures; but from these simple measures, if carried out from a love of humanity and with the persistence characteristic of the true sanitary pioneer, there will assuredly result a great decrease in the mortality from preventable disease and, what is more important, an immense improvement in the stamina and well-

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ordered the construction of an immense lodging house capable of accommodating some 6,000 people, and if so, the latter is likely to afford an admirable centre of development for an epidemic. *v.*, also, discussion and tables, Trans. VIIth San. Sci. Cong., Vol. XI., p. 39, and B.M.J., 4th Nov. 1893, p. 1013, and references therein given.

being of the people. The question of village sanitation has received a considerable amount of attention lately from eminent civilians, medical officers and others, as also at the late International Congress on Sanitary Science (1891); and though it is undeniably difficult of solution, chiefly because of the apathy of the people themselves, and because of the immensity of the problem as compared with the ways and means available, it will certainly press itself more and more upon the attention of those in authority, till some one is found able and willing to devote the time, experience, and ability—possibly genius—that it demands for its proper settlement.

A frequent cause of delay in the progress of hygiene, and a powerful weapon in the hands of its opponents, when used with skill, is the question of the Pecuniary Considerations involved. On rare occasions, indeed, the cry thus raised may ultimately prove to be a blessing in disguise inasmuch as a scheme containing in itself the germs of good, but crudely and expensively planned, may, perforce, be delayed for revision and improvement; in addition to which, the money thus saved can be profitably applied elsewhere. This, however, is an unusual state of matters, and it is much commoner to find that an important reform or work is hindered and obstructed in every possible manner under the guise of 'undue expense,' until finally, when the condition of things is almost hopelessly bad, a most elaborate and costly remedy is sanctioned, the expense and benefits of which are in inverse ratio to what they would have been had permission been at once accorded to the original proposal. In some cases the cry of 'expense' is raised from perfectly sincere and honorable motives, and is simply the result of the official concerned not having fully grasped the fact that in a settled country, where there is no immediate danger to life from actual violence, *the public health is—not of great, but—of supreme importance, and should always take precedence in the estimates of expenditure.* As said before, no one who has not grasped this fact fully and clearly can claim to take front rank as an administrator. And not only so, but he must give practical evidence that he has convinced himself of the absolute truth and accuracy of the already-quoted classic statement of Edmund Parkes—the result of years of careful work, observation, and unrivalled experience—that "*It has been proved over and over again that nothing is so costly in all ways as disease, and that nothing is so remunerative as the outlay which augments health, and in doing so augments the amount and value of the work done.*" Would that these two sentences, embodying both the financial and the moral or humane aspect of the question, were written in letters of gold in every Council chamber, Municipal office and Board room throughout India. It is not that there have not been, and are not, men who fully comprehend the unvarying truth and application of these principles, for there have been, and are, many such who have proclaimed these truths in season and out of season; but too often, alas, they have been as voices crying unheeded in the market-place or have been regarded as worthy but quite unpractical enthusiasts. Let any intelligent and well educated man consider carefully the relative cost of efficient sanitary measures and precautions, and of the awful sickness and wide-spread misery resulting from the want of the same; let him read the accounts of the various campaigns and expeditions of the British* and other armies; of the enormous invaliding and mortality in former days from pulmonary tuberculosis in the army and navy; of the diseases due to unhealthy trades and occupations; of the cost of epidemics of cholera, small-pox, etc., in European towns; and having done so let him honestly confess that the bad effects thus produced, both morally and physically, and the actual pecuniary loss thus resulting, are infinitely greater than they would have been had those in authority been a little less 'penny wise and pound foolish.'

Such a mistaken policy is bad enough, but there is a worse

* Not omitting a comparison of the mortality and invaliding of recent expeditions, where the Sanitary and Medical precautions have been efficient or the reverse.

form of obstruction, and that is where, under an excuse of excessive sanitary expenditure or a plea of greater emergency, local bodies are enabled successfully to block all important proposals for hygienic improvements, in favour of the execution of other works which will redound more evidently to the fame of the proposers or, possibly, lead to the more solid advantages resulting from the bestowal and receipt of contracts. More than this, the question of self-interest at once arises, and a landlord who owns half a street of damp and defective houses, a tanner whose wealth is represented by heaps of noisome and foul-smelling hides, or a person who considers his front verandah the proper place for keeping his cows and ponies, are not likely to be enthusiastic with regard to bye-laws and regulations framed with the direct object of interfering with their free license in spreading dirt and disease. Such cases occurred, and do occur, only too freely in all countries, and constitute a form of obstruction to counteract which requires the strongest determination and most fearless courage of all concerned in sanitary administration. It is for this reason that it has been found necessary in England, after many years of trial of different plans, to make the local sanitary authorities as independent as possible, and to ensure that the medical officer of health, the sanitary inspectors, and other officials shall not be obstructed in their duty by fear or favour of any man.

The only objections to hygiene having any pretension to the attribute Scientific are, first, the assertion that by rendering the conditions of life more healthy, the diseased or deformed who would otherwise perish are kept alive, to the detriment of the future race, and second, that as a result of the lessened death-rate an excessive degree of over-population, and the misery resulting therefrom, are brought about. The first of these was well discussed by the late Surgeon-Major McNally, in the introduction to his hand-book, and the falseness of the proposition involved so clearly shown therein that no apology is required for reproducing the passage here. "A partial application of Darwinian principles has led to the conclusion* that sanitation interferes with natural law, and that degradation of the human race must be the result of a suspension or abrogation of disease as a cause of natural selection and the survival of the fittest. It may be pointed out that this objection would apply to curative more aptly than to preventive medicine. Its confutation, however, must rest upon evolutionary principles. The fact is certain that insanitary conditions affect not only the weakly, whom they kill, but the strong, whom they debilitate, and, in this way, they tend to produce a depraved race; whereas improvement in sanitary conditions, according to the doctrines of the influence of environment and improvement under improving conditions, must tend to improve the race. It might be conducive to improvement—unless the race were totally wiped out by the process—if individuals attacked by diseases which permanently enfeebled them were all to die, and thus be prevented from propagating a feeble offspring; but it is a fact that, for each one who dies, a considerable number recover with more or less damaged constitutions; such diseases being unchecked must, therefore, necessarily tend to cause degeneration of the race. On the other hand, the aim and effect of sanitation is to prevent the enfeeblement of individuals by disease, and not only to act thus, in a negative way, by preventing deterioration of the race, but also to act positively towards the improvement of the race by improving their surroundings and their mode of life. Practical illustrations of the truth of these doctrines may be observed everywhere. Persons and communities who live under the best sanitary conditions are notoriously the most vigorous; those who live in the country are more vigorous than others of the same race who live in towns under inferior sanitary conditions; those who live on high lands, where the soil is comparatively dry and the air and water pure, are more

* A conclusion which has partly been supported by the great authority of Herbert Spencer.

vigorous than those who live on ill-drained low lands; the unhealthy life conditions of the inhabitants of malarious tracts in South Canara and the Wynaad have produced a puny, stunted, short-lived and degenerate race, who compare unfavorably in every way with the inhabitants of healthier localities in the neighbourhood. Drainage and improved ventilation have enormously reduced the prevalence of scrofula in many parts of England to the obvious benefit of the race. From these and innumerable other examples of the kind the conclusion is inevitable that the aim of the sanitary evolutionist should be not to deprave the race by adapting it to unhealthy surroundings, but to elevate it by improving its surroundings."

The second assertion is certainly deserving of far more careful consideration than it has yet received. It is undoubtedly a fact that in Great Britain, where the benefits of applied hygiene have had fullest play, the population is increasing by leaps and bounds, in spite of a diminished birth-rate, and at the same time is tending more and more to concentrate itself in the large towns. This subject has been already alluded to, and in one sense is a matter for congratulation; but it is evident that there must be a limit so far as any one country is concerned, and in the case of Great Britain that limit will very soon be reached.* The accompanying extract† will show that this is not a fancied danger looming in the dim future, but is one which even now has assumed no mean proportions.

"Let the reader endeavour to form a mental picture of London multiplied by three. If the gruesome spectacle thus conjured up does not make him shiver, he must be either very callous, or else endowed with an enviable amount of optimism."

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* A mass of interesting information on this and kindred matters of the most vital importance to the student of hygiene will be found in a lately-published work, *Studies in Statistics*, by Dr. G. B. Longstaff, which should be studied by everyone interested in the social and economic problems of the day. *v.* also, Newsholme, *op. cit.*

† From an instructive paper, entitled *Overcrowding*, by that eminent hygienist, Dr. Greene Pasha, *v.* Medical Magazine, Vol. I., p. 1036.

"The following short statement may serve as a foundation for the representation :—

Population of London, 1892 = 4,263,294.

Weekly increase, 870 = 45,240 per annum, or 1·06 per cent.

An increase of one per cent. alone would in 100 years suffice to bring up the total to 11,531,328.

Allowing for the decimal, but taking no account of immigration, the London of our grandchildren will in round numbers contain 12,250,000 inhabitants.

It must be borne in mind that this fearful array of figures refers to the Metropolis solely. In rural England, generally speaking, the death-rate is lower and the birth-rate higher than in London; but supposing, for the sake of illustration, that the movement of population should be identical in both metropolitan and country districts during the next hundred years, our descendants at the end of that comparatively short period will find themselves struggling for air and food in the midst of a compact phalanx of their fellow-sufferers—all more or less starving—amounting, for England and Wales, to upwards of eighty millions."

"The horror of the tragedy embodied in this picture is so great that further amplification could scarcely add to it. In order, however, that the reader may have no doubt on the subject, his attention is directed to a few more unassailable facts, which unhappily only deepen tints already far too sombre. According to the Census of 1881, the population of England and Wales was 25,974,439, or in round numbers, twenty-six millions. In 1891 it had risen to over twenty-nine millions, being an increase at the rate of upwards of 300,000 per annum. This represents a percentage of 1·16 against the London rate of 1·06. Instead of eighty millions, therefore, the population to be dreaded is really ninety-one millions."

That this is a question urgently demanding the attention of legislators is a matter that admits of no question.* Of its ultimate solution there can also be no doubt, but by what means, whether through continued immigration to every habitable and cultivable quarter of the globe, and through the adoption by the more enlightened peoples of strict laws regarding the non-marriage of those in any way physically or mentally unfit, or through a recrudescence of dire pestilences and famines in certain quarters, or, finally, through fierce and protracted struggles between contending nations with the accompanying slaughter of human beings on a gigantic scale, there is no knowing. It is possible that within the next one hundred years mankind may have realised practically the uselessness and horror of warfare, and that the peace and security resulting therefrom may enable them to give their undivided attention to the peaceful arts; so that with true hygiene in their midst, taxation reduced to a fraction of the present burden, and ample leisure to develop the material resources of the world the cost of living may cease to be the chief concern of life, and all men may have time to devote their attention to the due and sufficient cultivation of their bodily, mental and spiritual faculties. Then, at length, will the Golden Age—sung of by poets and dreamt of by dreamers through countless years—have dawned upon the children of men, whose lives are now but too frequently a record of sorrow and disease from the cradle to the grave. Whatever may be the final solution of this problem it still remains the duty of the hygienist to further by every means in his power the cause of the public health, but he must also recognise and study those other social questions which have arisen and will continue to arise as the future history of the human race is day by day and year by year unrolled.†

In the light of what has been said as to the gradual

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* It must be remembered that though Great Britain and its capital, London, are specially alluded to here, the question of over-population and its fearful evils is also applicable, or soon will be, to the whole of the civilised world.

† *v.* post.

development of hygiene from ancient times until now, and especially as to the enormous progress made during the last fifty years in all its branches, from preventive medicine to sanitation, progress which had raised it definitely and permanently to the position of a leading science, let the student turn his attention for a little to the work already accomplished in India in this direction.* Previous to 1858, the year in which the Hon. E. I. Company handed over the care of British India to the Crown, sanitation had received but scant attention. Thereafter, as before noted, the Royal Commission on the Sanitary State of the Army in India was appointed and, as a result of its labours and report, attention was forcibly directed to the absolute neglect of all sanitary principles throughout the country generally, and the enormous amount of disease and high rate of mortality thereby ensuing.

In this connection it is interesting to note the great change that has already been wrought with regard to the health of Europeans in India. At the beginning of this century, and for many years after, the mortality amongst the European settlers, from a variety of causes, was fearful, and doubtless exceeded considerably that of the native population. Speaking of Bombay, one writer said, "I reckon they walk in charnel houses; in five hundred, one hundred survive not." The Europeans in Calcutta used to congratulate themselves on having survived another hot weather and rainy season. The three factors that chiefly contributed to this excessive death-rate were, probably, the extreme unhealthiness of the native population and the universal prevalence of filth and pollution, the disregarding by new comers of the fact that they were living in a tropical climate and under conditions quite different to those to which they were accustomed in Europe, and last, but by no means least, the abuse of alcoholic stimu-

* Much of the information here given is derived from the interesting and elaborate paper entitled *Sanitary Progress in India*, by Sir W. Moore, K.C.I.E., late Surgeon-General with the Government of Bombay. *v.* Trans. VIIth San. Sci. Cong., Vol. XI.

lants. True, many of them tried to adapt themselves to the customs of the country and possibly escaped certain dangers by this method, but on the other hand, as appears from old journals and biographies, they often adopted customs injurious in themselves or unsuited to the ordinary European constitution, *e.g.*, the total abandonment of regular exercise, the taking of large quantities of bulky food at one meal, etc. Since that time, although the general mortality in India remains very high, the health of the ordinary Anglo-Indian has very greatly improved and the death-rate declined in proportion; the chief contributing causes to the above improvement being, (1) the greater facilities in journeying, both by land and sea, whereby unhealthy localities can be largely avoided in travelling, short leave can be spent in the cool, healthy climates of the hill stations, and access to Europe and other countries is rendered easy and rapid; (2) the sensible alterations made in nearly every point relating to personal hygiene, *e.g.*, the adoption of suitable clothing and head gear, the avoidance of heavy meals during the heat of the day, moderation in the use of alcohol, etc.; and (3) the fact that the Anglo-Indian, owing to his own habits being sanitary as a rule, is enabled to reap the advantage of the little (comparatively) that has been done in the way of general hygiene.

As regards the native population of India, the conditions obtaining throughout the land, on occupation by the British, were in many ways similar to those of Europe during the Middle Ages, allowing for certain differences in the eastern climate and customs. The cities were mostly composed of Forts and Palaces, within and around which clustered the various 'bazaars'; whilst the remainder of the population lived in small, scattered villages close to the land they cultivated, or in remote jungle tracts. Of course there were exceptions to the above, especially in the case of places possessing shrines of repute, or with a great name for commerce. Here there was generally a straggling town, irregularly grouped round the sacred shrine or business quarter, and in and around which at certain seasons enormous multitudes of pilgrims or traders, as the case might be, were wont to congregate. Sometimes, under favourable circumstances, these swarms of human beings would escape any serious calamity, but when exposed to wet weather, scarcity of food, pollution of the drinking water, or other defective sanitary conditions, disastrous outbreaks of disease would occur and decimate the local population and the camps of the strangers. The old custom of protecting a town from sudden surprises from without still survives in the form of the hedges of prickly pear or aloes, etc., which are seen surrounding so many Indian villages, and which, like the mud walls and hedges around each individual village hut, are but too invariably the receptacle of every kind of filth and excrementitious matter, and also oppose a very efficient barrier to the perflation of the village lanes and bye-ways by the light breezes that prevail for many months annually.

To the insanitary state of the towns and villages at the time of the British occupation, as above-noted, must be added the important fact that owing to the unsettled condition of affairs the inhabitants of many districts were liable to attack at any time from hostile invaders and, in the event of defeat, to be either dispossessed of their land and goods, or to be crushed by grievous taxation, from which latter they themselves would derive no single benefit. Following these disasters would probably come famine and its miseries, and on the top of this cholera or other epidemic disease, reducing the miserable people, to whom escape or relief was impossible, to utter despair. Of course this state of matters was not general throughout the country, in many parts of which the people, when sufficient rain fell for their crops, led a careless and happy life, but it is undoubtedly true that this peaceful and pastoral existence was liable to sudden irruptions of human enemies or of more insidious, but not less destructive, foes in the shape of famine and disease.

It is impossible to follow in any order or detail the various improvements which have directly or indirectly contributed to the amelioration of the insanitary conditions formerly prevailing throughout India. Amongst these, however, must be noted the steady and effective pacification of the country, the introduction of law and order generally, in place of injustice and insecurity of life; the opening up of free communication by railways, roads and waterways; the conservation of existing, and creation of new, water supplies for agricultural purposes;* the formation of forest reserves; and many other systems and reforms by which the vital surroundings of the population at large have been greatly improved and ameliorated. Of still greater immediate value has been the establishment of hospitals and dispensaries throughout the length and breadth of the land, whereby not only have countless thousands of sick been benefited, but the timid or sceptical have been forced to realise that they are governed by a nation to whom the life of the humblest outcast is a matter of concern. As in other countries, so in India, there is nothing so convincing of the good intentions of the governing towards the governed, once that initial fears or prejudices have been overcome, as the establishment of institutions to which all alike have access for relief from their burden of sickness and disease. Hand in hand with the establishment of hospitals has gone the building of asylums wherein those mentally afflicted are treated, not as criminals or even as nuisances to the State, but with all kindness and attention. So also with leper asylums; whilst even the criminals are fed, lodged, and looked after at enormous cost and with the greatest care under a system which has deservedly a world-wide reputation for humanity and efficiency. Finally, there must be noted the favourable influence exercised by the spread of general education. And here arises a question which is not so very easily answered in practice,

* With the important reservation that in many places the introduction of extensive artificial irrigation schemes, whilst increasing the local revenues and food supplies, has been the direct cause of districts previously healthy becoming extremely malarious, or otherwise unhealthy, as in Egypt.

namely,—Is it better to introduce sanitary reforms at once and, by improving the general health of the population, to pave the way for the reception of mental instruction, or is it better to educate the people first and then, when they can understand the *rationale* of sanitary regulations and improvements, to make and carry out the latter? The proper answer to which question is probably the following. The first essential is to spend time and money in introducing at once simple and easily-appreciated sanitary reforms; follow this up by a sound education, which must include the elements of physiology and hygiene as a *sine quâ non;* the sanitary reforms being meanwhile steadily continued and increased in number and efficiency. Once that arrangements have been made for securing to all the benefits of a thorough grounding in the *essentials* of education, then hygiene, in the full and modern sense, should take absolute and continued precedence in expenditure, instead of being sacrificed in turn to every other department.*

With regard to the more directly sanitary improvements, a great deal has undoubtedly been done, but the fringe of the subject has scarcely been touched as yet; though many who do not realise the immensity of the problem imagine that the sanitation of India has made great progress. In former times all sanitary work was planned, supervised, and executed officially, with the result that in places where the military or civil authorities took an intelligent personal

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interest in the matter, a high standard of cleanliness was maintained, whilst in other places little or nothing was done. So far as military stations, cantonments and jails, etc., are concerned, the work is still largely in the hands of Government officials and, as a consequence of the powers possessed by these latter and the constant supervision exercised by them, a cantonment or the 'lines' of a native regiment are almost invariably distinguishable at a glance from the surrounding portions of the town by their orderly and cleanly condition. It is not contended, of course, that the civil population is, or can be made, amenable to the same hard and fast regulations as govern these military and purely official institutions, but it is asserted that faithful and systematic work by the municipal and sanitary authorities, coupled with the devotion to pure sanitation of a due proportion of the local funds, will very materially lessen the commonly existing marked difference between the military and civil portions of a town. The establishment of municipalities was undoubtedly a most important step, and may be said to have been attended with a considerable, and far from discouraging, amount of success. The history of the local bodies in England will demonstrate to any reader how great are the difficulties and abuses to which such a system is certain to give rise, and how obstinately men, of otherwise good reputation, will resist the introduction of rules or measures that clash with monopoly or self-interest. How much more, then, in a country where the idea of local self-government is foreign, where bribes are universally offered and expected, and where bodily and mental apathy are the rule rather than the exception. The following extract* may help to convey some idea of the importance of such a change. "At the onset it was felt that no real progress could be made unless the assistance of the people themselves was secured. It was further considered desirable that municipalities should form the centres from which education in sanitary matters

* Sir W. Moore, *op. cit.*

should emanate. The first step was, therefore, the establishment of municipalities. A special Municipal Act was passed for the Presidency Capitals about the year 1863, and soon afterwards another Act was passed for provincial towns. Still more recently legislation has endowed these bodies with considerable powers for securing the sanitary improvement of towns and villages, and has placed at their disposal much money for expenditure on that object."

"Before 1871-72 expenditure was centralised in the Supreme Government, and grants were made to local governments on detailed estimates showing the need of each department. Local Governments asked as much, and the Supreme Government gave as little as possible; but certain heads of expenditure, including sanitation, were now transferred to local governments, with fixed annual grants to meet them. In connection with local self-government by municipalities, it should be stated that the latter were relieved in 1882-83 of police charges; the intention of the concession being that more should be spent on sanitation and improvements. Government have also granted loans to some municipalities."

"According to the most recent reports, I find that there are some 755 municipal towns in India, not including the large number of small villages where there are only sanitary boards; but the people living under municipal control comprise only 5 per cent. of the total population."

"The total receipts of all the municipalities for the year 1889-90 was Rs. 3,720,000, including Rs. 806,000 from loans. About 45 per cent. of this was spent on sanitation.* The income is derived from house tax, tax on rentals, octroi duties, bazaar-stall rents, wheel tax, water rates, rents of properties, public garden and park fees. The population of the municipal towns was 14,275,858. There are also numerous district and local boards for the administration of district hospitals, dispensaries, schools, roads, etc. The

* [Sanitation is a word with a wide meaning in Indian reports, and may include anything, from a road leading nowhere in particular to the purchase of *eau-de-cologne* as a disinfectant!]

importance of the work done by all these local bodies may be estimated by the fact that they have at their disposal, according to the last "Moral and Material Progress Report" of India, more than £7,000,000 sterling annually."

In each of the presidencies and larger provinces there is a Sanitary Commissioner devoting the whole or part of his time to sanitation, and under him there are one or more Deputy Sanitary Commissioners, in the case of Bengal, Madras, Bombay, the North-West Provinces, and Punjab. The towns of Madras, Bombay and Calcutta have each a Medical Officer of Health, and Calcutta, Bombay and Karachi have each a Port Officer as well. In addition, there are Sanitary Engineers for Bengal, Madras, Bombay, the Punjab, and Central Provinces. In the larger towns there are also Sanitary Inspectors. Each District Surgeon, in addition to his other extremely multifarious and constantly increasing duties, is also the Sanitary Officer for his own district and is in charge of the vaccination staff as well. Some idea of the amount and frequency of the supervision that can be exercised by these officers, whose hands are already full of purely medical work, can be gathered from the fact that most of the Madras districts range from 5,000—10,000 square miles, with railways few and far between, whilst the district of Vizagapatam, in which the first railway is only now being constructed, is more than 18,000 square miles in extent, and has a population of over 2,000,000! The various duties of these officials, and other details regarding sanitary organisation and administration are discussed in Part V. of this work.

In commencing the sanitary reform of any district or country the most urgent matter is the provision of a pure water supply: following this come the necessity for the systematic removal and disposal of waste matter, more particularly fæcal matter, the improvement of the air supply by attention to both internal and external ventilation,* the

* *v.* pp. 19-20. It should never be forgotten that the first step towards pure air is not ventilation, the widening of streets, etc., but the regular removal of all filth from streets and habitations, and the more abundant use of soap and water by the inhabitants.

drainage of the subsoil when the ground-water level is high, and last, but not least, the improvement of the food supply of the population when, as is so largely the case in India, it is defective both as regards quantity and quality. Of course there are many other points to which careful attention must be given, but when the population of a country has been supplied with pure air and water, when the pollution of the soil has been stopped as far as possible, and the food supply rendered cheap, good and abundant, it may be safely predicted that the health and general conditions of life of the people will have been very greatly improved.

All these important points have received careful attention for the last thirty or forty years, and in the larger towns considerable progress has been made. What has been done and what remains to be done will be found in the various parts of this work. In the paper by Sir W. Moore, before referred to, there are tables showing towns in which drainage systems, pure water supplies and other sanitary improvements have been introduced, and it may be safely asserted that the Government of India, the Local Governments, and their sanitary advisers, are fully alive to the extreme importance and urgency of the work that still remains to be accomplished in this direction. The same cannot be said, however, for the military and civil authorities at all stations. It is with them, after all, that the actual carrying out of orders and the immediate responsibility for the health of those in their charge lies; hence the necessity for constant and fearless sanitary inspections of all towns, cantonments, villages, etc., by trained sanitary officers* who can judge of what has been done as compared with what might have been done, and upon whose reports, according as they are favourable or otherwise, action will

* At the present time the belief that any fairly good medical officer will do for a Deputy Sanitary Commissioner is all but universal in India, and this belief being put into practice by the appointment of medical officers without a single qualification for such posts, as has been done at times in every Presidency, the office of Deputy Sanitary Commissioner, which should be looked upon as reserved for specially selected and specially qualified officers, is regarded by some as a *dernier resort*, in case all other things fail!

at once be taken with a view to remedying defects. But such inspections can only command the attention and respect they should when it is known that the knowledge and ability of the inspecting official are of the highest, and that he is versed in all that appertains to the theory and practice, the science and art, of his special subject. This alas, is not always the case in India, and it is certain that the technical knowledge of hygiene demanded of first class Sanitary Inspectors in England is greater than that possessed by many who are here, often against their will or concern, designated 'Sanitary Officers.'

Put very shortly, the following are the chief sanitary improvements which have, up to the present time, been accomplished in India. But firstly, it must be noted that, with the exception of vaccination, they are practically confined to the towns, and very largely to the towns with a population of over 20,000 inhabitants. Now the number of towns with a population of 20,000 or more is 227, with a total of less than 14,000,000 inhabitants*; leaving a remainder of 1,808 towns and more than 500,000 villages, containing about 270,000,000 inhabitants, to whom sanitation, in any effective degree, may be said to be unknown. The accompanying table† may serve to give an idea of the area, population, etc., which is under the charge of one District Sanitary Officer,‡ with occasional visits from the Sanitary or Deputy Sanitary Commissioner. In the three presidency towns, Calcutta, Madras and Bombay, in Rangoon, and in some of the larger *mufasil* towns in India, very large sums of money have been spent in providing an abundant supply of pure water, and, in some cases, in introducing a partial or complete system of sewerage. In addition, an enormous establishment of sweepers or *mehters*, bullock carts, etc., is maintained for the removal of excreta, town refuse, etc., and in certain towns, notably

* *i.e.*, almost exactly the population living in municipal towns, *v.* p. ciii.

† Compiled from the latest Census Report (1891).

‡ The fact that many of the larger towns possess hospitals or dispensaries in charge of a medical subordinate, who is also nominally in charge of sanitation, in no way affects the essential truth of the above conclusion.

DISTRICT OF MADURA.*

AREA IN SQ. MILES 8,808.

Towns and Villages Classified by Population.

1—199.		200—499.		500—999.		1,000—1,999.		2,000—2,999.		3,000—4,999.		5,000—9,999.		10,000—14,999.		15,000—19,999.		20,000—49,999.		50,000 and over.		TOTAL.	
No.	Population.	No.	Population.	No.	Population.	No.	Population.	No.	Population.	No.	Population	No.	Population.	No.	Population.	No.	Population.	No.	Population.	No.	Population.	No.	Population.
1,948	168,194	932	299,378	566	403,657	363	507,404	143	354,284	100	376,058	38	244,370	8	96,555	3	50,873	1	20,203	1	87,428	4,103	2,608,404

* The average area of a district in Madras, excluding Madras but including the agency tracts, is 6,722 square miles, which is about 300 square miles more than the area of Wales.

Calcutta and Bombay, systematic attempts are being made to dispose of such rubbish in a suitable manner, as explained in chapter IV. In Calcutta, there is that most essential institution, a municipal laboratory, for the analysis of food-stuffs, water, air, soil, etc., and altogether, the city possesses a large and very complete health establishment. Many other points have received attention in these cities, such as the establishment of vaccine stations, the registration of births and deaths, the notification and inspection of cases of infectious disease, the filling up of tanks, the improvement of *parcherries* or *bustees*, the regulation of buildings, of slaughter-houses, of fairs, etc., and other things too numerous to mention, but there remain the facts that, with the possible exception of one or two of the largest cities, the attention given to sanitation and the money expended upon purely sanitary works are by no means what they might be, considering the enormous importance of these matters. It is, however, extremely gratifying to notice that in several of the largest and most powerful Native States in India, this subject is receiving very considerable attention, and much money is being spent on the introduction of sanitary reforms.

That the difficulties of more effective sanitation in India are great, cannot be denied. The various causes of obstruction to improved sanitation common to all countries, or to India in particular, have already been considered, but it is interesting to note here the views of a most capable and experienced medical officer as lately expressed.* "The Government of India has already done a great deal, and when it is reproached for not having done more, it can only plead the enormous extent of the work remaining to be done, and the impossibility of doing it all at once. It is sore let and hindered by two great obstacles,—the ignorance, apathy, and prejudice of the native populations, and the lack of money. The natives, though differing enormously among themselves in race, in religion, manners,

* Surgn.-Colonel R. Harvey, D. S. O., I. M. S. *v.* Trans. Internat. San. Sci. Cong., Vol. XI., p. 104.

customs, and other ways, are unanimous on two points, their dislike of innovation and of taxation. They have for the most part no idea of the benefits of sanitation, nor of the dangers which result from its neglect. What was good enough for their fathers is good enough for them, and it is exceedingly difficult to bring home to them that they derive any personal gain from the expenditure on sanitary improvements. The cry of religion in danger is invariably raised when any innovation is attempted. It was so the other day, when the age of marriage for girls was raised from 10 to 12 years. It was so over schemes for better water supply, over vaccination, over public latrines and other matters. It will take a long time to educate them to appreciate modern ideas on sanitation. A government, and especially an alien government, cannot offend the root-ideas of its subjects; but the Government of India are doing their best. The second great obstacle in the way of the Government is the question of cost. The needs of India are enormous. An income much larger than that available could be profitably spent in developing the resources of the country. A crowd of greedy applicants assail the Government on all sides for grants. Roads, railways, canals, and irrigation schemes, forests, telegraphs, barracks, court-houses, and other public works, to say nothing of periodical famines, and the constant demand of the military authorities for troops, munitions, and frontier defences, would take much more than Government can spare; and all are urgently needed, so that it is hardly to be wondered at that schemes,—the practical advantages of which are not immediately apparent, and the results of which may not be evident till the next census,—which, moreover, are sure to be met with strenuous opposition and protests from the very people intended to be benefited,—should be crowded out in the scramble for Government allotments." So that, although it is hardly to be wondered at that sanitation is "crowded out" in the struggle for allotments, what is wanted is a clearer recognition by all, from greatest to least, that in a country which is fairly settled there is *no one thing so urgent,* nothing of such supreme importance, as Health, and that the Statesman by whom this belief is strongly held and practised will be the man whose memory future generations will delight to honour.*

Of the actual value of all that has been done under the name of Sanitation in India, it is exceedingly difficult to form a reliable estimate.† In the larger towns the mortality from cholera has been very greatly reduced by the introduction of a pure water supply. Dysentery, formerly a most fatal disease, has to a great extent lost its terrors for those Europeans who live carefully as to diet, clothing, avoidance of chill, etc., whilst even the Native population, particularly those who avail themselves of rational treatment, suffer to a much less degree. Guinea-worm is now extinct in many localities where it formerly abounded. The improved sanitary conditions and vital surroundings now obtaining in India have chiefly, as before noted, been instrumental in improving the health of the European population, and also, to a certain degree, the health of those Natives of India who by wealth or education are enabled to live in somewhat the same manner.‡ Amongst the mass of the people, the conditions of life and personal habits, through poverty or custom,|| are still so completely insanitary that many years must pass ere they can be freed

* "The great social question which should engage the attention of Statesmen is the health of the people."—Lord Beaconsfield.

† Chiefly owing to the very deficient Registration Returns in India.

‡ *i.e.*, as regards rational sanitary precautions. There is no necessity, actual or implied, to adopt the more distinctive habits of Europeans, as so many, particularly in regard to the taking of alcohol, are doing.

|| A certain municipality in India not long ago gravely carried the following resolution and submitted the same to Government. "The Commissioners disapprove of the following passage in the statement of causes assigned for the excessive mortality * * * .—"To enumerate them . . . . and lastly, the general social, conjugal and religious habits and customs of the people." " They apparently forgot that mere disapproval, or even negation, cannot alter stubborn facts. *V.* also, *Notes on the Hygienic and Demographic Condition of India*, by R. B. Vishram Ramji Ghole, L. M., F. Bo. U., Honorary Assistant Surgeon to H. E. the Viceroy, Trans. VIIth Internat. San. Sci. Cong., Vol. XI. The grieved Commissioners, above referred to, however, may console themselves that neither their town nor their nation is by any means unique in respect that the mortality is increased by the 'social, conjugal and religious habits and customs of the people.'

from the present excessive mortality save, possibly, that resulting from epidemic infectious diseases, which is largely controllable directly by general sanitary measures. Of all diseases Malaria is still by far the most deadly. Out of about 5,700,000 deaths in 1890 from Cholera, Small-pox, Fevers and Bowel Complaints, over 4,000,000 were returned as due to Fever, of which, after making all necessary deductions, at least 75 per cent., or 3,000,000, may be safefy considered to have been caused, directly or indirectly, by malaria.

Having thus indicated, in the briefest manner possible, the essential outlines of the past and present history of hygiene, and having shown the gradual evolution of the science, the difficulties which its supporters have had to surmount, the obstruction wherewith they had, and still have, to contend, the triumphs they have gained, and are continuing to gain, in the fight against disease and misery, it behoves us to examine in detail into the qualifications and training which are necessary for the modern hygienist; and to define the goal towards which all such, who are worthy of the name, are resolutely striving.

The essential qualifications for persons called upon to occupy a high position in the Public Health Service in any country are at least as varied and extensive as those required for any other single office, probably more so. They are primarily divisible into two great classes, *viz.*, the purely technical knowledge, which results from study and experience, and those mental qualities which are more or less necessary to all who aspire to govern or direct public affairs with any degree of success. First, then, as to the exact nature of the subjects with which the hygienist is concerned. Of such, it is impossible to give a complete list here, but some idea of their number and variety may be gathered from the statement that the list should include almost all that is required for the separate degrees in Science, in Medicine and in Public Health. The time has not yet arrived when it has become customary for students to commence their studies with a view to devoting their future to the pursuit of hygiene, and, indeed, it is still considered by many that the possession of a medical degree is evidence of the possessor's knowledge of hygiene—than which no greater error is possible. No one can now be appointed Medical Officer of Health to any large town or district in England without possessing some sanitary qualification in addition to his purely medical qualification, a step in the right direction*. It was long ago remarked by Lord Herbert that a sanitarian must needs possess a considerable share of the professional knowledge of the physician, physiologist, geologist, meteorologist, topographist, chemist, engineer and mechanic, a list which might now be considerably extended. It is possible that with a few officers thus trained and equipped, particularly as regards the means and methods of research in modern laboratories, the more subordinate sanitary officials might be medical officers pure and simple; provided, however, that they are not already overburdened with other work, and that they have given solid evidence of special training in the essentials of sanitation. The latter should never, on any account, be considered suitable for the purely hygienic appointments, but simply as medical officers who, possessing a sound knowledge of the ordinary sanitation of towns, buildings, etc., are

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* For the training of the skilled Hygienist in the future the proper course to pursue would probably be as follows. He should first of all go through the training and examinations for the degree (B. Sc.) in Physical Science as required, for example, by the University of Edinburgh. He should then commence his special training for a special degree, Bachelor of Hygiene. It is without doubt essential that he should be familiar with disease as seen at the bed side, and have a thorough knowledge of anatomy, physiology, etc., but it is absurd to waste his time in the acquirement of a minute knowledge of Surgery and Medicine, Midwifery, Diseases of the Eye, Lunacy, Therapeutics, etc. Instead of such subjects he should be called upon to study Climatology, Demography, Epidemiology, Sanitary Law, Sanitary Engineering, etc., after having passed his examinations in Anatomy, Physiology, Pathology, and especially Methods of Research. He would then be really a trained and skilled sanitary *authority*, competent to give a valuable opinion on proposed sanitary works, to investigate the causes of outbreaks of disease, to offer suggestions of great value to local boards, municipal councils, etc., to work out the cause of specific diseases, etc., etc. He should be neither a medical officer, pure and simple, nor an engineer, but an officer capable of criticising effectively the proposals of both classes. The idea can only be outlined here, but the writer hopes to amplify it elsewhere.

permitted to act as sanitary officers for the time being. To some it may seem that too great insistence is laid on the special training of hygienists and sanitary officers, but the recorded experience of the past fifty years in England and other European countries, the opinions of all whose names are eminent in this connection, the constant expansion and increasing importance of the subject, one and all demonstrate that such training is absolutely necessary and of direct benefit to the public health and public funds alike. The need for specialists in every subject—geology, meteorology, sanitary engineering, medicine, etc.—still remains, but there must be picked men, highly trained and experienced, who are capable of receiving and assimilating the results of the work accomplished by the former, and of judging its value and application in the field of hygiene. For both the hygienist and sanitary officer it is absolutely essential that their training be *thoroughly practical.* Courses of lectures unaccompanied by practical demonstrations are largely a waste of time, and yet the latter appear to be unknown, or at all events unpractised, in India.* The following extract may serve to illustrate what is meant, and also what is needed for students of medicine, for newly-arrived medical officers (the future 'District Sanitary Officers'), for sanitary inspectors, and above all, for candidates for the degree in sanitary science. Of course, the demonstrations would not be the same for all, either as to quantity or quality, it is merely the necessity for analogous practical work in India that is here insisted upon.

THE SANITARY INSTITUTE.

Sixteenth Course of Lectures and Demonstrations for Sanitary Officers, 1893.

Sept. 29. Elementary Physics and Chemistry.

Oct. 3. Ventilation, Warming and Lighting—Sir Douglas Galton, K.C.B.

* The author has tried to carry out such practical demonstrations to some extent by taking the students of his class to see Sewage Farms, Sewerage Systems, Meteorological Stations, etc., but for various reasons, over which he has no control, it has been found impossible, for the present, to carry on the practice.

Oct. 6. Principles of Calculating Areas, Cubic spaces, etc.; Interpretation of Plans and Sections to Scale—H. Law, M. Inst., C.E.
„ 7. Visit to Sewage and Destructor Works—Ealing, at 3 P.M.
„ 10. Water Supply, Drinking Water, Pollution of Water—J. Wallace Peggs, A.M.I.C.E.
„ 11. Visit of Inspection in the Parish of St. George's, Hanover Square—2 P.M.
„ 13. Sanitary Building Construction—Keith D. Young, F.R.I.B.A.
„ 14. Visit to Express Dairy Company's Farm, College Farm, Finchley—3 P.M.
„ 17. Sanitary Appliances—W. C. Tyndale, A.M.I.C.E. Visit to East London Soap Works, Bow.
„ 20. Details of Plumber's Work—J. Wright Clarke.
„ 21. Visit to Beddington Sewage Farm—Croydon.
„ 24. Sewerage and Sewage Disposal—Prof. H. Robinson.
„ 25. Visit of Inspection in the Parish of Chelsea—2 P.M.
„ 27. House Drainage—W. C. Tyndale.
„ 28. Visit to Isolation Hospital, Museum, Sanitary Depôt, Sewage Disposal works, etc.—Highgate.
„ 31. Scavenging, Disposal of House Refuse—Charles Mason.

etc. etc.

If such courses were organised in India, and every medical officer, before being appointed Sanitary officer for a town or district, was compelled to attend, and thereafter examined practically as to his knowledge of the various subjects demonstrated and lectured upon, it is certain that great improvement would take place in many directions, and that many whose interest in hygiene is now of the smallest would be led to devote a greater share of their time and energies to this work. But, let it be remembered that all the knowledge and learning in the world will not transform the student into the true hygienist if he does not in addition possess those high mental and moral qualifications that have distinguished so many whose names are indissolubly linked with the development and evolution of this science. He must have an enthusiasm for the work great and extinguishable, but so completely kept in hand

and controlled that men may not realise the force which is continually impelling them into the paths of health and cleanliness;* still more must he be able to 'possess his soul in patience', not using such as an excuse for idleness, but merely as affording time for the current of public opinion to set in a favourable direction. The man of tact will succeed where the rash or over-hasty will fail, and the best of all is he who, like a wise General on the field of battle, knows just what the forces under his command can do and wherein the strength and weakness of the opposing army lie. And not only is the hygienist engaged in a constant struggle against misery, dirt and disease, but more frequently than not he finds himself in a country where the very inhabitants whom he is seeking to deliver from these tyrants, regard him with dull suspicion or active hatred. To win these doubting or careless ones to his side and to enlist them under the banner of Hygiene; to fight continually and untiringly against all foes to the health of mankind; to consider no labour too great, no matter too trivial for attention—is the work of the hygienic reformer. In a word, he must himself illustrate and amplify the meaning of the Roman poet's saying†:—*Homo sum: humani nihil a me alienum puto.*

What, then, remains to be learnt as to the present position of this science and its expansion in the future? To show this clearly, no better means can be adopted than to lay before the reader a few extracts from the final words of one who has devoted a lifetime to the service of Hygieia.‡

Speaking of the gradual but steady investigation into the varied causes and means of prevention of disease which is now being carried on in Europe, and the application of

* By many, now-a-days, enthusiasm is looked upon as a grand mistake, a weakness to which no man, who is a man, should be liable. Let the student remember, however, that nothing great was ever accomplished without faith and enthusiasm, and, above all things, let him always keep the golden mean between the Scylla of sloth and scepticism and the Charybdis of feverish hurry and fanaticism.

† Terence.

‡ Sir John Simon, K.C.B., whose book, *English Sanitary Institutions*, is by far the most complete history of English Sanitary Science extant, and is worthy of careful perusal by all who study the subject.

the knowledge thus resulting to the control of disease, he says, "The progress which has been made consists essentially in practical applications of Pathological Science; and happily that branch of knowledge shews every sign of continuing to give lessons for application. In the eyes of those who cultivate it in a spirit of becoming modesty towards the magnitude and the difficulty of their subject-matter, it, no doubt, like many other branches of the infinite study of Nature, appears hitherto as only in that first stage of true growth where the known is immeasurably less than the unknown; but even in this early stage it has already given ample light for very large preventions of disease; and, so far onward as we can foresee, we may expect that its light will continue to be an ever-advancing guide for advances of law and conduct. It is now proceeding with such activity as the world has never before witnessed, and the various kinds of knowledge which supply resources for the prevention of disease are increasing with immense rapidity. Clearly we have to hope that, in proportion as exact knowledge is gained of agencies prejudicial to the public health, the nation will provide against them by appropriate law and by effective administration; but, for obvious reasons, it is not likely that practical reforms will keep themselves immediately abreast of scientific progress. For them, namely, the rate of advance must in chief part depend on the progress of popular education as to the facts and interests and duties of the case, and can therefore hardly be expected to be other than gradual and somewhat slow. Thus it has been that down to the present time, our disease-preventive provisions of law have certainly not in all respects kept pace with what we know as to the causes of disease; and even less advanced in most instances is the readiness of persons and authorities to make full use of the provisions which exist.

Even as regards those parts of the case where popular education might now be supposed to have become comparatively ripe—the parts which specially regard the Cultivation of Cleanliness, it would be flattery to pretend that average England has yet reached any high standard of sensibility to dirt.* Against accumulated obvious masses of filth, against extreme ferocities of stench, local protests no doubt are pretty commonly to be heard, and, at moments when there is panic about disease, may often rise to considerable warmth of indignation; but in regard of the less riotous forms of uncleanliness, far too much insensibility is widely shown.†

"A great people, determining what it will deem to be

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* When I speak of *average* England still having to learn lessons, and even rudimentary lessons, in various matters of sanitary cleanliness, I do not intend to imply that the wealthier classes of society are an exception to that average reproach. It is by no means alone in comparatively poor and ungarnished dwellings, that filth-diseases and odours of filth are to be found. In the houses of wealthy and self-indulgent persons, who perhaps may be spending money and raptures on the fine arts, and who certainly would think it strange to find themselves under imputation of dirt, and in the highly-paid lodging-houses which these classes inhabit from time to time at their so-called health-resorts, it is not very rare—indeed, as to the lodgings, it is rather frequent,—to find that the staircase is pervaded by more or less sewage-odour from defective drain-structures thereabouts or in the basement; and even the wealthiest know but too well that enteric fever, with its congeners, does not leave them unscathed. Persons, not fairly educated to profit by their sense of smell, stumble as naturally into certain sorts of disease as the more or less blind stumble into other pit-falls.

† See, for instance, how little fastidiousness prevails in the popular mind as to the domestic and commercial arrangements which supply *Drinking Water*. That even the London water-supply, after half-a-century of disgusting disclosures, and after various very terrible disasters, is not yet secured against gross defilement, is a fact to be sufficiently gathered from the reports of the official examiner under the Metropolis Water Act, 1871, and is in other ways deplorably notorious. In the summer of 1886, the *Lancet* medical journal brought to light that, during the week of the Henley Regatta, the Thames, for about a mile's length of its course, were supposed to be sacred to the water-supply of London, had had, on and about its surface, a floating and riparian encampment of some thousands of holiday-makers, using the river as their latrine and middenstead, and with their house-boats purposely closet-piped into it: all this apparently not anything new, but a story which would perhaps strike the popular mind when the medical journal had commented on it! What sentiment of cleanliness prevailed among the thousands who could thus deal with their neighbours' drinking-water, and among the millions who were placidly bearing the outrage, is a question which may be left for such future historians as will discuss the curiosities of English civilisation at the close of the nineteenth century; and in the meantime national education will perhaps have taught that a river, having manured fields and sewage-farms and populous urban districts along its banks, and constituted by law "a navigable highway on which all persons have right to pass and repass for pleasure or profit," is not (even apart from regattas) likely to supply such drinking-water as moderate sentiments of cleanliness would seem to demand.

proper purity for air and water, has not to measure only from the scavenger's point of view, but surely also with some sense of the help which accrues to the human mind from beholding the pure aspects of Nature, and with some readiness for displeasure when the beauty and bounty of Nature are wantonly affronted by slovenliness and waste. For rich and poor alike, it cannot be too clearly understood that the claims of cleanliness are fastidious. In order to sanitary self-protection by its means, there must be sufficient refinement of taste to abhor even minor degrees of dirt, and to insist throughout on the utmost possible purity of air and water; there also must be sufficient sharpness and cultivation of sight and smell, to immediately discover even minute infractions of the sanitary rule; and there must be sufficient intelligence and watchfulness as to the channels, commercial and other, which can clandestinely admit uncleanliness from without."

Again, as regards the progress made since the early part of the present century in the direction of local self-government, more particularly in connection with the Common Health, careful study will show that it has been phenomenal in amount and, in the main, eminently satisfactory. If those in India who are in any way concerned with municipal affairs, indirectly or directly, will but carefully study the historical details of such work in England they will derive from such study an invaluable amount of information and encouragement. "Our last sixty years of English political life have been so transformatory of local administrative relations, that popular intelligence has hardly had time to follow the change, and to realise conscientiously for itself how large a new creation of popular duties and responsibilities has taken place. A period of immaturity in such relations may be expected to have its transient weaknesses, requiring treatment more or less transitory; and, for them, all candid minds make allowance; but, in the more prospective sense which regards permanent norms of action, it of course is supremely to be hoped that democratised local government will know how to secure due diligence and honesty in the administration of its affairs, without having in any great degree to depend on the punishing powers of Courts of Justice. Surely, far more than on any such exterior corrective, it ought to be able to rely, preventively, on itself; for educated local patriotism can ensure from beforehand, that misdemeanors in local government shall not arise. In this, as in other parts of our electoral system, the high integrity, the dutifulness and disinterestedness of each representative of the people, must be for the people itself to regulate, and, with its respect and gratitude, to reward. Equally, too, the nation is concerned in this correlative hope: that to be elected member of a district, or county-council of local government, and thus to become a participator in functions of essential service to the State, will more and more commend itself, as an object of legitimate and generous ambition, to persons of good business ability and of sufficient leisure, who would have in view no other purpose than that of being actively useful in public duty; and that thus, while true popular education shall be strengthening all electoral bodies to identify and reject the candidatures of persons who are intent only on personal aims, the bodies shall have before them in increasing numbers candidates whom it will be honour to themselves to elect."

"For the further development of our sanitary institutions and their working, the educational onward impulses may be expected to come pretty continuously from members of the Medical Profession, and are perhaps not in any essential sense to be expected largely except from them.* This is not meant only with regard to the abstract science of

* ["The ascendancy of Hygiene has greatened and glorified medicine, without dimming the lustre of any other branch; but though her cult is established, her mission has not ended with the recognition of her supremacy and the faithful following of her own ilk. To day she turns to the people and their rulers, outside the medical fold, and demands the place in their councils that is hers of right. A makeshift share in the administration of the sanitary interest of the country has been grudgingly allowed, but the inexorable demands of modern enlightenment cannot be

the matter, but equally with regard to administration. Regarding the science, it has long been evident enough, that, for such new researches and observations as will supply increase to the body of exact knowledge on which the prevention of disease depends, the world cannot expect much help except from the work of the Medical Profession; and the same is now constantly becoming more and more clear in regard of public sanitary administration. Whether for kingdom, or for county, or for district, the organisation or procedure which purports to *prevent disease* must sooner or later be judged from the medical standpoint,—from the standpoint of question, whether it has attained, or can attain, the *disease-preventive* good which is its professed aim. Thus, more and more, the practice of sanitary administration is having to adapt itself to the experience and judgment of the medical officers engaged in it; and whatever other services may be auxiliary in the matter, the administration, in essence, tends more and more to define itself as a specialty of medical skill. Therefore and for other reasons, the progress of popular education in sanitary knowledge, and in the art of sanitary government, will depend, to an incalculable extent, on the personal influence of the Health-Officers throughout the country; each of whom is virtually authorised to be the

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satisfied until the Conservator of the public health shall sit a peer among the rulers. The minister of war may build mighty engines for destruction and defence, and muster vast armies and navies, which disease can disperse with a weapon so tiny that the eye cannot discover it and no mere military expedient antagonize it. The Minister of Finance may fill his treasure houses with gold and silver by the ton, which can buy human souls' honor, virtue, independence, everything but the boon of health, God's free gift to man, through which alone he can be like His own glorious image. Commerce, agriculture, manufacture, fishery, mining, and all the industrial occupations of the human race, which are the objects of the intelligent supervision of cabinet ministers, who are grand masters of political economy, and social science, cannot thrive without the vigour of human blood and brains and brawn, which are the machinery of these occupations; yet until this decade it has not been thought that the intelligent supervision of a grand master of the divine science of medicine was necessary to preserve this vigour of health of the community, without which even these other ministers can themselves only imperfectly perform their own offices of administration." From *Introductory Address* by A. L. Gihon, M.A., M.D., at the First Pan-American Medical Congress, *v.* N. Y. Med. Journ., 30th September, 1893.]

sanitary educator of his district; and it may reasonably be hoped and expected, that, in proportion as those officers are of attainments and character entitling them to have weight, each of them will be accepted as an influential public teacher, and especially will be encouraged to inform and inspirit for sanitary purposes the local authority under which he acts."

"The fact that Preventive Medicine has now been fully adopted into the service of the State is indeed the *end* of a great argument; and if the institutions of the country are to be valued in proportion as they favour the greatest good of the greatest number, it may be assumed that those which represent the counsels of Preventive Medicine will never henceforth be held in low esteem. There no doubt exist schools of thought, to which this branch of political duty may appear but a trivial and niggling kind of industry. From beside the Main* it has been expounded to us in language equally learned and lugubrious, that the radical error of the universe (next to the fact of its having come to be) is the fact of its preferring not to come to an end; and, in the light of that creed, it may seem an absurd anachronism that even the millions of mankind, whom a late much-respected philosopher of ours used from time to time to describe as "chiefly fools," should be willing to let their existence be prolonged. But however great may be the academic interest of those opinions, there seems no likelihood of their being accepted as bases for national policy; and to minds which have had the happiness of discipline in the Art of Medicine, they will not count as of more practical import than any mere curious wreathing of tobacco-smoke."

Let not the student of hygiene in India despair, therefore, because there seems so much to be done and so few to do it. The lesson to be derived from a study of sanitary reforms in England is one of hope and of great things

* [An allusion to the so-called pessimistic philosophy of Schopenhauer, whose writings contain, nevertheless, some very valuable hints on mental and bodily hygiene.]

accomplished from small beginnings. Let him remember, also, that personal example and influence are of far greater value than mere words. Do not expect to be welcomed as the harbinger of good tidings. By far the greater portion of the human race objects—like a dirty child—to have itself and its surroundings thoroughly clean, and many years must elapse ere true cleanliness becomes the rule rather than the exception. Of the ultimate triumph of Hygiene over the rude and insanitary conditions prevalent at the present time throughout this vast country there is no doubt. Let each take up, as he is able, his share in the mighty work of reformation and shew that he has realised for himself that "cleanliness is next to godliness," and that for the full and proper development of the latter, cleanliness of mind and body, notwithstanding many would-be examples to the contrary, are most absolutely essential. "Meanwhile," wrote one,* "let the Sanitary Reformer work and wait. "Go not after the world" said a wise man, "for if thou stand still long enough the world will come round to thee." And to Sanitary Reform the world will come round at last. Grumbling, scoffing, cursing its benefactors; boasting at last, as usual, that it discovered for itself the very truths it tried to silence, it will come; and will be glad at last to accept the one sybilline leaf at the same price at which it might have had the whole. The Sanitary Reformer must make up his mind to see no fruit of his labours, much less thanks or reward. * * * * But his works will follow him—not as the preachers tell us, to heaven,—for of what use would they be there to him or mankind?—but here on earth where he set them, that they might go on in his path, after his example, and prosper and triumph long after he is dead, when his memory shall be blessed by generations, not merely 'yet unborn', but who never would have been born at all had he not inculcated into their unwilling fathers the simplest laws of physical health, decency and life." And since those

* Chas. Kingsley.

concluding words of one who spent years of his life in inculcating and practising sanitary reform were penned, the world, or at least the major portion of the civilised world, has in large measure "come round" to an appreciation of the efforts made by these pioneers and to the adoption of the principles so forcibly insisted upon by them. To apprehend these principles and to apply them, to educate and raise the millions sunk in dirt, disease and misery, is the great, but not insuperable, task, the weightiest responsibility of each and all on whom the blessing of education has been bestowed—a responsibility which has received great, and will receive greater, recognition from those who govern, and a task, the ultimate and successful accomplishment of which, demands the untiring co-operation and sympathy of every one whose heart has responded to the cry of suffering humanity.

PART I.

GENERAL HYGIENE.

AIR.

WATER.

SOIL.

REMOVAL AND DISPOSAL OF WASTE MATTER.

BUILDINGS.

CLIMATE AND METEOROLOGY.

THE INDIAN MANUAL OF HYGIENE.

CHAPTER I.

AIR.

Atmospheric air consists of a *mixture* of oxygen and nitrogen, with small quantities of carbonic acid and aqueous vapor, and traces of ozone, nitric acid, ammonia, and marsh-gas or some other combination of carbon and hydrogen. Air is impure when it contains excess of any of its ordinary components or any additional substance.

The normal proportion of Oxygen may be taken as 20·96 volumes in 100. In pure air over mountains it rises to 20·99; in towns it falls to 20·90 or even lower.* Ozone is a modified and more active form of oxygen. It is generally present in the atmosphere, more abundantly at night than by day, and is believed to be beneficial, unless when in excess, in which case irritation of the bronchial passages results. It is absent from the air of ill-ventilated sick-rooms, and is said to be at a minimum during cholera epidemics. It is produced by the passage of electrical discharges through air, and by other means. Its amount is estimated by the degree of blueness given in a definite time to test-papers

* The variations are almost invariably confined to the second or third decimal place, but the air in badly-ventilated mines may contain only 20 *per cent.* of oxygen or even less.

prepared with a mixture of potassium iodide and starch. Other causes, however, are capable of producing the same coloration, and a quantitative test for ozone which can be depended upon has yet to be discovered. It is converted to ordinary oxygen by heat, slowly at 100° C., instantaneously at 300° C.

Ozone is an allotropic modification of oxygen, and its molecule is supposed to contain three atoms, while that of ordinary oxygen contains two. Its density is one-twelfth greater; its power of oxidation superior. Its oxidising powers may be ascribed to its easily yielding atomic oxygen $O_3 = O_2 + O$. When strongly compressed, ozone liquefies and forms a deep blue liquid and the gas itself has a blueish tinge. All the processes of Nature which develope electricity by friction, chemical action or otherwise, generate ozone. Its presence in considerable quantity is attended with a peculiar pungent odor, as when the electric spark is passed several times in succession through air, and from this fact its names is derived. The oxidation of the essential oils of odoriferous plants is also supposed to cause the evolution of ozone. In most cases the development takes place only under the influence of sun-light, but it also occurs in the dark. The cultivation of aromatic and flowering plants about unhealthy places is, therefore, indicated.

Nitrogen is not directly poisonous, and slight excess of it, which may occasionally and temporarily exist, is not injurious. The average proportion may be stated as 79 volumes per 100.

Carbonic Acid varies in amount, in pure air, from 0·2 to 0·5 volume in a thousand. The average is taken at 0·4 and the quantity is excessive when it exceeds 0·5.* The proportion increases as we ascend from sea-level to a height of 11,000 feet, diminishing above this elevation; it is less over sea than over land, and is greater in sea-air by day than by night, the difference being from 0·054 to 0·033 per cent. It is diminished by heavy rain, which washes it out of the atmosphere, by vegetation and by strong winds. The ordinary causes of excess of carbonic acid in the atmosphere are the respiration of animals, the exhalation from their skins, combustion, putrefaction and stillness of the air. It is, therefore, more abundant in densely populated

* This amount of CO_2 is not *in itself* injurious; it is considered to be excessive because it has been ascertained that there is a constant ratio between the amount of CO_2 present and of organic exhalations, and that when the CO_2 exceeds 0·5 volumes *per* 1,000 there is almost always an injurious amount of organic impurity in the air. *v.* pp. 11 and 21.

districts. The mean of 18 determinations by Dr. A. Smith of carbonic acid in the air of close places in London was 1·288 volume per 1,000, the maximum 3·20. In a crowded school-room Pettenkofer found 7·23 per 1,000. Respired air contains 40 volumes of carbonic acid in a thousand, an adult man at ordinary labor giving out from his lungs from 12 to 16 cubic feet in 24 hours.* An undetermined quantity is exhaled from the skin of living animals.

A given volume of coal-gas produces, when burnt, about twice its bulk of carbonic acid. The combustion of a pound of oil generates nearly as much as 10 cubic feet of gas. A pound of dried wood requires 120 cubic feet of air for complete combustion, the principal product being carbonic acid; and a pound of coal requires twice as much.

Putrefaction consists chiefly in the slow oxidation of organic matters through the activity of micro-organisms, by which, amongst other changes, carbon is converted into carbonic acid. This gas constitutes 16 per cent. of the emanations from sewage, and sometimes 2 or 3 per cent. of sewer-air. The atmosphere of burial-grounds has been found to contain from 0·7 to 0·9 volume per thousand, and that of marshes from 0·6 to 0·8 or more. The effects of breathing air containing excess of carbonic acid vary, not only with the quantity present, but also with individual peculiarities. In some persons 15 to 20 volumes per thousand produce severe headache, while others can inhale with impunity air containing a much larger proportion. The fatal dose ranges between 50 and 100 volumes per thousand. It is probable that a much smaller amount than 15 per thousand produces a degree of discomfort indicative of incipient intoxication. It is difficult to ascertain the effect of excess of carbonic acid alone. In respired air organic matters and other deleterious gases are present also, and are answerable for much of the injurious result of its inhalation. In manufactories of aërated waters air containing 2 volumes per thousand of carbonic acid is breathed without mischief; but respired air containing one volume produces perceptible ill-effects, and if from 1·5 to 3 be

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* *v.* p. 20 and p. 23—note.

present, headache and vertigo result. It has been conjectured that inhalation of air containing excess of carbonic acid is a common source of phthisis, but the facts which appear to support this view relate to air vitiated by all the products of respiration, not by carbonic acid only. The ill-effects of the latter are only partly due to direct intoxication. Its presence in excess diminishes the supply of oxygen to the blood, and impedes effective elimination of carbonic acid from the lungs. The estimation of the amount of carbonic acid present in the atmosphere is effected by means of a solution of lime or baryta of known strength. A certain quantity of the solution being agitated with a known volume of the air to be examined, the carbonic acid of the latter forms a carbonate with the base, diminishing proportionately the alkalinity of the solution. *The loss of alkalinity is, therefore, a measure of the carbonic acid* present.

The quantity of Aqueous Vapor varies from 10 per cent. of the amount necessary for complete saturation upwards. Air absorbs moisture from water with which it is in contact; respired air is saturated with watery vapor, and the lungs and skin of an adult exhale from 25 to 40 ounces of water in 24 hours; water is one of the products of the combustion of ordinary fuel. The hygienic effect of dryness or humidity upon health, and the proportion of atmospheric moisture most favorable to health are not known. The latter has been supposed to be from 65 to 75 per cent., but many healthy climates exhibit a much higher degree of humidity than this. The amount present may be ascertained by drawing a known volume of air through a tube containing pieces of pumice-stone moistened with strong sulphuric acid, which deprives the air of its water, and weighing the tube before and after the process. The increase of weight represents the quantity of water present in the known volume of air. Hygrometers or comparison of two thermometers, one with a wet bulb and the other under ordinary conditions, enable us, with the aid of tables, to determine the amount of aqueous vapor in the atmosphere at any particular time. The processes will be explained hereafter.*

Traces of NITRIC ACID are always present in air, and more distinctly after heavy rain and electrical disturbance. It has no influence upon health. It may be detected and estimated by applying to rain-water, or to distilled water through which a given volume of air has passed, the appropriate tests; which will be referred to under the analysis of Water.†

Traces of AMMONIA also are present in pure air, and the quantity is increased after heavy rain: as a rule, however, the ammonia is in combination with nitric, carbonic or some other acid. When moist animal matters, containing both nitrogen and hydrogen, decompose, ammonia is formed. Nascent hydrogen, derived from water resolved by any means into its constituents, unites with atmospheric nitrogen to form ammonia. It is one of the products of the combustion of coal. It never occurs in sufficient quantity to be directly hurtful, except, perhaps, as an irritant of the conjunctiva; but its presence in abnormal amount indicates the existence of danger from other substances directly noxious. Sewer-air and the liquid which collects on sewer walls are often alkaline from ammonia. It is present in excess in the atmosphere of burial-grounds, and occasionally in that of marshy places. The presence of ammonia in the air may be determined by drawing the air, by means of an aspirator, through pure distilled water and applying the Nessler test to the latter.‡

IMPURITIES.

IMPURITIES of the air are either Suspended (Solid) or Diffused (Gaseous). An immense number of substances of all kinds are constantly passing into the air, more especially

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* *v.* Meteorology.
† *v.* Water, Examination of.
‡ *v. ibid.*

in the case of large cities. These impurities are necessarily inhaled to a considerable extent by persons during the act of respiration, but so perfect are the arrangements by which Nature tends to purify the air that the injurious effects produced are surprisingly small. As a rule it is only when such arrangements are thwarted or neutralised by human perversity that serious diseases are produced by these impurities. Thus, careful examination shows that the air of the open spaces or *maidan* in the largest towns is nearly as pure as sea or mountain air whilst the air of Manufactories, Workshops and even dwelling houses is often extremely impure. Suspended impurities may be either Inorganic (Mineral) or Organic (Animal or Vegetable).

Inorganic solids are derived from the soil or sea, from buildings, and from the materials with which certain employments are concerned. Minute particles of flint, clay, carbonate and phosphate of calcium, ferric oxide, of carbon, tarry matters and sulphur, (arising from imperfect combustion of coal or wood), are raised from the surface and kept suspended in the atmosphere. Chloride of sodium, derived from the sea or the soil, is almost invariably present. The air of coal mines, of potters' workshops, of rooms where steel instruments are ground, of stone-cutters' yards and of other places where the nature of the work involves the dispersion of fragments of mineral matter, becomes more or less impregnated with inorganic impurities. Organic suspended matters are more numerous, more varied and more dangerous. Winds raise dust from the soil which is found to contain from 36 to 46 per cent. of organic matter. Evaporation from the surface of water, especially in marshy places, raises minute organized particles into the atmosphere. Thus the remains of dead animals and vegetables, minute living organisms, as vibrios, bacteria of all kinds and other micro fungi, infusorious, ova of various animals, pollen, spores and seeds float in air comparatively pure. In sewer-air meat and milk are tainted rapidly, owing to the abundant presence of low forms of animal and vegetable life. Starch-cells, hair, wool, cotton-fibres are also present, especially in dwellings, and more abundantly where manufactures of bread, clothing, &c., are carried on. Pus-cells and epithelium, excretions, cutaneous, pulmonary, urinary of fæcal, dried and pulverized, will abound in the atmosphere of dirty and ill-ventilated houses, and in ill-kept hospitals more particularly: the nature and amount of each impurity being in direct ratio to the cleanliness and efficient ventilation of the buildings or the reverse.

Suspended atmospheric impurities act injuriously upon health in several ways. The pus-cells of ophthalmia may float from affected to healthy eyes and communicate the disease. Certain parasitic skin-diseases, erysipelas and hospital gangrene, perhaps metria, may also be propagated by germs or by direct local action of organic poisons so conveyed. The poison of typhoid may thus reach the intestinal mucous membrane and act. The lungs or nasal mucous membrane may be mechanically irritated by particles of mineral matters, or by fibres of cotton or wool, and bronchitis and other pulmonary affections or coryza ensue. The blood may be poisoned by air inhaled containing the specific virus of cholera, typhus, typhoid, paludal fevers, dysentery, variola, scarlatina or measles. Phthisis possibly, the pleuro-pneumonia of cattle certainly, may be propagated by sputa. Whether diseases are propagated by living germs or by dead animal poisons the morbific cause may enter the blood through the lungs.* Again, suspended impurities, except the very lightest, are not likely to reach the lungs, but will lodge on the mucous membrane of the nose, the fauces or the mouth, and pass thence by deglutition into the stomach and intestines. Here they may set up dyspepsia, &c., by local irritation, or they may propagate specific diseases through the intestinal tract.

* The condition of the organic substances which cause specific diseases is unknown. They may act directly as thrown off from a diseased surface, or after undergoing putrefactive changes.

When maladies, not pulmonary, are due to inhalation of foreign matters suspended in the air, these more probably act by being swallowed than by entering the blood through the lungs. This is true not only of diseases due to organic poisons, but also of the saturnine, mercurial, cuprine and arsenical intoxications, to which painters and plumbers and workmen employed with mercury, copper and arsenic are liable.

Air containing much organic matter blackens sulphuric acid through which it may be drawn, and reddens a solution of silver nitrate. The nature of suspended impurities is ascertained by the microscope. For collecting them two methods are available. A vessel of known capacity is filled with water which is allowed to run out below while an aperture above, to which a funnel with its neck drawn into a fine tube is fitted, admits the air. Below the opening of the funnel a slip of glass moistened with glycerine is fixed, which catches the solids suspended in the air as it enters. Or a known volume of air may be drawn through distilled water and the sediment collected.

The remedies for this form of impurity are heat, corrosive disinfectants, filtration and ventilation. Cotton wool intercepts all foreign substances suspended in the air drawn through it, and respirators made of this material are capable of protecting efficiently persons engaged in employments which disperse solid particles in the atmosphere, and all who are liable to diseases dependent upon the inhalation of solid morbific material. The nasal passages, to a certain extent, filter the air which passes through them and the unnatural habit of breathing through the mouth should, therefore, be avoided. Ventilation will be considered hereafter. It is only necessary to remark in this place that *topical* ventilation—bringing a strong stream of air to bear upon the immediate neighbourhood of tool-grinding and similar machines—has been attended with results most favourable to the health of the workmen. Natural processes tend to keep down the amount of suspended impurity. The heavier substances spontaneously subside. Rain washes others to the earth or carries them down in solution. Part of the organic matter is gradually oxidized into carbonic acid and water or other gaseous substances.

The chief DIFFUSED impurities of air are: organic vapors of unknown composition, carbon dioxide when exceeding 0·5 per 1000 parts of air, carbon monoxide, marsh-gas, sulphuretted hydrogen, sulphide of ammonium, sulphurous and sulphuric acids, carbon disulphide, hydrochloric, nitrous and nitric acids, and phosphide of hydrogen. Of these the most important, because the most injurious to health, are Organic Vapors of unknown composition, and probably of many different kinds. Some properties of these substances render it even doubtful whether they are aëriform or solid. They do not appear to be diffused like true vapors, but seem to float in clouds in foul atmospheres, and the offensive odor which is characteristic of them is not equally prevalent in all parts of a room in which they have been generated. They resist oxidation longer than other impurities, and therefore require freer and more prolonged ventilation than they. It is probable that they are either in combination with, or in solution in, aqueous vapor; as substances which most readily absorb water (hygroscopic), or condense it upon their surface, are found to collect most abundantly the organic products of respiration. The color of the absorbent material is said to influence the amount of organic matter absorbed; black objects collecting most, then blue and yellow, white least. The decomposition of organized structures gives rise to organic vapor; but the most important source is the exhalations, cutaneous and respiratory, of men and other animals. Putrid organic vapor exists in the air of sewers and of burial-grounds, but that which accumulates in ill-ventilated and crowded buildings is more abundant and more noxious. The quantity of organic matter given off from the lungs and skin of an adult man is considerable but has not been determined,* the organic products of the skin being suspended, those of the lungs vaporous.† In hospitals and rooms where sick or wounded persons lie organic exhalations are still more abundant. To the ordinary products of respiration increased cutaneous exhalations are added, and effluvia from various excretions.

It is not possible to isolate the effects of inhalation of organic vapor from the other consequences of breathing air contaminated with sewage emanations or with the products of respiration; the general effects will be mentioned hereafter. Of the complex poison of respired air the organic vapor is the most active ingredient, and those symptoms which cannot be traced to deficiency of oxygen are chiefly due to it. In cases where death has resulted from overcrowding, without absolute exclusion of fresh supplies of air, organic vapor has probably been the cause. The peculiar fœtid odor of organic vapor exhaled from lungs and skin enables its presence in occupied rooms to be detected. Barrack-rooms, jail-wards, school-rooms and rooms where crowded meetings have been held are likely to present this conclusive evidence of insufficient ventilation. Few hospitals are free from it (though all may be and ought to be), the productive causes being more active in them than in other buildings. The odor is too often perceptible, in barrack-rooms for instance, by day; but suspected quarters should be visited in the early mornings after the full number of inhabitants has occupied them for some hours. It is to be remembered that the inmates themselves are unconscious of the fœtor; that it is more perceptible in proportion to the purity of the atmosphere from which the inquirer has passed in; that breathing foul air impairs, and gradually destroys for the time, the

* Dr. Angus Smith estimates the animal matter in *respired* air at 3 volumes per mille, in the form of putrescible albuminoid substance.

† The following numbers represent, with reference to the quantity of "organic matters" present, the comparative purity of different atmospheres, as determined by Dr. Angus Smith:—pure air on high ground 176 and 209; in a bed-room 56 and 64; inside a house 16; in a closely packed railway carriage 8; in a house sewer 8; in a cesspool 0·062.

perception of its foulness, and that this sensibility is not immediately restored on return to purer air; and that ability to perceive lower degrees of this peculiar taint is capable of cultivation by practice. *Organic vapor of this kind being generated simultaneously with carbonic acid, the quantity of the latter arising from respiration affords a means of roughly estimating the degree of contamination by the former.* Much carbonic acid usually implies the presence of much organic vapor and *vice versâ*, but not invariably so. When the atmosphere of a room, previously pure, becomes gradually vitiated by respiration, the organic fœtor is easily perceptible when the carbonic acid rises to 0·7 volume per mille, and very strong when the proportion amounts to 1·0. More accurate means of determining the quantity of organic matter present in the air are supplied by the potassium permanganate test and the process of conversion of nitrogenous impurity into ammonia—a known volume of air being drawn through distilled water.

Carbon Monoxide or carbonous oxide is one of the products of combustion of coal and wood. It is capable of passing through the heated walls of iron stoves, less freely through wrought than through cast iron, and its passage is impeded if the stove be lined with fire-clay. Air containing less than five volumes per 1,000, breathed by a small animal, produces symptoms of poisoning, and if more than 10 be present it proves rapidly fatal. It enters the blood through the lungs, displacing an equal volume of oxygen, and can only be removed gradually after oxidation and conversion into carbonic acid. The red globules of the blood become incapable of their function of carrying oxygen to the tissues. Consciousness is lost, reflex action destroyed, atony of the vessels produced, diminishing vascular pressure, causing retardation of the circulation and finally paralysis of the heart. The inhalation of this gas is found to produce very rapid parenchymatous degeneration of all the muscles and of the solid abdominal viscera. The so-called 'water-gas,' now largely used as a heating agent in America contains 30-40 per cent. of carbon monoxide and many cases of poisoning have already occurred from the escape of this gas by leakage.

MARSH-GAS or light carburetted hydrogen is a product of the decomposition of organic matter, and constitutes 73 per cent. of the gases emanating from London sewage. It is generally found in the air over marshes, arising from the putrefaction of vegetable substances. It is a principal constituent of coal-gas. In small quantities it does not appear to produce any ill-effect, and air containing as much as 200 or even 300 volumes per mille may be breathed for some time with apparent impunity. In larger proportion it produces headache, vomitting, convulsions, stertor with dilatation of the pupil and death. Habitually breathed even in small quantities it can scarcely fail to be injurious.

HYDROGEN SULPHIDE results from the putrefaction of organized substances containing sulphur ; and also from the action of organic matter on sulphates dissolved in water, which are converted into sulphides, these being decomposed by animal or vegetable acids : it is also an occasional product of combustion of coal and wood. Hence it constitutes sometimes 2 or 3 per cent. of sewage emanations and may amount to 3 per cent. or more of sewer atmosphere ; it is found in the air of marshy places, especially of salt-marshes, as those of Singapore ; it is present in the foul holds of ships,* and in the smoke of brick-kilns. It is invariably present in coal-gas and rarely in less proportion than 0·3 per cent. There are great uncertainty and conflict of opinion as to the effects of this gas upon the system when inhaled. Breathed undiluted it destroys life at once. Injected in solution directly into the blood it produces the same train of symptoms as putrid animal fluids —profuse diarrhœa, sometimes resembling cholera in the loss of animal heat and general collapse, congestion of the

* Grain saturated with sea-water becomes highly offensive from this cause chiefly : and in a recent case a man employed in clearing a wrecked vessel of putrid rice died poisoned or asphyxiated.

lungs and abdominal viscera, irritation of the spinal cord and opisthotonos. In the smaller doses of inhalation, however, the lower animals, as dogs and horses, suffer from diarrhœa with prostration of strength when the atmosphere contains from 1·25 to 4 volumes of this gas per 1,000: while men have breathed as much as 29 per mille, for a short time, with impunity. In ordinary cases, where inhalation has been continuous but the proportion small, effects have been contradictory: some persons suffering, others remaining apparently unaffected. The intensity of malarious intoxication in some Italian marshes has been attributed to the admixture of sulphuretted hydrogen in the air; while others have supposed it to have a neutralizing effect upon malaria. The symptoms of chronic poisoning seem to be weakness, anorexia and anæmia. In acute cases the symptoms are sometimes narcotic, sometimes convulsive. The characteristic odor of this offensive gas renders its presence, even in small quantities, perceptible. It blackens white paint prepared from lead carbonate, and a slip of white filter-paper dipped in a solution of a lead salt, (as the acetate), is blackened by a quantity too small to be detected by the smell, the black lead sulphide being formed.

Sulphide of Ammonium is derived from the same sources as sulphuretted hydrogen. In large doses it asphyxiates when inhaled; in smaller it produces vomiting without purging, quickness of pulse, heat of skin, followed by collapse. Injected in solution into the blood, its effects resemble those of sulphuretted hydrogen. Its presence is detected by the sodium nitro-prusside which, with this (and the other alkaline sulphides), gives a brilliant purple color.

Sulphurous Acid, Sulphuric Acid, and Carbon Disulphide are products of the combustion of coal and, in a less degree, of wood. Imperfectly purified coal-gas generates, when burnt, the former two, but none of them is of any importance as regards health, their quantity being insignificant. Inhalation of sulphurous acid undiluted is fatal; in small amounts it produces lacrymation and sneezing; in considerable quantity, bronchitis and ultimately anæmia.

Hydrochloric Acid vapors were formerly given off in large quantities from alkali works in England, the result being the total destruction of the surrounding vegetation. This practice was put an end to by legislative interference. If the vapor is concentrated as in some processes for making steel very serious or even fatal inflammation may be set up in the lungs.

Nitrous Acid is formed by the oxidation of nitrogenous substances and traces of it are frequently present. Phosphuretted Hydrogen arises from the decomposition of organic animal and vegetable matter containing phosphorus. It is found occasionally over marshes and in burying-grounds.

VITIATED AIR.

The effects of breathing an impure atmosphere are found to consist not merely in the production of definite, still less of specific, ailments, but also in an impaired condition of general health, shown by increased liability to, and greater severity of, diseases, protracted convalescence, shortened duration of life, higher death-rate, especially of children. None of the impurities above described occurs singly save only in very exceptional circumstances: as a rule varying combinations of them are found to exist, producing various effects. These must be briefly considered before entering upon the subject of the means by which atmospheric impurity is mitigated or removed. The air of Crowded Rooms or Dwellings contains excess of aqueous vapor and of carbonic acid, as well as the fœtid and exceedingly poisonous organic vapor exhaled from lungs and skin. The effects of breathing such an atmosphere are well marked. A few hours suffice to produce febrile symptoms, hot skin, rapid pulse, furred tongue, anorexia, thirst, &c., and these effects persist for one or more days afterwards. If the intoxication be still more acute, as when the proportion of space to number of living beings is excessively low, asphyxia from deficiency of oxygen and direct poisoning from organic exhalations combine to destroy rapidly the life of the most susceptible, while the survivors suffer for some days subsequently from symptoms similar to those just described; and the impairment of the vital powers is sometimes evinced by boils. Living habitually in an atmosphere tainted in a lower degree with the products of respiration exercises a most injurious influence upon the general health; often aggravated by want of exercise as in the case of tailors, sempstresses, school-children, &c., by the presence of dust of various kinds in many manufactures, or by idleness and ennui in the case of the soldier. Paleness, with loss of appetite, strength and spirits, shows deterioration of health and consequent inability to resist epidemic or infectious disease. The proportion of phthisis and of pulmonary diseases is higher amongst persons exposed to these unfavorable conditions and the diminution of such affections among soldiers and sailors by improved ventilation of barracks and ships has been marked. Cows, horses, &c., suffer like human beings, and it is well known that the monkeys in the London collection died in large numbers of tubercular phthisis, so long as the arrangement of their quarters was such as to prevent the escape (except by diffusion) of the products of respiration.

The air of sick rooms or Hospitals necessarily contains additional impurities. The proportion of organic matter, both suspended and vaporous, is much increased; producing, unless corrected, not only general impairment of vital power, shown by intensified disease and retarded convalescence, but also specific maladies of which the generating causes accumulate if not removed. Under such circumstances erysipelas and hospital gangrene may be developed and the communication of other infectious diseases favored.

The Products of Combustion rarely accumulate. Breathing the air of close rooms where lamps, especially gas-lamps, are burning, sometimes causes headache and a feeling of oppression, owing to the formation of the oxides of carbon; and much sulphurous acid arising from the combustion of coal-gas may produce some bronchial irritation. Indirectly combustion may be injurious to persons chilled by passing from a heated room to the colder atmosphere without.

Since the decomposition of animal matter yields carbonic acid, marsh-gas, nitrogen in large quantity, (sewage emanations sometimes containing 10 per cent.), sulphuretted and phosphuretted hydrogen, ammonia and acetic acid; and that of vegetable matter, carbonic acid, nitrogen and acetic acid; Sewer-Air may contain some ingredients which are asphyxiating and others which are directly poisonous. In well-constructed and well-ventilated sewers, however, the air has been shown to be remarkably pure and it is only when deficient in one or both of these important points that disease is directly caused by their presence. The opening of cesspools has thus proved fatal to workmen. Ophthalmia, bilious diarrhœa, and colic have been known to prevail amongst persons employed about sewers. The habitual inhalation of air polluted by communication with sewers produces headache, nausea, diarrhœa, general malaise; and, if continued long, great impairment of health and a state of anæmia. Sometimes brief febrile attacks, characterized by severe headache and derangement of digestive organs, have been observed. Diarrhœa may arise from the emanations from fæcal matters in sewers, especially if the poisonous effects are concentrated by high temperature and drought, which may also assist by rendering the water-supply impure. The connexion of enteric fever with sewer-air is still obscure. It is almost certain that emanations from sewers containing the stools of typhoid patients will undoubtedly produce the disease in persons unprotected by a previous attack. Imperfect sewerage favors the spread of typhoid, improved sewerage has been followed by disappearance of the fever. On the other hand fæcal accumulations may exist for years, and their emanations pollute the air without the production of this specific disease. It seems probable, therefore, that, as a general rule, sewer-air must contain the specific poison of enteric fever in order to generate the disease; while the possibility of *de novo* origination, through the concurrence of complex and unknown conditions, cannot absolutely be denied. Other diseases, as erysipelas, hospital gangrene, the exanthemata, venereal affections, puerperal fever, &c., have their severity aggravated in an atmosphere tainted by sewer emanations.

The effect, general and special, upon health, of Fæcal Matters accumulated and concentrated in sewers is pernicious, if they are permitted to contaminate the air we breathe; but, when they are scattered upon the surface of the ground, they are comparatively harmless, however disagreeable.* Their emanations are immediately and copiously diluted with ordinary air. Collected in heaps they are nearly as hurtful as in open sewers. Mixed with earth they, in most cases, lose all dangerous properties; though specific poisons, as that of enteric fever, may not be thus destroyed and may propagate disease. Emanations from streams into which sewers discharge excrementary matters will generally be diluted to harmlessness, but the emanations from masses of sewage and mud left bare by the drying up of a stream or tank or by the ebbing of the tide at an estuary are often most disagreeable and dangerous to health.

Residence in or in the neighbourhood of Graveyards is necessarily unwholesome. Although the impure atmosphere may cause no definite disease, it impairs health and diminishes power of resistance to morbific causes. The polluted water of such localities contributes to this result.

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* There is no necessary connexion between a bad smell and injurious atmospheric impurity; some offensive gases and vapors (as sulphuretted hydrogen, ammonium sulphide and organic respiratory vapor) being deleterious, while others, also poisonous, (as the carbon oxides and malaria) are not perceptible by the sense of smell. On the other hand, air impregnated with innocent odors may be exceedingly offensive to the nose.

The decomposition of unburied animals, as in dissecting-rooms on the small scale and battle-fields on the large, sometimes appears to produce bowel-complaints and can scarcely fail to render the air unwholesome always, though satisfactory evidence is wanting. Attendance at funerals appears to have been sometimes injurious to the health.

The air of Marshes, and of other places not *apparently* wet, where organic vegetable matter is undergoing decomposition, produces intermittent fevers and congestion of the spleen with impairment of nutrition and shortening of the mean duration of life. Malarious dysentery sometimes results. These effects, however, are probably due as much to the water of such localities as to the air.

PURIFICATION OF AIR—VENTILATION.

Air is purified by rain which carries dissolved and suspended matters to earth; by winds and currents dispersing and diluting foreign substances; by the vegetable kingdom which, under the influence of light, decomposes carbon dioxide, retaining carbon for its own structures and giving out oxygen; by oxidation of putrescent organic matter; by diffusion of gaseous bodies; by deodorants* and disinfectants*; and by ventilation.

Diffusion is the intermixture of gaseous bodies which do not act chemically on each other and which are either directly in communication or separated by a porous medium such as an ordinary brick wall. Two gases or vapors thus intermixed can be separated only by chemical action or condensation of one of them. The rapidity with which diffusion takes place varies with the difference of densities of the diffusing bodies; the greater this difference, the more active is the process of intermixture.†

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* *v.* Disinfection.

† The diffusiveness or *diffusion-volume* of a gas varies inversely as the square-root of the density; therefore, the time of diffusion (which is inversely as the volume diffused) varies directly as the square-root of the density. As all aëriform bodies may be taken to expand equally under the influence of equal increments of heat, their relative densities are constant

We have seen that the air is constantly being purified by various natural means. In the case of the general air-space of a town advantage is largely taken of such means: by making the streets wide and building the houses not too close together nor too high circulation of the air is unimpeded and a high standard of purity is maintained. This has been called "external ventilation" and it is a most important part of the duties of Municipal Authorities to see that no obstruction of any sort to such external ventilation is allowed to exist. In addition most other impurities can be prevented from entering the air by the watering of streets to lay the dust, by the enforced consumption by manufactories and furnaces of their own smoke and other noxious products, by careful inspection and cleansing of all drains and sewers and by the removal to a special quarter of all offensive trades and occupations. In all large English towns great pains are taken to provide open spaces or parks where the inhabitants of the neighbouring streets and alleys can assemble for physical exercise and be sure of breathing retatively pure air. Such open spaces have been called the 'lungs' of a town. In India nearly every town has plenty open spaces or *maidan*, and in addition the buildings are not so high, but withal the air in the narrow streets and bazaars is often extremely impure, full of dust and filthy-smelling. Every opportunity should be taken by Sanitary officials to secure good external ventilation by the gradual widening of streets, demolition of unused buildings and so on. The term VEN-

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and, therefore, their *relative* velocity of diffusion is unaffected by changes of temperature. The *total* rate of diffusion of equal volumes is increased by increase of temperature, because thereby the densities are diminished; but the rate of diffusion does not increase so rapidly as the expansion by heat. Whence it follows that a given weight of any gas or vapor is diffused more rapidly at a low than at a high temperature. Suppose air and hydrogen to be the diffusing gases, the density of air is taken as unity and its diffusion-volume will be 1, the density of hydrogen is 0·0692 its diffusion-volume $= \frac{1}{\sqrt{0 \cdot 0692}} = \frac{1}{0 \cdot 2632} = 3 \cdot 7994$. Actual experiment gives 3·83. Thus if a body of air and a body of hydrogen are in communication 3·83, volumes of hydrogen pass into the air while one volume of air passes into the hydrogen.

TILATION is usually restricted technically to the means by which the air *in buildings inhabited by men or other animals* is kept at the normal standard of purity and that implies the removal of vitiated air and the supply of fresh air. This is sometimes called 'internal ventilation.' Hence the extreme importance of efficient external ventilation, for upon the purity or otherwise of the outside air depends the possibility of good internal ventilation.*

The points requiring special attention in the study of this subject are. 1. The Rate at which the air becomes impure. 2. The Quantity of pure air necessary to maintain health. 3. The Means of providing the amount required. 4. The Measurement of the supply. 5. The conditions essential to Effective Distribution.

1. The Rate at which the air becomes impure. It will be remembered that normal or pure air contains 0·4 volumes CO_2 per 1,000 volumes of air. To this is constantly being added in dwelling-houses the CO_2 exhaled by the inhabitants and often also the CO_2 which results from the combustion of wood-fires, oil-lamps, etc. Disregarding for the present this latter source of impurity, we can ascertain by direct experiment that *each person gives off on an average* 0·6 *cubic foot* CO_2 *in one hour*. Suppose then one person to be placed for one hour in a room of 1,000 cubic feet, *i.e.*, 10 feet long, 10 feet wide and 10 feet high, and that no fresh air is admitted; at the end of that time the room will contain 0·4 volumes CO_2, (the original amount in the 1,000 cubic feet of air) + 0·6 volume (or cubic foot), *i.e.*, a total of 1 volume CO_2 per 1,000 volumes of air. Suppose now that a person is shut up for one hour under the same conditions in a room containing 3,000 cubic feet of space; at the end of that time the amount of CO_2 present would be (0·4 × 3 =) 1·2 cubic feet CO_2 originally present in 3,000 cubic feet of fresh air, + 0·6 cubic foot CO_2 exhaled by the man, *i.e.*, 1·8 cubic feet CO_2

* In some large buildings, such as concert-halls, etc., the fresh air supply is drawn through a pipe from a distant spot, by means of a revolving fan, owing to the constant impurity of the air immediately outside the building.

per 3,000 or 0·6 volume CO_2 per 1,000. Now in practice it has been found that when the ratio of CO_2 to the air reaches 0·7 volume CO_2 per 1,000 the smell of organic matter begins to be perceptible and injurious effects are produced by the continued respiration of such air. Note accordingly, that the actual amount of CO_2 present is not in itself hurtful but only serves as an *indicator* of the amount of organic matter present. From numerous experiments then a certain standard of purity for the air in inhabited buildings has been fixed, *viz.*, 0·6 volume CO_2 per 1,000 volumes air. From this, however, must be subtracted the 0·4 volume CO_2 per 1,000 normally present in the air and that leaves 0·2 volume CO_2 per 1,000, which has been fixed as the maximum amount of Admissible Respiratory Impurity in well ventilated dwellings.

So, then, if the air of any room contains more than 0·6 volume CO_2 per 1,000 including the CO_2 originally present in the fresh air or more than 0·2 volume per 1,000 excluding the original CO_2 it is said to be impure.

2. Having fixed the standard of purity we have next to ascertain the Quantity of fresh air which must be supplied in order to constantly dilute the air of a room, so that it will not contain more than 0·6 volume CO_2 per 1,000.

a. The amount required for this purpose is always expressed in *x thousands cubic feet of fresh air per head per hour* and is most conveniently calculated from the following formula:

$$F = \frac{E}{R} \times 1{,}000$$

When F = the number of cubic feet of Fresh air required per hour,

E = the amount of CO_2 Exhaled per hour*,

R = the admissible Respiratory impurity.*

* Of course, if we adopt other standards for E and R, *e. g.* E = 0·7 in the case of a room occupied entirely by adults, as in barrack rooms; or make R = 0·3 as is sometimes done; then the amount of fresh air required will be correspondingly altered.

Example.—$F = \frac{0 \cdot 6}{0 \cdot 2} \times 1{,}000 = 3{,}000$ cubic feet of fresh air required in an hour for one person, or for ten people $F = \frac{0 \cdot 6}{0 \cdot 2} \times 10 \times 1{,}000 = 30{,}000$.

b. From this formula used conversely we can calculate the average amount of fresh air which has been supplied and vitiated. Instead, however, of R being equal to the admissible respiratory impurity, in this case it is equal to the Actual Respiratory Impurity as ascertained by chemical examination of the air—say ·8 volumes CO_2 per 1,000.

Then F = number of cubic feet of fresh air per head per hour that has been supplied and utilised,

E = as before,

R = the *actual* Respiratory impurity of the air in the room.

Example.—$F = \frac{0 \cdot 6}{0 \cdot 8} \times 1{,}000 = 750$ cubic feet of fresh air utilised per head per hour.

c. Again, if a given amount of air is supplied per hour to one or more persons in a room, we can calculate the *probable* amount of CO_2 in the air. In such a case E and F are known and it is required to calculate the value of R.

Example.—7,000 cubic feet of fresh air per hour are supplied to and utilised by 10 people occupying one room :* estimate the probable amount of CO_2 per 1,000 volumes of the air in the room.

$$R = \frac{E}{F} \times 10 \times 1{,}000.$$

$$R = \frac{0 \cdot 6}{7{,}000} \times 10 \times 1{,}000 = 0 \cdot 85 \text{ volumes } CO_2 \text{ per } 1{,}000.$$

* In all such cases it is understood that the amount of vitiated air which escapes from the room is the same as that of the fresh air supplied.

From the above formulæ and from practical experiment it has been ascertained that under ordinary conditions the following amounts of fresh air should be supplied per head per hour.

For children	... 2,000	cubic feet per head per hour.
,, Women	... 3,000	,, ,, ,, ,, ,, ,,
,, Men	... 3,600	,, ,, ,, ,, ,, ,,
		(*i.e.*, 1 cubic foot per second).

During work these quantities should be considerably increased and adult men in hard work require about 7,000 cubic feet or more.* Large animals such as horses and cows each require 10,000—20,000 cubic feet of fresh air per hour, which is almost the same as saying they ought to be in the open air.

Hospitals or other places occupied by the sick demand a higher minimum of supply. In some diseases the amount of organic exhalations is so large that it is almost impossible to give pure air enough to remove their characteristic odors. A ward containing many cases with open wounds requires at least 4,500 cubic feet of fresh air per man per hour. When hospital gangrene, pyæmia, erysipelas, typhus, variola or plague prevails the supply of air should be limited only by the necessity of protecting the patients from wet or excessive cold. In such cases free ventilation not only promotes the recovery of the sick but also opposes the spread of disease. It has been observed that the organic poisons of some diseases are more capable of destruction by oxidation, or dilution to harmlessness, by pure air than those of others. Thus, a few feet of freely ventilated space suffice to protect from the poisons of typhus and of plague; while variola and scarlatina spread in spite of abundant air supply, and the diseases are communicable even after months of free exposure to pure air.

* An adult male in hard work gives off as much as 1·52 cubic feet CO_2 in 1 hour, therefore, by formula *a*, ($F = \frac{1 \cdot 52}{0 \cdot 2} \times 1000 =$) 7,600 cubic feet are required.

Provision has also to be made for Combustion and its consequences. Air must be supplied in sufficient quantity to yield oxygen for fires and lights, and to dilute the gases resulting from combustion when these are permitted to escape into a room. 240 cubic feet of air should be allowed for the complete combustion of 1 lb. of *coal;* 120 for 1 lb. of dry *wood,* the carbonic acid and other gases produced escaping by the chimney. A cubic foot of *coal-gas* requires 8 cubic feet of air simply for combustion; therefore, about 25 should be allowed per hour for each burner, without taking into consideration the vitiation of the atmosphere of the room by the products of combustion, which latter should, if possible, be conducted immediately and separately to the open air.* As a cubic foot of coal-gas generates when burnt about two cubic feet of carbonic acid, an ordinary burner adds six cubic feet of this gas per hour to the atmosphere of the room, to compensate which 5,000 cubic feet of normal air must be supplied, unless the special outlets be provided. An ordinary *oil-lamp* generates about half a cubic foot of carbonic acid per hour, requiring 400 cubic feet of air for dilution. For a good *candle* 500 feet per hour should be allowed.

3. The Means of supplying the requisite amount of pure air may be divided into Natural and Artificial: the former including *perflation, aspiration* and *circulation;* the latter, *extraction* and *propulsion.* In tropical climates where the air is always warm the difficulty lies not so much in the supply of fresh air, as in the supply of *cool* fresh air; just as in other countries the air must be warmed. In the latter case the problem has been thoroughly and scientifically studied; as regards the former it is almost untouched.

PERFLATION is the blowing of a natural stream of pure air through a room or other space. General perflation by the passage of wind through doors and windows or

* By means of a tube with a funnel-shaped mouth placed directly over each gas jet, the other end of the tube opening into the outer air by passing through the wall of the room.

other openings is the most efficient means of ventilation and, in the present state of our knowledge, that which is, as a rule, best suited to this country and climate. A current of air moving at the rate of two miles per hour—a rate which does not produce a perceptible draught—through a doorway ten feet by four in area supplies 422,400 cubic feet of air per hour, a quantity sufficient for about 150 healthy men. A stronger wind will pass readily through a tent-wall, or through matting; and perflation takes place to some extent through single planks of wood and even through unplastered porous brick if the velocity of the current be high. Doors and windows should always be so arranged as to permit free perflation when the wind is only moderately strong.

It is desirable that the movement of the air blowing through a room should be nearly or almost imperceptible to sensation, so that there shall be no draught or chill. Air may be moving at a rate of a mile or even a mile and a half per hour while no movement is perceived. Imperceptibility of movement depends not only on velocity but upon temperature; and the higher the latter the more rapid may be the rate without inconvenience.* With the thermometer at 21° C. (70° F.) or upwards perflation at a considerable rate of velocity is attended by no sensation of chill. Even at lower temperatures than are ordinarily experienced in this country a velocity of a mile per hour is imperceptible, and a rate of a mile and a half is not disagreeable. It may be taken as a general rule that the rate of movement should not exceed 3·5 feet per second, *i.e.*, 2·4 miles per hour; and a lower rate will be objectionable if the air be moist or if it be of lower temperature than that it replaces.

There is another, but a less efficient and manageable, way in which perflation may be applied. Cowls turned

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* Up to a certain point only. In the case of the extremely hot and dry *land winds* in this country a most disagreeable and even serious degree of exhaustion, accompanied by other unpleasant symptoms, may be produced.

towards the direction from which a wind is blowing may be placed at the top of a building, from which pipes of wood or metal convey the air received to rooms below. Direct communication between the cowls and the apartments to be ventilated is liable to be attended by draughts; but the streams of air can be conducted to the basement story of a house, there warmed or cooled as may be desired, and thence distributed by tubes to other parts of the building. Corresponding outlet pipes and openings, with cowls turned *from* the wind, will be provided for the issue of air commensurate with that blown in; and these by their aspirating effect will aid in ventilation. This second mode of perflation is applicable to the holds of ships, which the direct method cannot reach. A funnel of canvas, wood or metal receives the wind and a tube conducts it downwards. Distribution without draught is difficult here as in a house. The force of the in-blowing current may be reduced by having the conducting tube bent at right angles, once or oftener; or by interposing screens of perforated zinc in the passage; but ventilation is impeded in proportion as friction is increased by these expedients and the plates are liable to become clogged with dust and are with difficulty got at for cleaning. The stream of air admitted by this method may also be regulated by valves.

Aspiration is the drawing of air out of a room or building through a shaft by means of the wind blowing at right angles to the latter. In this way a small current of air moving with a high velocity over the upper end of a tube, provided with a cowl turned *from* the wind, influences a large body of air below, by producing an upward draught. This method withdraws air from a room and provision must be made for free admission of pure air in compensation. The stronger the wind the more copious will be the updraught and the more effective the aspiration, while a powerful blast cannot, as we have seen be borne in perflation. Neither method, of course, is applicable where the outer air is absolutely stagnant, and ventilation will then depend upon either circulation or artificial means. It is also to be borne in mind that wind may impede ventilation by blowing across unprotected exit-openings, or down chimneys or other shafts.

The movement of air caused by differences of temperature is called CIRCULATION. Air heated by lights or fires or the bodies of men or other animals becomes lighter, rises and is replaced by colder air from above or from without, which is in turn warmed and similarly replaced. As this circulation depends upon the generation of a higher temperature within a room than that of the outer air and is active in proportion as the former exceeds the latter, ventilation by this means is chiefly applicable to cold climates and to rooms or buildings artificially warmed. In all inhabited rooms, however, it needs to be taken into consideration and due provision made for ingress and egress of air. In this country the external air is sometimes warmer than sometimes colder than and sometimes of equal temperature with the inside air, the result being that downward upward or no currents are formed, and in any case the current is never very strong owing to the fact that the difference in temperature between the external and internal air is never great. Still, when in very hot weather houses are closed in the early morning, the air within is, during a great part of the day, cooler than that outside; so that circulation is in this way also established and there is then no necessity for direct exposure of the body surface to the trying hot winds.

When this circulation is maintained, not by the ordinary sources of heat but by special contrivances, it forms one of the artificial methods of ventilation; namely, ventilation by EXTRACTION.* In an ordinary chimney, when a fire is burning below, an upward current of air, moving at a rate of from three to six feet per second, is produced; and if

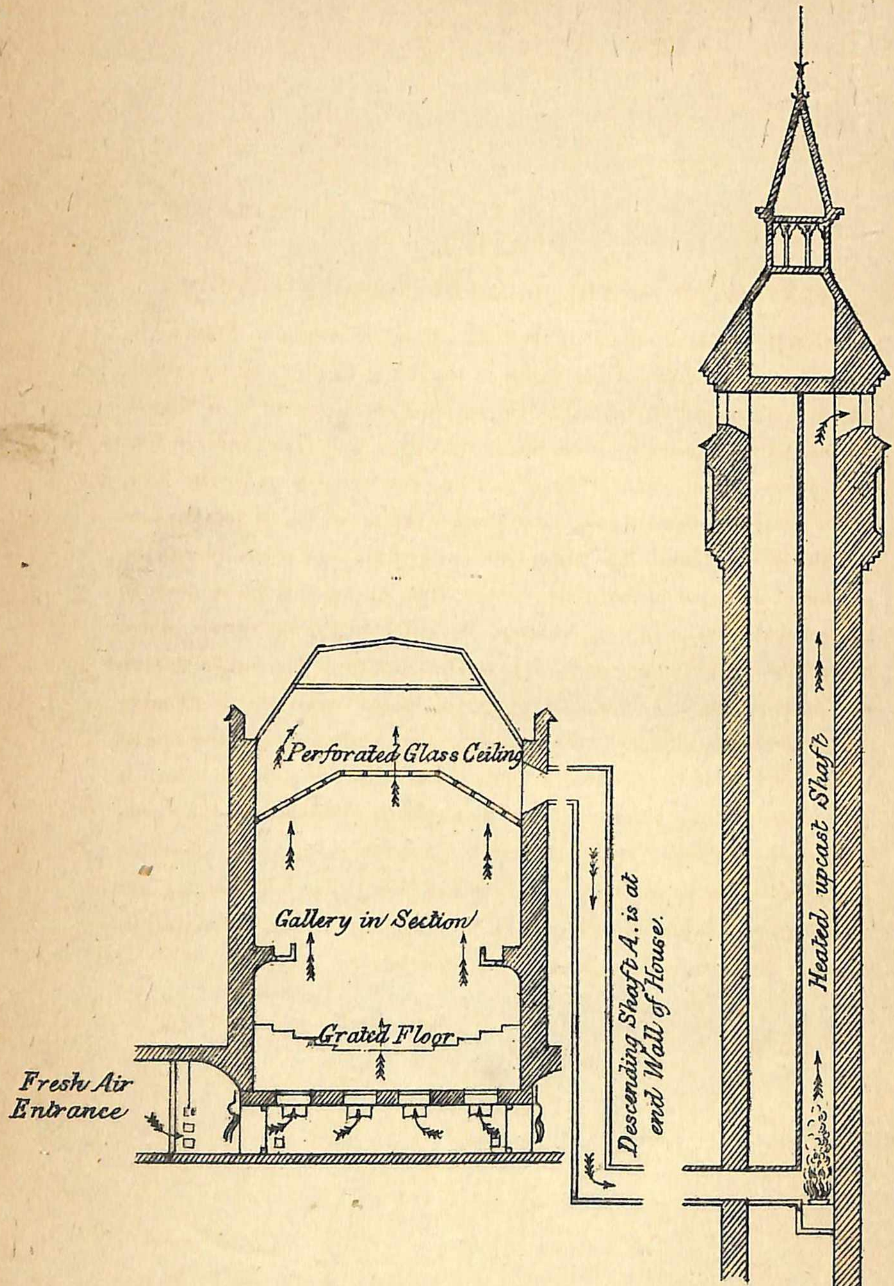
* The Vacuum Method.

the fire be very large a velocity of nine feet per second may be attained. Equilibrium will be restored by streams of air passing from other openings towards the fire-place, or, if there be no such openings, by a down-draught in the chimney itself, simultaneous with the up-draught. This principle is applied on the large scale to the ventilation of mines, where a large fire burning at the bottom of a shaft maintains a powerful upward current, while fresh air from the surface, descending through other openings, supplies the place of that withdrawn. In like manner large buildings are sometimes ventilated. A fire or a number of gas-burners or pipes filled with hot water heat the air at the lower part of a central shaft into which, owing to the strong upward current thus set up, the foul air from all the rooms is drawn, by means of special pipes opening into the shaft near its base. The fresh air is supplied to each room by windows or special inlets.

Several disadvantages attend this mode of ventilation, especially in the case of small buildings such as dwelling-houses. Heat supplied by a fire, which is the source most generally available, is not easily kept at a fixed temperature nor regulated to suit the varying circumstances of different rooms; if, from any cause, the requisite up-draught is not maintained from below, a down-draught will be generated in the shaft, which may bring with it into the building smoke or other products of combustion; and, under certain conditions, the air which is thus withdrawn may be replaced by air entering from any source, as for instance from sewers or through water-closets. Extraction by a screw-shaped Fan has been suggested and practised, especially in mills where a great deal of dust is thrown into the air: but the mechanical power which it requires can, as a rule, be more economically and efficiently applied to ventilation by propulsion.

PROPULSION is the forcing in of pure air by mechanical means, either directly or through flues constructed for the

PLATE I.



LITH: BY ROSS, BROS.

To face p. 28

PLATE I.

VENTILATION OF THE HOUSE OF COMMONS—LONDON.

(AFTER GALTON).—To illustrate ventilation by artificial means. Fresh air is supplied from the adjacent courtyards of the House by revolving fans which propel it along special conduits. On entering the basement it is filtered, washed, warmed or cooled, according to the season, and passed through four large circular openings (3′ 6″ diam. ea) into the chamber under the floor, which latter is perforated to allow of the free passage of the air into the general body of the House. The vitiated air rises gradually and passes through the perforated glass ceiling into a space above, from whence it is drawn down an exhaust shaft opening into the basement at the foot of the clock-tower, where a large fire is kept burning in order to create a draught. The heated air then rises again and finally passes out through the heated upcast shaft. As much as 1,500,000 cubic feet have been passed through per hour, a quantity equivalent to 2,000 cubic feet per head per hour if the house was quite full, which it very rarely is for any length of time. The method above described is a combination of 'extraction' and 'propulsion'. [A simple modification of the above plan could easily be adapted for the ventilation of Indian hospitals, etc., the air being cooled before entrance, and an upward current created in the shaft by means of the sun or of a fire, according to circumstances (*v*. p. 227).]

purpose.* When labor is cheap and thorough ventilation by natural methods not attainable propulsion may be applied with great advantage. The quantity of air thrown in can readily be measured and regulated, and its temperature raised or lowered. The common thermantidote is a familiar instance of this method. It supplies a constant stream of pure air to a room or building, which may be passed through a moistened tatty and thereby cooled. The mechanism of the machine is simple and not easily deranged, and little labor is required for working it; but the distribution of the supply is generally faulty. Air enters at a high velocity and is liable to pass directly through a room in streams to the outlets instead of intermixing, thus producing draughts and inefficient ventilation.

Distribution can be more satisfactorily managed by the use of this method on the large scale. Large fans, worked by men or cattle or steam-power, force air drawn through a shaft, at least forty feet high and situated well away from all buildings, (to ensure purity of supply), into flues which communicate by branches and pipes with every part of the building to be ventilated. This plan is suitable for a jail† if the absence of wind for long periods renders natural ventilation insufficient, cheap labor being superabundant; but the first cost of machinery and buildings must be considerable. Its inventor suggests that canvas shafts may be substituted for masonry flues in applying this method to buildings; and also that portable

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* The Plenum Method.

† Mr. Stuart Clark introduced his "plenum method" into Agra Jail. One fan, 3½ feet in diameter, worked by hand at a speed of less than 300 revolutions per minute, was found sufficient to ventilate a corridor 283 feet in length with 68 cells opening from it. The machinery is placed to windward, about 300 feet from the middle of the line of buildings. An underground main-flue of masonry (4½ feet by 3) conveys the air to the jail. Smaller flues (2½ × 2 feet) pass under the floor of each block, and from these diffusion-pipes of earthenware, 9 inches in diameter, are distributed through the walls, communicating with the rooms by openings covered with perforated zinc. Besides the diffusion-pipes, "diffusion cases" are placed over the central flue and connected with it, 20 feet apart, in each building. With reference, however, to the foregoing, I am informed by the present superintendent that the method has fallen into disuse, "apparently because it did not prove a success."—[Ed.]

fans, etc., should accompany troops marching in the hot season, for the ventilation of tents.*

To ascertain whether sufficient provision has been made for the ventilation of any room the number of occupants and the volume of fresh air entering the room per hour, either by natural or artificial means, must be known. Dividing the latter quantity (after reductions for lights, fires, etc.,) expressed in cubic feet, by the former, the volume of pure air supplied for each person is obtained for comparison with the quantity stated above to be necessary.† The amount of air entering and escaping is determined by the anemometer, or, in the case of ventilation by circulation, by calculation.‡ The anemometer is an instrument which shows the velocity of a current of air in feet per second. The openings through which air enters having been ascertained by the deflection of a candle-flame, or by the direction taken by the smoke of smouldering brown paper, the rate of the entering current at each is determined. The rate per second multiplied by 3,600 gives the rate per hour; and this multiplied by the area of an opening in feet is the number of cubic feet per hour which that opening yields. The instrument should be placed as nearly as possible in the middle of the length of the passage and about two-fifths of the breadth from the side in order that the mean velocity may be given. It often happens that the outlet openings are less numerous

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* The Punkah is a form of air propeller, but only to a limited extent. Opinions as to its efficacy differ considerably and exact experiments are wanting. The splendid steam-driven punkahs in the General Hospital, Madras, show this method of causing air-propulsion to its fullest extent. A punkah promotes intermixture and diffusion: when the temperature is lower than that of the body, it cools, by removing the layer of heated, ill-conducting and vapor-loaded air from the surface, substituting a colder film and favoring evaporation; when the temperature is higher it acts only in the latter way. Its use is favorable to comfort and to health, but not by promoting ventilation.

† This can be ascertained more directly by the chemical examination of the air coupled with the use of the formula (*b*) on p. 22.

‡ By the use of Montgolfier's formula (*v.* Parkes' Hygiene, 8th ed., p. 196), but ventilation by circulation is so imperfect in the tropics as a rule (*v.* p. 27) that this method of calculation is very rarely of any use.

than those of ingress of air, as, for instance, when a chimney discharges from a room a volume admitted by several inlets. It may then be more convenient to estimate the outgoing air, with which the supply will necessarily correspond. Casella's anemometer or air-meter will be found best adapted to the purpose.

The Relative Value of Natural and Artificial Ventilation is a question that must be decided by the special circumstances of any given case.* In very large buildings both methods may be available. In a cold climate like that of Great Britain, by far the larger number of houses are ventilated partly by perflation (when the weather permits) and partly by extraction, the chimney of each room being used as an exhaust shaft and the fresh air derived from any available source such as partially-opened windows, the chinks of the door, the entrance hall, etc. Such a method is usually exceedingly faulty, as any one who has occasion to enter an inhabited room on coming from the fresh outer air can testify. "In some circumstances however, as in the tropics, with a stagnant and warm air; and in temperate climates, in certain buildings where there are a great number of small rooms, or where sudden assemblages of people take place, mechanical ventilation must be used."†

In this country there is usually no difficulty in obtaining fresh air, and Europeans largely owe their health to the fact that they pass a great part of their time in what is practically the open air. But at times when the air is very stagnant and the difference between external and internal temperature almost *nil*, ventilation becomes most imperfect and the heat is proportionately trying. This is especially the case in large buildings such as town-halls, reception rooms, etc., which are liable to become suddenly crowded. Under such circumstances, if the air was first cooled and then driven through the house or other building

* As also in the case of Water-Supply and Disposal of Sewage.
† *v.* Parkes' Hygiene, 8th ed., p. 214.

by means of a fan, *e.g.*, the Blackman air-propeller, care being taken for its proper distribution, there is no doubt that great improvement in health would follow, sound sleep would be obtained and the climate would prove less trying.

CUBIC SPACE AND SUPERFICIAL AREA.

Having settled upon the amount of fresh air we are going to supply to any given room, we have next to consider the size of the room into which the air must be supplied, *i.e.*, the CUBIC SPACE. If 30,000 cubic feet of fresh air per head per hour have to be supplied to a room containing 10 men, it is obvious that if the cubic space of the room is 30,000 cubic feet the air in the room will have to be changed once in the hour; if it is 10,000 cubic feet the air must be changed three times, and if 3,000 cubic feet the air must be changed ten times and so on. If the air is changed too frequently draughts will be produced, and in a cold climate this is a very serious matter; for not only does serious illness frequently result, but the individuals for whose benefit the ventilation of the rooms is carried on frequently render abortive all such attempts by blocking up the chief places of entrance of fresh air. It has, accordingly, been found necessary to allot 1,000 cubic feet of space per head, and in this way 3,000 cubic feet of fresh air per head per hour can be supplied without the creation of a perceptible draught, the air of the room being changed only three times an hour. This of course is the amount that *should* be allowed, but in practice far less is given as a rule though public opinion is gradually being educated up to realise the importance of pure air. As we shall see later, in calculating the amount of cubic space certain deductions must be made for solid objects of furniture, etc., which diminish the cubic space, and it is necessary to remember also that the air is apt to stagnate in the corners of a room and thus the useful cubic space is still further diminished. Hence, it is easier to ventilate a large room than a small one.

In the tropics a somewhat smaller space might be allotted so far as the liability to the formation of draughts is concerned, but other considerations, such as frequent stagnation of the air, the heat absorbed by and afterwards radiated from buildings, etc., have to be taken into account so that instead of a smaller a somewhat larger space is necessary. Thus, it is ordered that in barrack-rooms in the plains 1,800 cubic feet should be allotted to each man; in hill-stations 1,200 to 1,400; in European hospitals 2,400 in the plains, 1,600 to 1,800 in the hills; in Native hospitals 1,500; in Jail-wards 648 cubic feet.*

In all cases there is a danger of overrating the importance of space allotment. *In an ill-ventilated room abundant space cannot postpone the consequence of deficient ventilation,* and the most careful obedience to rules providing against overcrowding should never supersede examination into the quantity of pure air entering and the quality of the atmosphere within.

But there is another matter which requires very careful consideration, and that is the amount of SUPERFICIAL AREA or 'floor-space' available for each occupant of a room. If the walls of a room are built very high the amount of cubic space may be large but the floor-space (*i e.,* the length of the room × the breadth) may be proportionately very small. Whenever possible, the floor-space should be at least one-twelfth of the cubic space and never less than 80 square feet per head. The considerations limiting the amount of cubic space and superficial area are chiefly those of expense and it is the duty of the Sanitarian to insist upon the importance of compliance with those standards as compared with the external or internal deco-

* In the English Poor Law Regulations on this subject the minima are 850 cubic feet for ordinary patients, 1,200 for puerperal or offensive cases, 700 for the infirm and aged occupying the room day and night (otherwise 500), for healthy adults 300. The common lodging house allowance is 240 cubic and 30 superficial feet. The Educational Department allotment is 80 cubic feet per head as a minimum; much too little unless mechanical venlation is used.

ration of a building. Horses and other cattle require about 1,500 cubic feet and 120 square feet more or less according as they are sick or in good health. It should be remembered that deficiency in cubic space is less likely to be hurtful than insufficient superficial area and should therefore be preferred when there is only a choice of evils.

Measurement of cubic space.—Measurements should be made in feet and tenths of a foot. If a measure so divided is not readily obtainable one inch should be disregarded, two inches are counted as 0·15, three as 0·25, four as 0·30, five as 0·40, six as 0·50, seven as 0·60, eight as 0·65, nine as 0·75, ten as 0·80, and eleven as 0·90. Square inches may be turned into square feet by multiplying by 0·007. In the case of an ordinary rectangular room the cubic space is found by multiplying together the length, breadth and height. In the case of irregularly-shaped rooms, tents, etc., the space to be measured must be divided into its component parts and the whole added together. By the use of the following table* the cubic space of any room, tent, etc., can be calculated whatever its space may be.

1. Area of circle	$= D^2 \times 0{\cdot}7854$.
2. Diameter of circle	$= C \div 3{\cdot}1416$.
3. Area of a square	= Length × breadth.
4. Area of rectangle	= Length × breadth.
5. Area of triangle	= Base × ½ height or height × ½ base.
6. Area of any figure bounded by right lines.	= Divide into triangles and take the sum of their areas.
7. Area of segment of circle.	= To ⅔ product of chord and height add the cube of the height ÷ twice the chord $\frac{2}{3}(Ch \times H) + \frac{H^3}{2Ch}$.

* Abridged from Parkes' Hygiene, 8th ed., p. 216.

8. Cubic capacity of a cubic or solid rectangle.	=	Multiply together the length, breadth & height.
9. Cubic capacity of a solid triangle.	=	Area of section (triangle) × the depth.
10. Cubic capacity of a cone or pyramid.	=	Area of base × $\frac{1}{3}$ height.
11. Cubic capacity of a dome.	=	Area of base × $\frac{2}{3}$ height.
12. Cubic capacity of a cylinder.	=	Area of base × height.

In this country the great majority of rooms are rectangular, the ceilings being flat; but where there is a ridged roof, as seen in many hospitals, etc., the cubic contents are found by dividing the room into a rectangle and a solid triangle and adding the cubic contents of these two together. Some forms of tent are merely solid triangles or cones, whilst others are more complicated; but, as stated above, the cubic contents of any confined space can be calculated from the foregoing table.

Having thus determined the capacity of a room or other space in cubic feet, with recesses or other additions not included in the general measurement, deductions are to be made for the bulkier articles of furniture and for the bodies of occupants. Large presses, chests of drawers, etc., will be measured. In hospitals, barrack-rooms and bedrooms 10 cubic feet are allowed for each set of bedding; and in all cases 3 cubic feet for each person.*

INLETS AND OUTLETS—THEIR POSITION, NUMBER, SIZE AND FORM.

The openings with which ventilation is concerned are divisible into two groups; those of Inlet or Adduction

* Women and children do not require so much fresh air nor so much cubic space as adult males; but abundance of pure air is so important that in the text and elsewhere no reduction is suggested on this account.

through which pure air enters and those of Outlet or Abduction for the escape of vitiated air. The direction and force of the air currents and, therefore, the proper distribution of the supply depend upon the management of the openings and the mutual relations of the two classes. In warm climates it often happens that doors and windows supply all necessary ventilation without producing draughts or chill and in some cases pervious walls, as of mats or bamboo, allow of free perflation without disadvantage.* In colder climates doors and windows must generally be closed, and special openings provided for inlet, and for outlet also if the chimney is not sufficient. In the colder parts of this country portions of walls of rooms may be formed of tiles so as to be freely pervious during the hot months, but requiring to be closed (as with movable wooden coverings) during the cold season, when other openings will be necessary for ventilation. The consideration of such special apertures, therefore, as well as of the ordinary openings of a room, tent or building is of great importance

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* We have usually in India to depend upon the wind for natural ventilation, and it is manifest that unless revolving cowls or artificial ventilation be resorted to, the same openings must serve somtimes for ingress and sometimes for egress of air. The most simple and direct methods of ventilation are therefore the best; and tubes, shafts, and valves, should, as a rule, be dispensed with. In single-storied buildings, with low roofs, ridge-ventilation may be all that is required. In higher buildings ventilators may be placed in doors or windows at a height of six or seven feet, or separate ventilators may be placed in the walls. Direct ventilation at the ground level through the walls is generally to be deprecated, as foul air is more likely to be found near the ground than higher. In the huts of the poor, and even in the houses of the wealthy, there is often an insufficiency of windows for good ventilation, even when they are open. Where this is found to be the case ventilators can, as a rule, be inserted at a very small cost. Tiled roofs, even where no ridge ventilation is provided, generally afford a pretty free passage to air. When, as occasionally happens, the wind fails entirely, and there is no difference of temperature outside and in, to cause any movement of air, natural ventilation is impossible, and the air can be but slowly purified by the diffusion of gaseous and the subsidence of suspended impurities. In such circumstances, doors and windows should be fully opened and people should, if possible, remain in the open air. The creation of movement by artificial means, as fans and punkahs, is particularly valuable under such circumstances. Ventilation by shafts with revolving or fixed tops of various kinds, is only efficient as long as the wind is pretty strong, that is, when they are least wanted; but when the wind fails they cease to act as intended, and are less useful than ordinary fixed openings. Such contrivances are therefore, as a rule, to be avoided for house ventilation.—*McNally*.

in ventilation. They may be examined with reference to Position, Number, Size and Form.

Inlet openings are to be selected or made in such Positions that the entering air may not be polluted before admission, as by marsh exhalations, sewer effluvia, emanations from latrines or water-closets, discharge from outlets of other rooms or buildings, etc.; secondly, equable distribution and thorough intermixture of the pure supply are essential. Hence, where perflation is possible, there should be doors and windows in opposite sides of the room. In other cases special inlets should be provided near the floor, unless when the supply is so cold that it cannot be borne with comfort and means of heating it artificially before entrance are not available; then it may be admitted at about ten feet from the floor and directed upwards so that falling subsequently by its greater weight it may be equally diffused through the atmosphere of the room. In our climate the floor openings will generally be found suitable.* Respired air first rises; therefore outlet openings are provided at the upper part of the room, tent, etc. In single-storey buildings with sloping roofs, as most of our hospitals, no arrangement can be better for discharge of vitiated air than properly protected ridge-openings along the entire top. As a general rule the highest outlet is that from which discharge is most rapid; but the application of artificial heat, whether specially for favouring egress of air or for other purposes, powerfully affects the rate of discharge through and position of outlets. Thus the chimney of a room in which a fire is burning is always the principal and often the sole channel of discharge; and heating an outlet-tube with gas, whatever its position, increases its effectiveness. Finally, the *relative* positions of inlets and outlets must be considered. It should not be possible for fresh air to escape, without intermixture, through an outlet placed too near the aperture by which it

* v. however, note on previous page.

entered, and, generally, the opening should be so arranged that the movement of air in the room will be vertical, not horizontal; so that air vitiated by one person's respiration (or, in hospitals, by one patient's exhalations) should not pass across the position of another.

The Number of inlet apertures will be determined by the necessity for equable distribution of the fresh air, so that whether they be the ordinary openings of the room, or specially provided for ventilation, they should be (if correspondent in size) at equal distances from each other. In hospital wards, barrack-rooms, etc., for each bed there should be an inlet aperture. Provided the number of inlets is sufficient for proper distribution, that of outlets is unimportant. An ordinary chimney, when a fire is burning, will give sufficient discharge for a room in which four or five persons breathe; and one large outlet, in other cases also, will suffice for a building which requires many inlets.

The Size of special ventilatory openings will vary with the number of occupants of the room, the degree in which ventilation is dependent upon such apertures and the difference between internal and external temperatures, on which rapidity of circulation depends. In the tropics, as explained before,* where ventilation by circulation is frequently very imperfect and where the changes in temperature when they do occur are apt to be very marked, it is impossible to apply the results of any given formula satisfactorily so as to have a system of inlets and outlets suitable for all occasions. In the colder parts of this country where the difference between the external and internal temperature may be 10° F. or more, it is useful to have a series of inlets and outlets which can be closed or opened at will, so that when ventilation by perflation is impossible and the doors and windows are closed, ventilation by circulation can be brought into play. Where

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* v. Note ‡ p. 30.

fires are used the only outlet necessary, save in large barrack rooms, etc., will be the chimney. The outflowing air being warmer and therefore bulkier than the incoming, the apertures of exit should, theoretically, be somewhat larger than those of entrance and the proportion is sometimes given as 11 : 10, but in practice this is a point of no importance. As regards absolute size of the two classes of apertures it is laid down that the distribution of the entering air is most successful when each inlet does not exceed 48 to 60 square inches (the allowance for two or three persons), and each outlet is not more than a square foot in size (or sufficient for six persons).* When a building is to be ventilated by one of the various systems of artificial ventilation the nature, size and arrangement of the inlets and outlets should be settled by skilled sanitary experts, as they vary very much according to the system adopted.

Lastly, the Form and management of ventilatory openings have to be considered. In the case of *perflation,* if the wind have a high velocity, means must be adopted for efficient distribution without the production of draughts. Windows should open at the top, or sloping from below upwards and inwards, so that the cooler entering air may be directed towards the roof or ceiling to sink equably by its superior weight. Or a window may be divided into sections each opening separately with such an upward

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* The Barrack Commissioners allow 11 square inches of outlet aperture for each healthy person occupying a room, *i.e.*, nearly a square foot for 12 men, in addition to the chimney. This may be taken as from 20 to 24 square inches per head for inlet and outlet, and the space should be doubled in hospitals. In Netley Hospital the total inlet area in nine-patient wards (besides doors and windows) is 162 square inches, or 18 square inches per man; in fourteen-patient wards, 15½ square inches per man. The outlets are 17 and 16 square inches respectively. There is great difference of opinion among hygienists in this matter of inlet and outlet areas, probably due partly to variations in the difference of temperatures and partly to estimating with reference to cubic space. One authority lays down that a square inch of inlet should be allowed for 120 cubic feet, or 60 square inches for a room occupied by 12 men with 600 cubic feet per head. As to outlet Parkes recommended 1 square inch of inlet for 60 cubic feet and for outlet 1 inch for 60 cubic feet on the ground floor, for 55 on first floors and 50 on second or for a one-storeyed building.

slope. In windows opening in the ordinary English way, *i.e.*, with the sash moving vertically, the requisite direction may be given to the stream of air by a sloping board. Some panes of the glazing may be double, with openings below in the outer and above in the inner glass; or one or more panes may be fitted with glass louvres. Some may be of wire gauze or perforated zinc instead of glass; or moveable frames with one of these materials may replace the sash when raised or thrown open. In India the windows nearly always open outwards or inwards instead of upwards and in such a case it is not easy to regulate the direct force of the wind. In the day-time the outer wooden venetians may be kept partially closed whilst the inner glass windows are open and thus excess of sun-light and wind be prevented from entering. When *aspirating* tubes and shafts are used the upper ends should be protected from the entrance both of rain and of wind, while their special action is favoured by widening the aperture so that its size exceeds considerably that of the passage itself. This expansion or cowl revolves, so that the opening is always turned from the direction of the wind, and its upper rim projects a little so as to exclude rain from the shaft. Louvred terminations to aspiration shafts are apt to admit rain and also down-draughts, and aspiration is not so powerful as when a revolving cowl is employed. It is a good arrangement to make the shaft terminate in a revolving cylinder open at one side and moved by a vane so that its aperture shall always be away from the wind, the whole being protected by a fixed louvred covering.*

Where ventilation is dependent upon *circulation* inlet passages should be short so as to admit of being readily cleaned, as dirt lodging in them may communicate impurity to the entering air; externally the openings should be pro-

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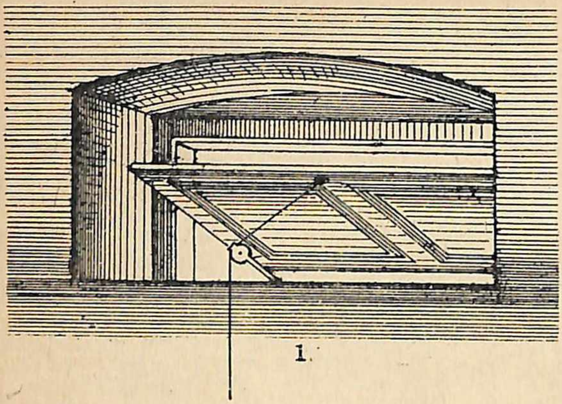
* For detailed description of the numerous forms of shafts, cowls, etc., in use in temperate climates, *v.* the works of Buchan, Eassie, Stevenson and Murphy, etc. There are still many points unsettled and a 'perfect' cowl is a thing of the future. The latest investigations seem to indicate that a revolving cowl does *not* increase the aspirating power of the wind.

PLATE II



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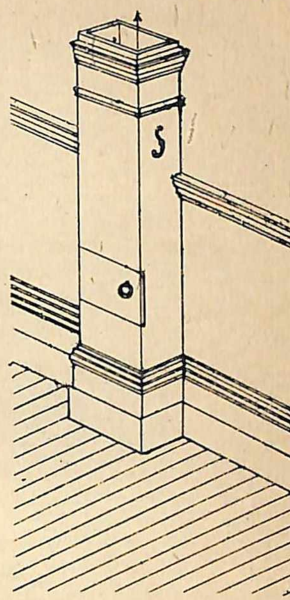

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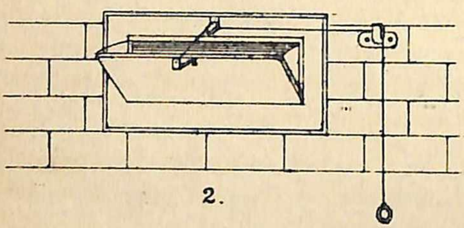

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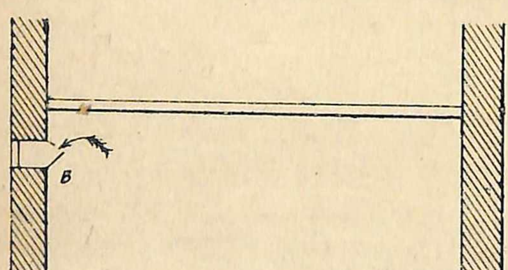

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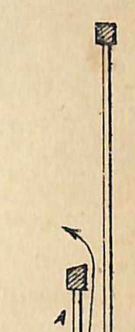

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LITH: BY ROSS, BROS.

To face p. 40.

PLATE II.

VENTILATORS.

Figure 1. Form of Ventilator commonly used in India and placed above doors or windows to form a Clerestorey. It may act as inlet or outlet, or both, according to circumstances. It may be opened or closed at will.

Figure 2. The Sherringham Valve. Externally it consists of a perforated brick or iron box placed in the wall, through which the air enters and is directed upwards by the valve. It sometimes acts as an outlet (*v.* fig. 4). Its chief advantage is that it prevents the wind blowing in directly and causing a perceptible draught. It can be opened or closed at will, and can be easily cleaned. (Usual size of inlet opening is 9″ × 3″ = 27″ square, the external opening being slightly smaller).

Figure 3. Tobin's Tube. The air enters from without through a perforated brick or iron plate at the floor level and passes up the tube. At a height of about 8 feet (3 or 4 feet above the top of the tube) it spreads out and mixes with the air of the room. In time, the tube is apt to become a receptacle for dust, insects, etc., and thus to render impure the incoming air. In addition, owing to its length, there is considerable friction, with a resulting diminished velocity of the air current.

Figure 4. Diagram of a Room Ventilated by Means of a Tobin's Tube (inlet), A., and Sherringham Valve (outlet), B.

Figure 5. Hinckes-Bird's Ventilator (seen in section). B. Block of wood placed under the lower sash frame, A., of the window, whereby the top of the lower sash is raised above the bottom rail of the upper sash, and an air-space left between, through which air enters in an upward direction. This method is only available for windows opening vertically, the use of which in India is chiefly confined to certain Hill stations.

tected from the wind by hoods and provided with means for diminishing their aperture or closing them altogether should circumstances require; within the room, if they open above the heads of the occupants, they may expand in size and be directed upwards; if they enter near the floor, coverings of wire gauze or perforated zinc may be employed, care being taken that the meshes or perforations are not so small as to impede the free entrance of air, and that they do not get clogged with dirt. Ellinson's perforated conical bricks in which the internal openings are large than the outer may be used. Mr. Tobin's method of introducing air may be useful in hill-stations: vertical tubes, communicating with the atmosphere without, terminate about four feet from the floor, and admit cool air in streams which rise for some distance and then fall over and descend. If necessary, the air may be warmed, cooled, washed, moistened or screened through coarse Jute cloth* before entrance into the room. Outlet passages should be as direct as possible and should have smooth internal surfaces so that friction will be reduced to a minimum; they should be protected from cold, and, therefore, not exposed but carried up through the walls. When convenient, outlet tubes should be heated. Thus gas-flames may be used expressly for this purpose; or, when a special tube is provided for removing the products of combustion of gas, an outlet shaft with openings near the ceiling may enclose it, with an interval between the two; in this way a double outflow will be produced. The external apertures must be protected from rain, not only on account of the direct inconvenience which would arise from its admission, but also because the evaporation of moisture from any part of the passage tends to cool it and so interferes with outflow dependent upon difference of temperature. A cowl, revolving so as to be always turned from the wind, will serve to protect from rain and also to favor aspiration through the outlet, while it prevents reverse perflation. For hot climates

* The quality known as *Light Hessian* is the best.

it is recommended that outlet shafts should rise some distance above the roof, the upper portion built of brick and blackened. Finally, it is to be borne in mind that an outlet may, under certain circumstances, become an inlet; and provision must be made for the proper distribution of the entering air, should this occur.

EXAMINATION OF THE VENTILATION OF A ROOM OR BUILDING.

1. For this to be done thoroughly the building and its precincts must first be carefully inspected with a view to the discovery of any nuisance in the shape of accumulations of rubbish, foul drains or latrines, stagnant water, etc., etc.*

2. The cubic space and superficial area of the various rooms must be estimated in the manner described above and the ordinary number of occupants of each room ascertained.

3. The number, size and relative position of the inlets and outlets must be noted and whether the inlets will act as outlets under changing atmospheric conditions and *vice versâ*. The actual amount of air entering or leaving the room, preferably the latter, is estimated by Casella's air-meter, or, under suitable conditions, by calculation. The most important point to attend to, besides the actual amount of fresh air entering, is whether the distribution of the air is equable and thorough. In many cases it will be found, by the use of a smouldering piece of rag or some strong-scented substance, that the air passes almost directly from an inlet to an outlet. A lighted candle held close to an orifice will show whether air is entering or passing out, even when the current is extremely slow.

4. A specimen of the air of the room taken during occupation of the room, *e.g.*, in the case of bed rooms about 3-4 A.M., should be examined as completely as possible by approved chemical, microscopical and biological tests.

* *v.* under Buildings.

5. If this (4) cannot be done, two rough and ready tests may be employed. *a.* Smell test. The examiner coming straight from the outer air should enter the room at a selected time of occupation and note whether there is any perceptible odor or not. If there is none the ventilation is probably satisfactory. If there is any smell he should note whether the atmosphere is "close," "close and unpleasant" or "very close and foul." A little practice enables very considerable accuracy to be obtained by this test. *b.* Lime water test. A clean dry eight-ounce bottle is filled with the air of the room by pumping into it with a small pair of bellows, and three and a half drachms of freshly-made and clear lime water is added. The bottle is then thoroughly shaken and put aside for six hours. At the end of that time the lime water should still remain clear; if found turbid it indicates that a total of more than 0·7 volumes CO_2 per 1,000, (*i.e.*, 0·1 volume CO_2 per 1,000 in excess of admissible respiratory impurity) was present in the air.

6. Finally, the amount of air supplied and utilised (as ascertained by chemical examination) should be compared with the amount indicated by the air-meter. If the distribution of the air is equable there should not be much difference in the two estimations. If the amount registered by the air-meter is in excess the distribution is bad, if it is relatively deficient then some inlet has escaped notice.

CHAPTER II.

WATER.

The provision of a sufficient and suitable water supply is of supreme importance in the tropics. The very existence of the population may be said to depend upon it, for famine in India is almost always the direct result of a deficient supply and consequent failure of the crops. Next in importance to the *sufficiency* of supply comes the question of *purity* of supply. An enormous proportion of the mortality and of chronic disease in this country is due to the fact that the use of impure water is the rule and not the exception. Hence for many centuries great and wise rulers wishing to perpetuate the memory of beloved friends and at the same time to confer lasting benefit upon their subjects have caused to be executed works for the collection and storage of water, in some cases for the purposes of irrigation and in others for the supply of good drinking water. The subject can only be treated of here in a very condensed form, but it is evident that it is steadily claiming greater attention from those in authority and from the educated classes of the Indian community, and while Irrigation works on a very large scale are being carried out on the one hand,* on the other the supply of pure water for household purposes to all towns, and ultimately, let us hope, to all villages, is being pushed forward. That the annual waste of water during the rainy season is enormous is evident to the most casual observer, and the consideration of the methods by which the surplus water may be conserved and utilised, as far as practicable,

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* *E.g.*, the so-called Periyar Project in Southern India, by which, when completed, a large portion of the excess of the rainfall that naturally runs seaward down the western side of the ghâts, will be dammed up and caused to run down the drier eastern slopes so as to irrigate the adjacent country.

is well worthy the continued attention of Meteorologists, Engineers and Sanitarians alike.

The subject falls to be considered under the following heads: 1. The Source of the supply, including the Search for water. 2. The Mode of Supply and Estimation of Supply Available. 3. The Storage of water. 4. The Distribution of water and the Amount Required for various purposes. 5. Drinking water, its Nature and Impurities. 6. Diseases resulting from an Impure supply. 7. The Purification and Filtration of water. 8. The Examination of water.

SOURCE OF THE SUPPLY AND THE SEARCH FOR WATER.

Whatever be the nature of the water supply in any particular place it is primarily derived from the rainfall.* Some of the water that falls as rain is evaporated, some of it flows over the surface of the ground and goes to swell already existing lakes and streams, whilst the remainder gradually sinks through the interstices of the soil till it is stopped and, it may be, partly absorbed, by a so-called impermeable stratum of rock or clay. The water which has thus filtered down to the deeper strata is known as the Ground-water† and forms a most important source of supply by means of natural springs, or wells made artificially. The exact proportion of the rainfall which is evaporated, flows away or sinks into the neighbouring soil depends on many factors varying with the season and the locality,‡ but it may be roughly estimated at one-third in each case. The remote source of any water supply is therefore the rainfall, whilst the immediate source is one of the following:—

1. Rain water itself collected as it falls. 2. Lakes or

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* In some cases as frozen rain or snow. The snow-clad mountain ranges of India and Thibet form immense natural reservoirs which yearly, at the time of melting of the snows, send down vast quantities of water to the parched plains below, by the great rivers that take their rise in these distant valleys.

† *v.* under Soil. Chapter III. ‡ *ibid.*

Tanks, which may be natural depressions in the earths surface, or artificially constructed by damming up the mouth of a narrow valley. Sometimes a small lake exists already and by deepening its bed and erecting a *band* its size may be very much increased. In India many of the tanks are altogether artificial and consist of an oblong or circular area completely *banded* round, and which is chiefly fed by the direct rainfall. 3. Wells—Shallow, Deep or Artesian. There is no fixed limit of division between a shallow and a deep well but the former is generally defined as a well which is of any depth up to 50 feet, the latter as about 100 feet in depth or more. Practically, any well which does not pass through an impermeable stratum is a shallow well. Artesian wells are made by boring, generally to a great depth, through various strata until a water-bearing stratum lying underneath an upper impermeable stratum is reached. They may be regarded as a variety of deep well or again as artificial springs. The water in the deep permeable stratum is frequently under considerable pressure so that it may be discharged in the form of a fountain or jet from the orifice of the well. 4. Springs. 5. Rivers and rarely Canals. 6. Distillation, chiefly of sea water.

The Search for Water.—The indications of the presence of water and the SEARCH for it may not improbably be points of great importance to exploring or survey parties, to troops marching in an unknown country or to officers selecting a site for a camp or a station. In the first place, wells should be sunk in permeable strata only, unless geological examination of the country has shown that impermeable rocks overlie permeable, and that the latter crop out, so as to receive the rainfall or water from other sources. On this principle, on the large scale, artesian wells are sunk to enormous depths through impermeable rocks into underlying permeable and water-bearing strata. Secondly, rivers apparently dry flow subterraneously and water will almost always be found by digging in their beds. Similarly, the dry courses of nullahs are promising sites for wells, and more especially at the point where two unite. Thirdly, greater abundance or verdure of vegetation often indicates closer proximity of water to the surface: and where there is no vegetation, as on a sandy plain, fogs in the early morning give reason to expect water at no great distance below. Fourthly, amongst hills the lowest convenient part of a valley should be chosen, and a spot which is nearer to the higher bounding hill: and the junction of two valleys will be preferred. Fifthly, if there is any indication of an extensive geological 'fault' in the neighbourhood, the probable presence of springs along the line of faulting must not be forgotten. Lastly, on the coast, the immediate neighbourhood of the sea should be avoided, unless an impermeable barrier of clay or rock prevent the percolation of salt water. In some parts of India as at Berhampore in Ganjam and Madras, etc., most of the wells yield brackish water unfit for drinking, whilst close by a well may be found to yield perfectly sweet water.* Norton's tube-wells are sometimes of great use if the soil is not too sandy. They consist of lengths of iron tubing which are driven into the ground, section by section, the first section being pointed and perforated with small holes. If the pressure of the water is insufficient to cause it to rise to the surface an ordinary pump will do so effectually up to 25 feet; beyond that depth it is necessary to use a special force pump.

METHOD OF SUPPLY AND ESTIMATION OF SUPPLY AVAILABLE.

In the case of small Indian towns and villages the method of supply is commonly the DIRECT one, *i.e.*, the water for domestic use is drawn by hand from wells or tanks, or sometimes from a river. Such water is usually highly

* Due to the existence of strata containing much chloride of sodium, the irregularity in the distribution of salt and sweet water being caused by irregular and impermeable beds of clay. The water of the Seven Wells at Madras is filtered naturally through a bed of fine sand 300 or 400 yards in breadth and from 1 to 15 feet deep, which extends northwards for several miles, and water drawn from below this bed is brackish.

impure and to its continued use may be traced a large portion of the annual mortality in India. In the larger towns also this custom still obtains but of late years a good many towns have adopted the much more satisfactory INDIRECT method, where there is one common regular source of supply, generally situated at some distance from the town, and from which the water is conveyed, after purification, by open or closed channels, to a suitable spot for distribution throughout the town. Before any such scheme can be adopted there are very many important questions to be settled, *e.g.*, cost of the work, permanence of the supply, etc., which questions however do not fall to be considered by the Sanitarian. The work of the latter relates entirely to the purity or the reverse of the proposed supply and before this can be settled the ground-surface whereon the rain falls, the so-called 'catchment area,' must be most carefully examined, all possible sources of contamination of the water supply at any point must be investigated and of course a careful analysis of the water itself must be made to see that it is free from hurtful impurities both organic and inorganic.

Estimation of Supply.—It is of great importance to know the probable amount of water which will be available for use under any known method of supply. This is chiefly a question for engineers, but a medical officer may have to calculate it roughly in the absence of skilled assistance.

1. Rainfall. In estimating the annual yield of water from rainfall, or the yield at any one time, it is necessary to know: (*a*) the greatest; (*b*) the least; and (*c*) the average annual rainfall; (*d*) the period of the year when it falls; and (*e*) the length of the rainless season. The greatest is generally about one-third more, and the least one-third less than the average. A safe basis is to take the average of the three driest years; this will generally be about five-sixths of the average annual rainfall. The rainfall varies in amount often in places very near

together. The amount of water given by rain is calculated from the amount of the rainfall and the area of the receiving surface. The former is ascertained by a rain-gauge. The area must be measured in square feet and the total multiplied by 144 to bring it to square inches. This multiplied by the rainfall (in inches) gives the total amount, in cubic inches, of the fall on the measured area in a given time. This multiplied by the short factor 0·003607 gives the number of gallons. One inch of rainfall is = 4·673 gallons on every square yard, *i.e.*, 22,617 gallons (101 tons by weight) on each square acre.

2. Wells. – The yield of wells is liable to vary greatly in different years. In the case of shallow wells this variation depends upon the rainfall directly: in deep wells, many causes, which cannot be detailed here, combine to produce a varying yield. The water supply from any well may be measured by making a mark at the then level of the water and pumping or baleing out water till the level is some feet lower; then measuring the space from which the water has been removed and noting the time that it takes to fill again. The cubic contents of the space are found by multiplying the *cross area* of the well by the depth of water removed. Ex. A circular well 5 feet in diameter, from which 3 vertical feet of water had been pumped out, took 6 hours for the water to reach its former level. Then, the cross area* is $5^2 \times 0·7854 = 19·6$ square feet. $19·6 \times 3 = 58·8$ cubic feet the cubic contents of the space. Now 1 cubic foot of water is = 6·24 gallons, and since the space took 6 hours to fill, the total yield in 6 hours was ($58·8 \times 6·24 =$) 366 gallons (nearly); *i.e.*, in 24 hours the total yield would be ($6 : 24 :: 366 : x$) = 1464 gallons. If a cask be used for measurement, its contents in gallons may be estimated as $= 26\ (h^2.\ 25 + b^2.\ 39 + bh.\ 26) \times 0·0000314 73 l$: where h = least and b = greatest width, and l = length, in *inches*. Should the only available measure be a part of a cask or a tub, the contents in gallons

* v. p. 34.

of each 10 inches are the quotient of the square of the mean diameter of those 10 inches by 3530·4. The mean diameter of the lowest 10 inches (for example) will be half the sum of the diameters at 5 and at 15 inches from the bottom. These methods are only approximative but rigid accuracy is obviously unnecessary in the case.

3. Springs. From the time which is required for filling a vessel of known capacity from a spring its yield is calculated. The yield of a spring or of a small stream often varies at different hours of the day; and determinations should, therefore, be made at several different times.

4. Streams and Small Rivers. The yield may be calculated in the following manner. Choose or make a straight length of as many feet as possible in the course of the stream. If the breadth and depth of this part of the channel are not uniform, measure them in several different places and take the mean of the products for the sectional area (a). Mark with two stones a distance of 150 to 200 feet at least, and note the time which a piece of wood about 4 inches square and $\frac{3}{4}$ inch thick, put into the middle of the stream above the upper mark, takes to reach the lower one. This observation gives the surface velocity; and this, multiplied by 0·8 (for small streams, 0·9 for rivers), is the mean velocity (V). Then $D = a\,V$, D being the discharge of water sought.* It may be more convenient to calculate by means of a Sluice-gate through which the stream is made to pass. Here $D = a\,5\,\sqrt{h}$; a being the area of the opening through which the water passes, and h the height of the water level above the sluice from the centre of the aperture. Or again, the whole stream, if a small one, may be dammed up and directed into a wooden trough or channel of known dimensions. Then, by measuring the depth of

* For example, let surface velocity be 50 feet per minute $V = 50 \times 0{\cdot}8 = 40$ feet per minute. Let mean depth be 1·5 foot, mean breadth 2 feet; mean sectional area = 3 feet. $D = 40 \times 3 = 120$ cubic feet per minute, which, multiplied by 6·23 = 747·6 gallons per minute.

water and noting the time a small float takes to travel from one end to the other, the necessary calculation can easily be made.

STORAGE OF WATER.

In any case where the indirect method of supply is determined upon it becomes necessary to arrange for the STORAGE of a fixed amount of water so that there may be no chance of its running short by reason of drought or a suddenly increased demand. In addition, the water has in nearly every case to be more or less purified by artificial measures before it is fit for distribution. Supposing then that the supply for any given town is from one or more tanks connected together by open channels, the tanks being filled by the rainfall over a chosen gathering ground or 'catchment area' or from a river at some fixed point situated well above the town; or from a series of natural springs or deep wells at the base of a range of hills; the first thing to be considered is what amount of water must be kept stored ready for use. In the first two cases it would only be necessary to build comparatively small storage reservoirs holding sufficient purified water for a month's supply or so, but where there is only one large artificial or semi-artificial reservoir it is essential to store a supply for a much longer period. "The dimensions of the reservoir must depend upon the distribution of the rainfall, and it may be laid down as a rule, that they should be calculated more with reference to the maximum demand and the minimum supply than to the average of either. A capacity of storage equal to about six months consumption, in addition to the quantity which is likely to be evaporated, appears to be the least which should be admitted when it is proposed to supply any agglomerated population in this manner."* Hawksley's formula for storage is as follows:—$D = \frac{1000}{\sqrt{F}}$, where F equals the mean annual rainfall in inches, say $\frac{5}{6}$ of average annual yield; D is the number of days' supply to be stored.

* Law—Clark, Civil Engineering, 7th ed., p. 82.

Thus, with a rainfall of 36 inches, we have $\frac{1000}{\sqrt{36}} = 166$ days' supply.*

Large reservoirs are made by excavation or embanking. The *band* should have a core of clay puddle and be faced internally with stone set in hydraulic mortar. Evaporation at a given temperature being proportional to extent of surface, the latter should be as small and the depth as great as possible.† Before entering the reservoir the water is made to pass, generally, through a rough filter consisting of a 'grating' or a 'submerged sluice' which stops all floating matter, a 'catchpit' or a small 'settling reservoir' in which the heavier suspended matters sink to the bottom, and finally through several layers of graduated gravel and sand, the water passing upwards ('upward filtration'). In addition, an overflow pipe or 'waste weir' and 'scouring' or 'cleansing pits' are provided so that the amount and nature of the water entering can be regulated and the whole reservoir be emptied and cleaned if necessary. Finally, the reservoir may be covered in or left open. In the former case the increase in the cost is very great, and it is rarely necessary.

Water thus stored in large reservoirs is very apt, like all water which is stagnant, or nearly so, to deteriorate by the growth and decay of low forms of animal and vegetable life and great trouble must be taken to prevent this. Certain plants such as *Vallisneria* and *Chara* seem to act beneficially by giving out a large amount of oxygen: the presence of fish and molluscs in limited amount is also desirable.‡ Sometimes the water is aërated artificially before distribution by exposing it for several hours to the atmosphere in fine jets.

In thinly-populated districts or isolated houses smaller

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* *v.* Parkes—Notter. Hygiene, 5th ed., p. 38.

† Loss by evaporation has been known in Calcutta to amount to as much as 2·5 ins. in 24 hours.

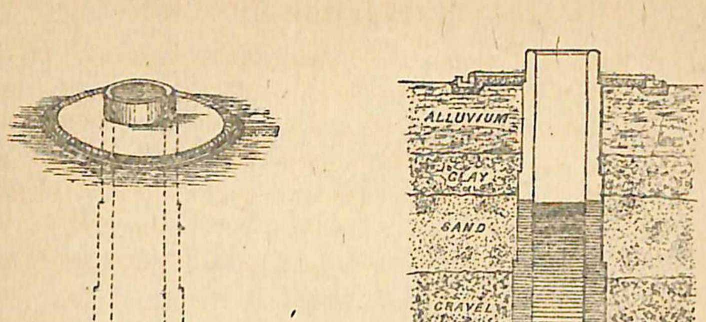
‡ *v.* Chevers—Indian Diseases, p. 136.

reservoirs made of stone or cement are used, but the principle is the same. In places where the annual rainfall is low, and consequently water is scarce, subterranean *reservoirs* may with great advantage be constructed for the storage of rain water falling on the roofs of large buildings. Such receptacles should be built of stone or well-burnt brick, set in hydraulic mortar and lined with portland or other suitable cement; they should be dark, but well-ventilated, deep rather than wide and capacious in proportion to the maximum rainfall. There should be no possibility of pollution by percolation from drain, sewer or cess-pool. The rain should not enter directly from the roof, but should be received in a shallow, carefully lined well, having two or three feet of sand and gravel through which the water passes on its way to the reservoir; and a second filtration by ascent may beneficially be interposed before the latter is reached. The filtering-well should be covered in; and the filters renewed before the setting in of each rainy season. Finally, whenever a reservoir becomes empty, it should be thoroughly cleansed.

Cisterns are used with great advantage for storing smaller quantities of water for domestic use. These are made of stone, brick faced with cement, slate, wood lined with glass, tiles, lead, zinc or iron. Slate is very good; lead is dangerous under all circumstances; zinc frequently so on account of the lead it contains. Cisterns should be emptied periodically and carefully cleansed; they should be covered in, and the pipe which conveys away overflowing water from them should never pass into a sewer or closed drain (lest offensive gases should ascend and be absorbed by the water); but it should terminate either in an open surface drain or at some distance above the opening of a covered passage. As to the *sufficiency* and *strength* of a tank or other reservoir, its capacity in cubic feet, multiplied by 6·23, gives its contents in gallons; and the weight of a cubic foot of water, and, therefore, its pressure on a square foot of surface, may be taken as 62 lbs.

When wells are used, as is so commonly the case in India, great care should be exercised to preserve the water from contamination. That portion of the rain which sinks into the ground percolates into wells, dissolving the soluble matters with which it meets in its course, aided, as we shall see, by carbonic acid derived from the soil. The space thus drained by any well, and consequently the supply of impurities on which it draws, varies with its depth and the nature of the soil. Thus if the soil is very loose a well of 80 to 100 feet in depth may drain a cone whose apex is at the bottom of the well, and whose base is a circle of 50 feet radius. A well may be considered secure from pollution situated external to a cone of half a mile radius, whatever be its depth or the looseness of its soil; but it is not possible to lay down precise rules on this point. Sea-water will penetrate through considerable distances unless impermeable clay or rock protect the well. Cess-pools, sewers, pools of stagnant water may contaminate wells with organic matters in solution and even in suspension, if situated within the drainage-cone. So also excrementitious and other refuse substances lying on the surface of the ground will contribute organic impurities to the soil and thence to the well water. It is true that the soil at first acts powerfully as a filter, intercepting most of the suspended impurities and those most likely to be injurious to health; but the purifying effect necessarily diminishes in time, and may even be reversed when the soil becomes saturated with filth carried in from the surface by percolating water. Besides the impurities to which the water of wells is liable, derived from the soil in which they are sunk, they may receive foreign substances directly from their mouths. Surface floods may wash into them every kind of impurity, organic and inorganic; animals may fall in; persons suffering from painful diseases not unfrequently choose throwing themselves into a well as a convenient mode of suicide; the wind will blow in dust, leaves, etc.; foul vessels will be used for drawing water; dirty people may wash themselves at the edge.

Plate III.



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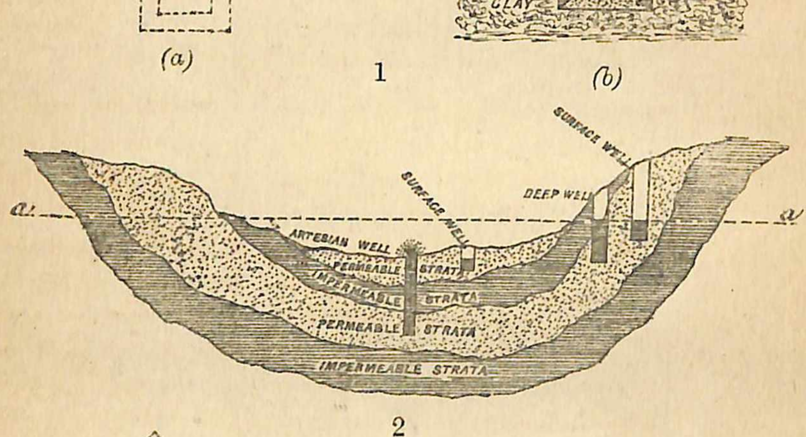

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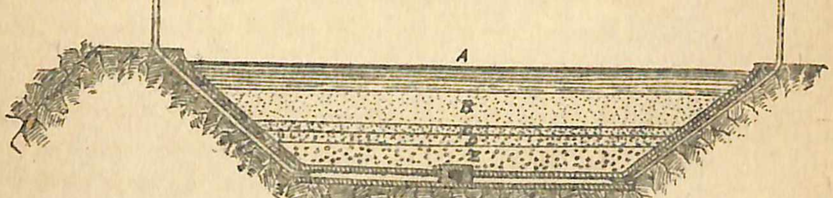

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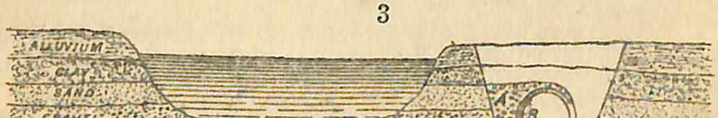

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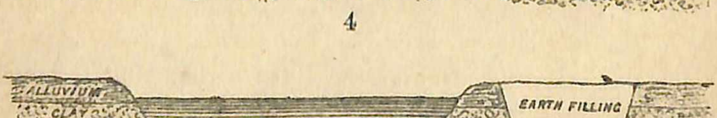

Open jointed pipes leading to Pump Well

5

C PALZENSKY LITH.

To face p. 54.

PLATE III.

WATER SUPPLY, FILTRATION, Etc.

Figure 1. Deep Well shown (*a*) in elevation and (*b*) in section. The water is here derived from the *permeable* strata of sand and gravel enclosed between the two (practically) *impermeable* strata of clay. The masonry of the well is impermeable as far as the bottom of the upper stratum of clay, open-jointed through the two following strata, to allow of the passage of the water, whilst the bottom of the well is made of solid concrete bedded in the lower stratum of clay.

Figure 2. Diagrammatic section through a Valley, showing the Arrangement of the Strata, and illustrating how a Well is 'Shallow', 'Deep,' or 'Artesian' according to circumstances.

Figure 3. Section through a 'Filtration Reservoir,' where the water is filtered *downwards* through layers of sand and gravel (after Clark). A. Water to be filtered; B. 24″ layer of coarse silicious sand; C. 6″ layer of coarse sand or of fine gravel the size of peas or dhâl; D. 6″ layer of coarser gravel the size of small limes; E. 12″ layer of rubble stones the size of oranges and small cocoanuts. Underneath the lowest layer are open-jointed drains connected with the pipe (shown in section) which leads the filtered water to the pure-water reservoir. The impurities in the water are nearly all retained by the first two or three inches of the sand, and a thin slimy pellicle is formed on the surface which offers a most effective barrier to micro-organisms, etc. (Koch).

Figures 4 & 5. To illustrate the 'Interception' System of Water Supply by a process of Natural Filtration. In both cases the river from which the supply is to be taken is seen in section, as also the strata of the soil in which the bed of the river is formed. A channel of the requisite length is dug at a certain distance from the river and parallel with it. In this is laid either a large aqueduct with one of its sides open-jointed (fig. 4, *s*) or else a series of small open-jointed pipes (fig. 5). Into these the water from the river flows through the *natural filter* made by the strata of sand and gravel between beds of clay, and finally runs into one or more wells, from which it is pumped up for use. After the work of laying the aqueduct, etc., is finished the channel is carefully filled up, as shewn in fig. 5, to prevent the water from contamination.

Wells sunk in granite, metamorphic rock or basalt generally yield pure water; in most cases, however, sand, gravel or alluvium is the material through which the water percolates; the last of which is the least desirable. Choice of soil in which to dig a well is rarely afforded, and, in general, it is only possible to preserve wells already existing from avoidable pollution and to select for use those which are free from obvious external sources of impurity. Thus the neighbourhood of burial-grounds, cess-pools, sewers or ill-constructed surface-drains, nullahs (invariably used as latrines), tanneries and slaughter-houses, unclean dwellings, stagnant surface pools or tanks in which human beings or animals habitually bathe or clothes are washed, fields which are freely manured, should be avoided in choosing a well for domestic use. The surface around, within the drainage area, should be kept free from animal and vegetable refuse, and should be carefully drained, so as to afford no lodgment to water. The mouth of the well should be protected by a parapet, and an impermeable platform sloping from its base and provided with a drain, so that spilled water may not return to the well. Should cattle be used for drawing the water, the path in which they travel must be drained and kept clean. The well should be covered with a shed as low as is compatible with convenience in drawing water, and the aperture should be restricted by the same limit; indeed, it is desirable that wells of average depth should be completely covered in and their water drawn by a pump. When a bucket is used, wood or galvanized iron is preferable to leather; and no private vessel should be employed, because there can be no security for its freedom from dirt, and it is probable that cholera and other diseases are thus disseminated. The vessel for general use should be examined frequently, and cleaned when necessary. Lastly, a well which has been long disused should, if required for use, be emptied, cleaned, allowed to refill, and the fresh water left long enough to deposit suspended matters.

DISTRIBUTION OF WATER.

Reservoirs are placed if possible at a higher level than the town so that the water has sufficient 'head' to allow of its flowing along the distributing channel, but in some cases, *e.g.*, where the supply is from a river close to the town, it is necessary to erect a pumping station by which the water is raised artificially to the necessary height.* From the reservoirs the water passes out, after secondary filtration into a smaller reservoir if necessary, by means of a curved pipe which opens at the middle depth of the reservoir so as to avoid both sediment and floating matter. From this pipe it enters the *aqueduct* which may be an open channel† but is preferably a closed iron pipe. Some of these aqueducts are of immense length, *e.g.*, that of the Glasgow water-supply from Lock Katrine which is more than 25 miles long and cost £468,000. In some cases supplementary service reservoirs are placed at the higher parts of the town to facilitate and regulate the distribution of water but more frequently the aqueduct leads directly to the smaller pipes which run along the streets and are known as the *distributing conduits* and *mains*. If there is a wet system of sewerage in the town it is important to lay the water mains as far as possible from the sewer-pipes for fear of leakage and contamination. From the mains the smaller *service pipes* carry the water to the houses where the *house pipes* convey the water, if the pressure is sufficient, all over the house. As regards material, all the pipes with the exception of the house pipes are made of iron as a rule and are frequently coated internally with bituminous or other substances to prevent contamination of the water. The house pipes are usually made of lead on account of the numerous turns necessary in leading the water through the house, but, however convenient in practice, it cannot be deemed a suitable material from a hygienic point of view.

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* This can be most conveniently done in places where the *Shone* system of wet sewerage is in use, by means of compressed air, as at Rangoon.

† As in Madras *v.* Appendix. Water supply of Madras.

In the early days of improved water supply in England the water was delivered on what is known as the INTERMITTENT SYSTEM which is still continued in a few towns but is rapidly falling into disuse.* Under this system water is delivered only at certain times, generally in the morning and evening and for an hour or two only, the supply being then cut off in order to save waste. Each house must have one or more cisterns in which to store a supply of water for use until such time as it is turned on again at the water-works. The principle disadvantages of this system are as follows: (1) The presence of cisterns in a house: they are almost certain to become foul. (2) The water is stagnant and absorbs impurities, *e.g.*, Sewer gas. (3) The supply pipes are left empty and are thus liable to draw in impurities, liquid or gaseous, by suction. (4) The pipes are exposed alternately to the action of air and water and are thus more likely to become corroded and the water rendered impure by metallic impurities, such as lead. (5) In the event of a fire occurring in the neighbourhood there may be no water at hand to quench it. (6) The noise of the water rushing into the cisterns twice a day is often distressing to invalids, particularly in small houses. If cisterns must be used, they should be of suitable material,† covered but ventilated, situated in a convenient place for inspection, *e.g.*, the roof of the house, and when the wet system of sewerage prevails a small and entirely separate cistern for flushing the water closets must be provided. They should be frequently inspected and cleaned. Under the CONSTANT SERVICE SYSTEM, which has almost entirely replaced the Intermittent, these evils are reduced to a minimum. Here the supply pipes are constantly kept full under considerable pressure, so that water can be obtained at any time and in any amount by simply turning

* Not necessarily in the East. In Calcutta there is an intermittent water-supply, during 14 hours daily, of over 44 gallons per head. (*v.* appendix). When an unlimited supply of clean water is furnished to an ignorant population, they are very apt to go to the opposite extreme from their usual habits; from the common use of a filthy pool to reckless individual waste of good water.

† *v.* under Storage of Water.

a tap. In order to prevent leakage the fittings must be very good, and meters or gauges must be placed on the pipes at intervals so that waste of water in any particular instance may be detected. Cisterns with all their attendant evils are, of course, under this system unnecessary.

Save in the largest towns, the distribution of water throughout India is at present almost entirely by the Direct Method. Owing to caste rules and other social customs the water for each household is drawn from a tank, well, or stream by some member of that household. In this way a careless or ignorant person may endanger the lives of many others by the use of a dirty utensil. The possibility of such an occurrence should be prevented as far as possible. In times of water-famine, disputes between different castes as to the exclusive right of use of particular wells are frequent and are the cause of much cruelty and injustice being done to the inferior caste. On the line of march and in action the services of the *pakâli* and *bhisti* will always be required and they cannot yet be dispensed with in mufasil hospitals and barracks. Their water-skins require frequent and careful inspection.*

The Quantity of Water Required.—The quantity of water necessary for health, directly or indirectly, is next to be considered and also the various purposes for which it is required. The golden rule of course is to supply a practically unlimited amount of pure water whatever be the use it is to be put to. But this is not always possible, hence the necessity for considering the minimum compatible with health. Accurate experiments in India on this matter, as on nearly every other matter connected with the details of hygiene, appear to be wanting. The manner in which the supply is obtained has a great effect upon the quantity used. If water has to be drawn from deep wells or even pumped up by members of the household, much less will be considered necessary for health and comfort. If the supply is constant and requires only the turning of a tap, there will be

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* *v.* Impurities of water.

more or less waste, and the quantity consumed will exceed the quantity really required. Except on boardship it rarely happens that an attempt is made to distribute to each individual or to each family the theoretical ration, but it is frequently calculated per head for the population of a town by dividing the total amount available or supplied, by the total population of the town. The following table gives a fair idea of the average quantity required per head in an English manufacturing town and the various purposes for which it is needed.

	Gallons per head daily.
A. *Domestic Use:*	
1. Drinking (besides which 30-50 ozs. is taken in bread, meat, etc.) ...	0·33
2. Cooking	0·75
3. Ablution, including bath (2½ galls.) ...	5·00
4. Share of utensil and house-washing...	3·00
5. Share of clothes-washing	3·00
6. Water-closets	6·00
7. General bath (weekly about 30 galls.)	4·00
8. Unavoidable waste	3·00
	25·08
B. *Town and Trade purposes:*	
9. Washing streets, etc., extinguishing fires, supplying fountains and drinking troughs, etc., allowance for trade and for animals	5·00
10. Allowance for exceptional manufactures.	5·00
	10·00
Total...	35·08

In India more will be required for most purposes, particularly bathing, but none directly under the items 5 and 6, and very little under 10, save in special cases.

The water required for food is partly drunk and partly sued for cooking. Under ordinary circumstances of temperature and exertion 0·4 gallon will be sufficient for the former purpose for a man in 24 hours. More will be required if the heat is great, or the exertion undergone severe. As women and children drink absolutely less than men, this allowance will be sufficient when supplied for each of the residents of a barrack, jail or town, or the members of a household of average composition. For cooking 0·6 gallon will generally be a sufficient allowance, making the total for food one gallon daily for each individual, and this is the quantity found necessary on boardship in the tropical seas. As a general rule, the water supplied for the two food purposes will be the same, but a difference may sometimes be compulsory. In this case it is to be remembered that saline waters unfit to drink may be freely used for cooking; and, on the other hand, that water of considerable temporary hardness may be palatable and wholesome to drink but unsuited to culinary use.

Washing of persons and cattle, clothing, houses, furniture and utensils is of very great importance to health, and ample provision should be made for it. For bathing the quantity needed varies considerably, a bath-tub requiring at least 30 gallons for comfort and often containing more than 50, while 12 gallons poured over the body from chatties affords a bath considered amply sufficient by many persons, and four gallons are enough for a sponge-bath. A plunge-bath measuring 20 feet by 12 by 5 holds 7,500 gallons of water, and if supplied continuously, so that it it should receive in two, or even in three days that amount of fresh water (entering above at one end and issuing below at the other), will provide ample means of ablution for a regiment, or the inmates of a large jail. In this country, where a complete bath daily is habitually taken and is necessary to health, provision for minor ablutions may be considered as included in the estimate for baths. The quality of bath-water is comparatively of little importance; it should be *water* however, and not the filthy putrescent liquid which fills so many of the tanks, sacred or otherwise, of India. It should not be muddy; and if it is too salt or too hard soap will be wasted.

The customs of the country relieve us from the necessity of providing water for the washing of clothing, for which dhobies are trusted to make their own arrangements, such arrangements being almost invariably insanitary and disgusting in the highest degree. As regards dwellings, floors of earth or plaster will not admit of washing; and walls, unless finished with polished chunam, are cleaned by sweeping or by a fresh coat of lime-wash. An allowance of two gallons per head will be ample for the maintenance of houses, jails or barracks in a state of proper cleanliness. For utensils three gallons will be sufficient.

It is apparent from the foregoing paragraphs that the total quantity of water necessary for a community varies within very wide limits according to circumstances. It is useless, therefore, to attempt to lay down precisely any general rule. The figures given above afford the means of estimating total requirements in any particular case.

Hitherto the wants of persons in ordinary health have been considered. Hospitals require a much more copious water-supply, in proportion to their number of inmates, than other dwellings. More water is drunk, more liquid food is consumed, baths are more frequent and more abundant, the boiling of clothing and bedding before sending them to be washed is often desirable, extreme cleanliness of floors, walls, cots and utensils of all kinds is essential, irrigation and washing of wounds, bruises, etc., consume a large amount of water. The supply to a hospital, therefore, should, if possible, be unlimited and waste is a less evil than even trifling deficiency. Should the total supply be limited, economy should be practised at the expense of the healthy, and the hospital amply provided. If it should be necessary to make an estimate for hospital use, 30 gallons per head will not be excessive for drinking, cooking, bathing and washing.

The quantity of water which should daily pass through sewers, in order to maintain their cleanliness, cannot be fixed: so much depends on their fall and shape and on the materials which are permitted to enter them. When solid and liquid excreta have to be removed by them, a minimum of 25 gallons per head daily (besides rain) has been laid down; but this is a case with which we are not likely to be called upon to deal. As a rule, our sewers will contain only the liquid refuse of the cook-rooms, the washings of houses and utensils, and the water which has been used for bathing; and the last will generally be sufficient, with ordinarily well constructed sewerage, to dilute and remove the others. Sewers will require watching to ensure their freedom from obstruction and from consequent generation of noxious or unpleasant gases; and flushing copiously with water of any kind will be the remedy, when they become foul. *The best test of the satisfactory state of sewers is not the quantity of liquid which they receive, but the quality of the discharge at their out-fall.* When this is scanty, semi-solid or offensive, careful cleansing followed by free flushing is indicated.

Provision has to be made for cattle also, both for their drink and for the preparation of their food. The quantity required for the former will vary, as in the case of men, with temperature and work; but the following numbers may be taken as applicable to ordinary circumstances in this country:—

Horse	8 gallons.
Bullock or cow	8 do.
Mule	6 do.
Pony	6 do.
Elephant	30 do.
Camel	12 do.
Sheep	1 do.
Pig	1 do.

Unless water of the best quality is scarce, it should be supplied to cattle for their drink. When they are fed on *chenna* which requires only steeping in cold water for its preparation, or when *khulti* is used without boiling, a gallon of water may be allowed for four "measures" of the food; when boiling is considered necessary, the allowance should be two gallons. As regards the quality of the water used for this purpose, the same remarks apply as in the case of preparing human food.

If it be necessary to make provision for the washing of other animals (to whose health and efficiency a clean skin is scarcely less essential than it is to their owners') two gallons should be allowed for a horse, bullock, cow or buffalo, and corresponding quantities for others in proportion to their size.

The effects of Insufficient Supply of water are closely connected with those of impure supply, and also with those of a polluted atmosphere. Absolute privation of water for drinking need not be considered here; partial privation is productive of so much inconvenience or suffering that any kind of water will be drunk—even from the foulest pools—to satisfy thirst. Not only, however, does this indirect evil consequence follow from want of drink, but also great muscular debility, with disinclination to and incapacity for exertion. It follows that a constant supply of the best drinking water available is essential to the efficient performance of labor of every kind, and that for soldiers on march or in action, for coolies at work, or for prisoners undergoing really hard labor, water should always be at hand to compensate the loss by lungs and skin. Under such circumstances, water should be, not merely procurable, but conveniently obtainable at any moment, so that the needful supply may be taken in small quantities from time to time, not in copious draughts at once. When water for cooking is insufficient, the processes necessary to the digestibility of food will be unsatisfactorily performed; or the same water used more than once will be more liable to putrefactive changes and consequently more likely to act injuriously both through stomach and lungs than if it were used once only and then removed. It is unnecessary to dwell upon the necessity of cleanliness to health. Insufficiency of water for personal ablution is incompatible with the due action of the skin which, in hot climates more especially, is of vital importance, and skin diseases as well as a generally depressed state of health will inevitably follow; while the atmosphere is polluted by effluvia, in great part organic, from unwashed or imperfectly washed clothes, furniture and utensils. People can be 'educated up,' as it were, to the use of sufficient water, as is well seen in England, since the introduction of a suitable water supply in towns and country districts. Lastly, if the water supply is insufficient for other purposes, it must be altogether inadequate to the free removal of refuse by the sewers. If these are intended to convey not only water which has been used but also excreta, the propagation of enteric fever, cholera and other diseases, and *possibly* the origination of the first and others, will be favored by the clogging of the sewers and the drying of their contents. In ordinary cases the air will be poisoned by noxious gases and organic effluvia generated in uncleared sewers.

THE COMPOSITION, IMPURITIES AND CLASSIFICATION OF DRINKING WATERS.

It is neither necessary nor desirable that water used for drinking or other domestic purposes should be absolutely pure. Such water would be insipid and perhaps unwholesome. Impurity to a certain extent is practically inevitable and neither disagreeable to the taste nor injurious to the health. A good water then is not one which is chemically pure, but one which is *transparent, colorless, odorless* and *tasteless,* which holds in solution a *sufficient amount of atmospheric air,* which contains *no suspended matters* and *no excess of total solids* nor of any particular substance dissolved.* The

* Good water, though tasteless, has a peculiar quality due to the dissolved gases, oxygen, nitrogen and carbonic acid, more especially the last: the absence of such gases rendering a water 'flat,' as in the case of distilled water. When carbonic acid is present in excess, as in soda-water, the water is said to be 'aërated.'

Impurities in water are either Suspended or Dissolved and may be roughly classified thus ;—

In Suspension.

Particles of animal, vegetable and mineral origin.
Microbes and other living organisms, vegetable and animal.

In Solution.

Gases.
Mineral salts.
Soluble organic matter of animal and vegetable origin.

Suspended Impurities are Inorganic or Organic. Inorganic impurities may consist of very finely divided silica, clay, chalk, chalky marl, ferric oxide, magnesium carbonate or other mineral substances. Rivers, especially in time of flood, carry down variable quantities of suspended matters, mostly inorganic. Thus the Rhine water contains from 1·73 to 20 parts in 100,000 ; the Mississippi from 58·82 to 80·32 ; the Ganges from March to June 21·71, from June to October 194·3, from October to March 44·86 ; the mean proportion of suspended matter being 86·86 in 100,000. Tank and shallow well waters also, especially after rain, are turbid from this cause. Such waters containing suspended mineral matters in excess may produce diarrhœa, dysentery, and even ulceration of the intestine, to which persons not accustomed to their use will be more liable. Organic impurities are more varied and more important. The *débris* of animal and vegetable organisms ; ova, seeds and germs ; living animalcules and plants of a low order ; fæcal and other excrementitious matters ; the specific poisons by which cholera and many other diseases are propagated—all these may be amongst the impurities suspended in water. Even rain water may contain some of these, but all of them may be carried from the surface into tanks and rivers or washed into wells by floods or percolate into them through the soil. Microbes of all kinds and in any number may be present. The great majority of these are probably harmless; many are undoubtedly useful as purifying agents, whilst others again, as the immediate cause of specific diseases, may work deadly mischief by their presence.

DISSOLVED IMPURITIES may be Gaseous or Solid, the latter being organic or inorganic. The Gaseous substances requiring to be noticed are *air, carbonic acid, ammonia, sulphuretted hydrogen* and *marsh-gas.*

The presence of AIR or, to speak more correctly, of a variable mixture of oxygen and nitrogen, rarely containing the same proportions as the atmosphere, is necessary to render water palatable and readily digestible. The oxygen is more readily absorbed by water than the nitrogen and it is also evolved by certain water plants; hence it may amount to as much as 32 per cent. of the total quantity of both gases present. Neither can do any harm, while the oxygen is useful by converting decomposing animal and vegetable substances into innocuous compounds. Water is rarely deficient of air; but when (as in distilled water) there is a deficiency, it should be artificially supplied, either by forcing air into the water or by letting the latter fall in divided streams, as through holes bored in a cask, from as great a height as possible, through air.* We may infer the presence of much oxygen if we have reason to believe that carbonic acid is present in abundance, unless in the case when the latter is formed from organic matter at the expense of the former.

CARBONIC ACID gives a sparkling appearance and a pleasant taste to water, and it can only be injurious by enabling water to hold in solution large quantities of carbonates of calcium, magnesium, etc. It may be derived (1) from decomposition of carbonates by subterranean heat, as in the case of carbonated springs; or (2) by absorption from the atmosphere, one volume of water at 20°·0 being capable of absorbing 0·901 of this gas; or (3) from the soil through which the water percolates, the air in which

* *v.* p. 52.

contains in some instances 250 times the normal proportion of carbonic acid; or (4) from the slow combination of the carbon of organic substances in the water with oxygen, in which case it represents putrescible and possibly injurious matter destroyed. Its amount in ordinary water varies from 3 to 300 c. c. per litre or parts per 1000. It is known to be present in considerable quantity when bubbles are seen on the inside of a glass vessel in which water is permitted to remain for some hours. Present in large amount it sometimes gives an acid reaction to test paper, the acidity being removed by boiling. Boiling removes it and the greater part of other gases; lime combines with it, the carbonate thus formed and other carbonates held in solution by it being precipitated.

Free AMMONIA is derived from the decomposition of nitrogenous organic matters, chiefly animal, in the water itself or in the soil through which it percolates, or from the atmosphere through which it falls. It is almost invariably present in ordinary waters. It is not in itself mischievous, but its presence in large amount indicates serious organic contamination. If present with nitrates or nitrites, or both, it is probably due to the decomposition of animal matters. If nitrites in abundance and ammonia co-exist the contamination is probably recent. Its odor betrays its presence if the quantity be considerable. Turmeric paper browned by alkaline water recovers its colour on exposure to air if the alkalinity was due to free ammonia. The reagent known as Nessler's solution will detect the presence of minute quantities of free ammonia by giving the water a yellowish coloration when added, or even throwing down a brown precipitate if the ammonia is present in large amount.* Filtration through fresh charcoal will remove ammonia from water and, to a great extent, the organic matter which generates it.

SULPHURETTED HYDROGEN.—When water contains a sulphate in solution (as that of calcium or of sodium) and also

* v. under Examination of Water.

organic matter, the latter takes oxygen and converts the sulphate into a sulphide; or a mineral sulphide such as pyrites may be present. This again being decomposed by a free acid, (probably organic, possibly by carbonic acid), SULPHURETTED HYDROGEN is the result. It is also one of the products of the putrefaction of albumen. Water in contact with it at 15° absorbs 3·23 volumes. The peculiar odor of this gas renders its presence even in small quantity readily perceptible, especially with the aid of gentle heat, and a solution of lead acetate in solution of soda gives a black or brown color with water which contains it. Boiling, agitation, exposure to air in divided streams, filtration through charcoal or addition of lime removes it from water.

MARSH-GAS is evolved in the slow decomposition of vegetable matter, air being excluded; but is only very slightly soluble in water. It would be found in marsh waters; and certain foul river waters, that of the Thames for instance, undergo when kept for a few days a kind of fermentative purification, during which great part of their organic impurity is given off in the form of marsh-gas and sulphuretted hydrogen. It may leak into water from gas-pipes. There is no reason to suppose that its presence in drinking water is mischievous. Boiling or exposure to air in divided streams frees water from it.

Dissolved Solid impurities are organic or inorganic; the former being the more important. The presence of Organic matter in solution is almost inevitable. Even rain dissolves and carries down some from the atmosphere and water which has percolated through the purest granitic or clay-slate soils may contain from four to ten milligrams per litre. Water collected from rich cultivated soils sometimes yields a volatile residue of 4 to 7 ctgms. per litre (parts per 100,000) or even more, while this amount is considerably exceeded in peat waters and marshes. In these cases the impurity is chiefly or wholly of *vegetable* origin, consisting of humin, ulmin and organic acids derived from these, none of which contain nitrogen, though the acids readily form ammonium salts when the base is supplied. *Animal* organic matter passes readily into waters derived from the neighbourhood of dwellings, which have washed or percolated through filth-soaked ground, or which have been polluted by communication with cess-pools or other accumulations of impurities. Dead animals slowly decompose in rivers, tanks and wells, and water from burial-grounds finds its way into sources of supply. Urea readily becomes ammonium carbonate, and a large proportion of the products of decomposition of animal substances contains nitrogen, which forms ammonia in the soil, and this is oxidized, with greater or less rapidity, to nitrous and nitric acids. Hence, water which has been exposed to pollution by animal impurities may contain in solution not only free ammonia but ammonium salts, nitrites and nitrates. Again, the decomposition of bodies of animals produces certain fatty acids, butyric and others, not nitrogenous, which form, with calcium and other bases of the soil, salts soluble in water; and these are probably not the least important dissolved impurities of organic origin. But little, however, is really known of the exact nature of the organic matter in water, for it is usually small in amount, unstable, varies much in its chemical composition and is highly complex.

Closely connected with the organic matters in solution into the composition of which nitrogen enters, are AMMONIA, NITROUS ACID and NITRIC ACID. The presence of any one of these implies, as a general rule, the previous solution of nitrogenous organic matter in the water. Though, therefore, none of them (except, perhaps, the second) is directly injurious to health, it is important to ascertain their presence and amount. Free ammonia has been considered already. The presence of nitrites in large proportion indicates a probable recent contamination with animal organic matter. They are easily oxidisable into nitrates. The presence of nitrates generally points to animal contamination. If no nitrites and little ammonia be present at the same time, the nitrates of potassium, sodium and calcium probably indicate that the contamination is of long previous occurrence. So too, nitrates in abundance with little oxidizable matter, indicate old animal impurity. The process of 'nitrification,' *i.e.*, the oxidisation of organic matter with the formation of nitrates, seems to be largely dependant on the action of microbes of several kinds, nitrites being primarily produced by the action of a particular micro-organism, and these being changed into nitrates by another microbe.* The nitrates are gradually removed and assimilated by the roots of growing plants.

The Inorganic dissolved impurities consist of mineral salts in solution derived from the strata through which the water has passed. In analysing these substances the various acids and bases can only be detected individually, the mode of combination being uncertain.

The chief ones are as follows:—Sodium, potassium, calcium, magnesium, iron and lead, in combination with chlorine, sulphuric, nitrous, nitric, phosphoric, carbonic or silicic acid. The most usual combinations are sodium chloride, sodium sulphate, sodium carbonate, calcium carbonate (held in solution by carbonic acid), calcium sulphate, calcium chloride and silicate, and magnesium carbonate; but the results of analysis may render other combinations necessary.† In addition, certain metals such as arsenic, magnesia, iron, lead, zinc and copper may be present: of these iron and lead are the most important practically, especially the latter. SULPHURIC and CARBONIC ACIDS will be considered in connection with the bases with which they are found in combination. NITROUS and NITRIC ACIDS have already been discussed.‡

CHLORINE is almost invariably present in natural waters, in combination with the alkaline metals or calcium. Even

* The oxidising power of the organisms in soil is by no means limited to the oxidation of ammonia or of organic matter, *e.g.*, iodides and bromides may be oxidised into iodates and bromates. *v.* Thorpe, Dict. of App. Chem., Vol. II, p. 699.

† *v.* Parkes—Notter, *ibid.*, p. 49. ‡ *v.* previous page.

rain water has been found to contain as much as 0·020 grm. of sodium chloride (0·012 grm. chlorine) per litre derived from sea-spray and which has been carried hundreds of miles inland by winds. This is one source of the presence of this salt in other waters ultimately derived from rain. Formations deposited originally in sea-beds or salt lakes undergoing a process of dessication (?) retain the sea-salts, including magnesium, potassium and especially sodium chlorides: and occasionally the latter two are found in mass.* Direct percolation from the sea is another source of chlorine in other waters. Lastly, sewage containing the excreta of men and animals includes a large proportion of sodium and other chlorides, which it imparts to water in contact or communication with it. It is owing to this last possible origin of chlorine in drinking waters that an exaggerated degree of importance has been attached to its presence. This is its least likely source, in this country at any rate; and its derivation from such organic contamination will always be indicated by the accompanying presence of other products of sewage pollution.

Waters not unfrequently contain phosphates in solution and, as these may have been derived from sewage or from animal remains as well as from harmless minerals in the soil, it is desirable to ascertain whether PHOSPHORIC ACID is present.

The silicates of soda and alumina are sometimes present but there is no reason to suppose that SILICIC ACID is of any importance from a sanitary point of view. Some, however, consider that in its absence water is enabled to exert a solvent influence on lead.†

CALCIUM is the most important of the bases found in water, whether used for drinking, cooking or washing. It is the principal cause of *hardness*, which, if excessive,

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* For interesting account of various salt-formations in India, *v.* Geology of India, Pts. I and II.

† *v.* Lead, p. 74.

renders water unfit for culinary purposes and causes great waste of soap in the cleansing of the person or of clothes. Its salts, so far as our purpose is concerned, are the carbonate on one hand, removable almost completely by boiling, and the sulphate, chloride, nitrite, nitrate and butyrate on the other; the latter group (to which the hydrate may be added) remaining in solution after the carbonate has been precipitated. As water percolates through soils it dissolves out more or less completely the lime salts almost always present. Spring, well or river water, therefore, generally holds calcium compounds in solution, and even rain water is rarely free from traces of them derived from the atmosphere.

It has been already stated that calcium exists in water in two kinds of combination and the distinction is of great importance both from the sanitary and from the economic point of view. Calcium carbonate is soluble in pure water only to a slight extent, about 30 milligrams per litre, but is freely soluble in water holding carbonic acid in solution. Rain as it falls takes up this acid from the atmosphere, and, as it percolates through the soil, the interstices of which often contain air highly charged with carbonic acid, it absorbs still more. The water thus becomes a solvent of any carbonate of calcium (and also of carbonate of magnesium or of iron) which it meets in the soil. Hence the water of chalk or limestone formations holds always a considerable and sometimes a very large proportion of calcium carbonate in solution, by means of carbonic acid. The expulsion or neutralization of this acid necessarily destroys the solvency of the water, and, as this can be effected by boiling (which drives off the acid) or by adding lime (which combines with it) this lime salt is readily removable from water. Hence hardness depending on the presence of carbonates thus held in solution is called *removable* or *temporary* hardness; and, as calcium salts are the principal cause of total hardness, so *calcium carbonate is the principal cause of temporary hardness.*

The presence of this salt will be made evident by boiling the water for half an hour in a glass flask. The carbonic acid will be thus driven off and any carbonates present thrown down. Another means of removing calcium carbonate, so far as its presence depends on free carbonic acid, is by 'clarking' the water, as it is called. Mr. Clark's process consists in adding lime to the water, which combines with the free carbonic acid to form carbonate, which, along with the carbonate which is now thrown out of solution, gradually subsides; carrying with it, as we shall see,* organic and other matters in suspension. It must be borne in mind that this process removes temporary hardness only, while it adds slightly to the permanent hardness, to the extent of the lime which is taken into solution. It is applicable, therefore, to waters containing a large quantity of carbonates in solution and not containing an excess of other calcium salts.

The other calcium salts, which are not precipitated by boiling, are more important than the carbonate, because their effect upon the health, even in small quantities, is injurious; while they are equally objectionable economically. The Sulphate is the most common, and next to this the Chloride, Nitrate and Nitrite. *The permanent hardness of water is mainly due to these salts*, which remain in solution after the carbonate has been precipitated by boiling or the addition of lime. Organic fatty matters undergoing putrefaction often generate butyric acid, which, itself highly irritating, combines with calcium to form a poisonous butyrate.

MAGNESIUM is a much rarer impurity than calcium; but it is found in water from many Indian stations.† Its salts are second in importance, as causes of hardness, but their presence in excess is very likely to produce intestinal derangement. When water is boiled to expel carbonic acid

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* *v.* Purification of water.

† *e.g.*, Coimbatore, Salem and Bellary in the Madras Presidency.

magnesium carbonate is deposited with calcium carbonate, but as the water cools, the former is re-dissolved.

Iron is a third cause of hardness. Few of our waters are altogether free from it and it is present in most cases as the carbonate, held in solution by free carbonic acid, whence it follows that it is thrown down by boiling, along with the calcium and magnesium carbonates. *Taste* detects a smaller quantity of iron than of any other impurity, and it is said that 3 mgms. per litre give an appreciable chalybeate flavor. Boiling, lime and perhaps filtration remove it.

The Sodium salts generally found in water are the chloride and the sulphate, and it is usual to suppose all the chlorine combined with sodium if the latter is present in sufficient quantity. The presence of common salt in water, unless largely in excess is, in itself, rather beneficial, especially in India. It *may* be derived from sewage contamination, especially recent contamination with urine, but in the majority of instances in this country it has no such origin. When so derived other evidences of pollution cannot fail to be present. It may be partly removed from water by filtration through a considerable thickness of sand and charcoal, and in this way brackish water may be rendered fit for use. The sulphate is not likely to be present in hurtful amount, but the carbonate if present in a proportion of more than 3 dgms. per litre (0·3 parts per 1,000 of water) renders the water unfit for continued use.

Lead salts are occasionally found in natural waters, but most commonly in water which has passed through leaden pipes or been kept in leaden cisterns. The solvent action of water on lead depends upon the nature of the impurities which the former contains: water absolutely pure being itself, in the absence of air, incapable of acting on the metal. Any impurity which forms, directly or by decomposition, a soluble lead compound favors lead contamination. Thus water containing oxygen, air, organic acids (animal or vegetable), nitrites, nitrates or chlorides should not be kept in contact with lead. Hence rain water, water containing sewage, or water which has lain on rich vegetable mud should not be conveyed or stored in lead. Others again attribute the solvent action of some water to the presence of certain micro-organisms ; yet others to the absence of silica from the water.* The matter is still undecided.

On the other hand an impurity which forms an insoluble lead salt, or which deposits a coating impervious to water upon the metallic surface, exercises protective influence against lead poisoning. In this way carbonic and, sulphuric acids, or decomposable carbonates and sulphates, forming insoluble lead salts protect from the usual consequences of the presence of lead—with this exception, that if free carbonic acid is present it renders part of the lead carbonate soluble. Hard waters deposit a protective crust which is found to consist of the carbonates, sulphates and phosphates of lead, calcium and magnesium. Calcium phosphate is especially protective.

The symptoms of lead poisoning (Plumbism) ore so well known that they need not here be described.† The quantity of lead likely to produce intoxication varies with individual peculiarities, but any water containing more than 1 part per 1,000,000 is unfit for domestic use. It is obviously much better that there should be none. When lead is present at all, accident, carelessness or mismanagement may readily cause increase in its amount from a harmless to an injurious degree.

Numerous remedies have been proposed having one of two objects in view, *viz.*, either the neutralisation of the solvent action of the water or the substitution of some material other than lead in the construction of the water-pipes. As regards the first, the remedy obviously depends on the cause, hence the addition of powdered chalk or

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* *v.* Silica, p. 71.

† *v.* Quain's Dict. of Medicine, p. 812 *et seq.*