SANITATION IN WAR

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J. & A. CHURCHILL

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SANITATION IN WAR

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confident hope that the knowledge gained in those years of progress would lead to the successes of peace time finding their counterpart in a marked reduction of the high rates of sickness which have hitherto been regarded as inevitable in the field. To the attainment of that aim there is one essential condition—the intelligent co-operation of the whole personnel of the field force—and it is upon the knowledge of sanitation possessed by medical officers that this essential condition primarily depends. To the R.A.M.C. officer the sanitary methods of field service are necessarily familiar; the civilian practitioner who serves with the army for the first time finds himself at a grave disadvantage when faced by problems in the solution of which the training provided by the civil medical curriculum affords little assistance.

In order therefore to lighten the difficulties of those practitioners who have loyally volunteered their services, a series of lectures dealing with subjects of practical value in war have been organized at the R.A.M. College. The appreciation of those gentlemen who have attended these lectures has indicated that the information thus summarized would prove of value to those who have been unable to attend the various courses arranged.

The wider the scope and the more precise the knowledge of medical officers on all matters affecting the health of the troops, the greater will be the measure of success attending their efforts to maintain that fighting efficiency upon which depend to so great an extent the prospects of a speedy and successful conclusion of the war.

ALFRED KEOGH

PREFACE

The medical officer who essays to write a book finds that the nomadic life of the service has prevented the collection of notes, cuttings, and annotated works of reference which are so essential to accurate speed.

During war the difficulties are enhanced by the absence on service of most of the colleagues whose aid would otherwise have been as freely given as frankly sought, while the few left stranded at home are so overworked that they are immune from appeals for help.

There remain only the facts, figures, and impressions that memory has stored in its many odd corners, whence they must be extracted, dusted, and marshalled during the hours that in less strenuous times would be devoted to peaceful slumber. Well as these may serve for the lecture-room, they call for confirmation and amendment in the light of recent investigation before being embodied in the text of a book, but for this purpose war-time affords no opportunity.

The past few months have witnessed the dislodgment of many—both at the front and at home—from secluded corners for which they have a strong preference: they have been forced from their quiet dug-outs into the danger-zones of the plateau and the platform. Among the number is the author of this work, who has been allotted the duty of assisting newly joined officers by lectures purporting to give an insight into the mysteries of sanitation on active service. The favourable reception accorded to these efforts indicated that to some extent they met a definite need, but many appeals for publication fell upon deaf ears until a wish expressed by "higher authority" led to the production of this unpretentious little volume. The difficulties referred to make it unavoidable that these lectures, if published at all, must be published practically as they were delivered and without the careful revision which other conditions would have made imperative. It is therefore advisable to forestall the inevitable avalanche of adverse criticism by frankly admitting their manifold defects and shortcomings.

Those defects would have been numerous and glaring indeed but for the kindly and invaluable aid of those friends who have remained within reach, and this opportunity is welcomed of gratefully acknowledging my indebtedness for the help given by Colonel W. H. Horrocks, K.H.S., A.M.S.; Lieutenant-Colonel D. Harvey, R.A.M.C.; Lieutenant C. J. D. Gair, F.C.S., R.A.M.C. (T.F.); Mr. H. Marshall Webb, B.Sc.; Dr. A. Strahan, of the Geological Survey Department; and Corporal J. A. Sadd, B.Sc., A.C.G.I., R.A.M.C. (T.F.).

P. S. L.

R.A.M. College.

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LECTURE I

PHYSICAL FITNESS FOR WAR

INTRODUCTION

GENTLEMEN,—When the news was broken to me—none too gently—that I, as a suspected expert, was to deliver these lectures, I recalled the cynic's definition of an expert as "one with just sufficient knowledge to mask a colossal ignorance."

The definition suggests the advisability of seeking refuge in safe seclusion, and—on being haled into the embarrassing prominence of the platform—I hasten to forestall detection by forthwith confessing to a colossal ignorance of the *science* of hygiene. As regards the *art* of sanitation, however, the medical officer is—necessarily—less ignorant, and it is upon this factor in the important duty of maintaining the health of the army in the field that I would therefore concentrate attention.

Sanitation, as I think you will agree, is not the subject that one would select with the object of being interesting, and the unpromising nature of the subject is enhanced by the difficulty caused by the fact that so many degrees of knowledge are represented in the audience. It is no easy matter to avoid, on the one hand, boring the officer who has had considerable experience of camp life or, on the other hand, neglecting the officer who is now facing these problems for the first time.

On each of the matters which must be dealt with there are some among my audience who are better qualified to lecture than to listen. There is, however, encouragement in the fact that the true expert is ever the kindliest critic of the efforts of others to deal with those problems of which he alone fully appreciates the inherent difficulties. In any case, the fact of your presence indicates that we have a community of interest which will ensure me a kindly and sympathetic hearing.

And now to pass on to the orthodox opening—by definitions.

Definitions

Hygiene is the science of health maintenance. Like all sciences, it concerns the investigation and enunciation of immutable laws.

Sanitation is the art of practically applying the laws of hygiene to individual environments. Like all arts, it involves adjustments as variable as the changing conditions which must be met. It is a somewhat important art, in that failure in adjustment may be followed by the extreme penalty—death.

Conservancy is that branch of sanitation which deals with the disposal of waste products. This sanitary necessity stands in relation to one of the most definitely established laws of hygiene which has yet been enunciated—that all life is choked by the accumulation of its own products.

A. THE RECRUIT

Passing from definitions, one would next consider the recruit. The chief essentials in war are, first, to get the greatest number of men into the highest degree of efficiency—fighting fitness; next to get them, fully equipped, into the firing line; and, finally, to keep them there. Therefore the logical beginning is with the recruit, *i.e.* the securing of suitable physical material. So one takes for preliminary consideration the weeding-out of the unfit.

1. Preliminary weeding-out of the Unfit

There are two aspects of unfitness—the physical and psychological.

With regard to the physical, we are all agreed that if a man is unfit physically or physiologically there is no question about his being rejected. The medical officer, in examining a recruit, is mainly concerned with his physical fitness, while, on the other hand, the combatant officer, to whom he is passed for training, also has to consider his mental and moral qualities. In many cases a man physically fit is mentally unfit for development into a really good type of soldier; and there is a tendency on the part of some combatant officers to try to use the medical officer as a means of getting the psychically undesirable man out of the Service. But the medical officer has to remember that in this respect he is, to some extent, a custodian of the public purse, and that every recruit, before the three months of his training are passed, has cost the Government £100 in hard cash. When the recruit after a certain amount of training is not a success, the combatant officer should deal with the difficulties which confront him in regard to the cultivation of the man's mental and moral qualities or himself take the responsibility of the man's rejection.

Having secured an initially sound body of men in the prime of life, it must be next considered what, precisely, are the objects of their training.

2. Objects of Training

The precise objects of training may be grouped under two heads: (1) enabling the recruit to march, (2) enabling him to fight.

(*a*) *Marching* consists in a man carrying himself and his equipment into the firing line, and marching powers determine the all-important preponderance of numbers at the critical point. The development of any great excess of muscle beyond that called for by these requirements should not be aimed at in training. The muscle-bound man is less active than is the man of whipcord and endurance, and the principal object of training is not to produce "strong men" in the popular sense of the term. We want to get our men strong enough to do the necessary work, with a little to spare, but after that our aim should rather be the maximum of endurance than the maximum of muscular bulk.

(*b*) The next requisite is that, having marched to the firing line, the men should be able to make the best use of their fighting powers when there. This involves proficiency in the use of their weapons, effective agility, and educated military intelligence. Higher speed and co-ordination in military exercises are matters of training which pass under the control of the combatant officer.

3. Causes of Physical Failure of the raw Recruit

A study of the physiological reasons why the raw recruit fails in exercises which tax his strength and endurance should enable us to consider intelligently the means of training best calculated to remedy those causes of failure.

This leads us first to consider (*a*) why the recruit when untrained is unable to maintain *any intense physical effort.*

The skeletal muscles are atonic and loaded with interfibrillar fat. This initial disadvantage is accentuated by the fact that lack of educated co-ordination leads to their doing far more work than is necessary to produce the required results.

The heart—especially the right heart—is too flabby to maintain the blood-flow against the increased blood-pressure, and it therefore tends to become distended. This mechanical disadvantage is increased by exaggerated action of the expiratory muscles, which are automatically stimulated into violent effort by excess of CO_2 in the blood reaching the respiratory centres. The resultant high intrathoracic pressure dams back upon the right heart the blood which the distended right ventricle is striving to force into the pulmonary vessels.

Next we have to ask ourselves (*b*) why the recruit succumbs so early to fatigue after *moderate, prolonged effort.*

This disability is due in large measure to the accumulation of the waste products of muscular action, which accumulate because the impeded heart is unable to maintain the necessary flush of blood through the capillaries of the muscles and excretory organs. Such products, for example, as sarcolactic acid, which the congested lungs cannot oxidize with sufficient rapidity, paralyse all muscular nerve-endings, thus blocking motor stimuli at the nerve-muscular junctions. This adversely affects muscular action throughout the body, but reacts with worst effect on the circulation. Failure of the cardiac muscle results in irregularity, rapidity and weakness of the pulse, which tends to become markedly dicrotic, while passive vaso-dilatation accentuates the resultant low blood-pressure.

The vicious cycle is completed by excessive loss of sweat from the dilated surface capillaries, which further reduces blood-pressure and thus adds to the distress.

4. Rationale of successful Training

In the process of training, if successful, the following results are obtained :

(*a*) Muscle loses its interfibrillary fat and regains its tone, while educated co-ordination produces the maximum work with the minimum of muscular exertion.

(*b*) Blood-pressure and blood-flow are maintained by increased cardiac strength, by vaso-constriction, and by reduction of useless loss of sweat due to extreme dilatation of surface capillaries.

(*c*) Increase in respiratory capacity leads to rapid oxidation of those waste products which stimulate the expiratory muscles to violent action, and paralyse the nerve-endings. Increased strength of diaphragmatic contraction first forces blood from the abdominal reservoirs into the right heart and then sucks it thence into the pulmonary vessels, thus doubly aiding the heart's action.

(*d*) Finally, the whole excretory organs are trained to rapidly dispose of inhibiting products.

5. Practical indications afforded by these considerations

(*a*) *Exercises.*—The best results are obtained by carefully graduated exercises, which should be made as varied and interesting as possible so as to ensure the best physiological conditions. The trunk muscles must first be developed so that they may afford a firm, strong purchase for the limb-muscles which they support. The men should not exceed a maximum of five hours' exercise daily until they are fit to march. Then their length of march should be progressively increased; and, finally, they should march with their equipment gradually made up to the full weight.

(*b*) *The medical examination of the recruit.*—What are the conditions which indicate *success?* The recruit undergoing these exercises feels, looks, eats, and sleeps well. After a slight fall at first, his weight increases; his chest capacity improves; his muscles develop progressively, especially those of the back and loin, which should be symmetrical. That is the first point to which the medical examiner of recruits directs his attention—the development of the back- and loin-muscles. The tendency of inexpert training, as I have already said, is to develop the "strong man," and the right side of the body is exercised disproportionately, so that one frequently finds the muscles of the right side standing out, while those on the left side are comparatively small. Finally, the pulse, after moderate exercise, should remain regular and strong however rapid it may be.

What are the *danger-signs?* First with regard to the heart. If the heart be enlarged, either by dilatation or hypertrophy, that is a cardinal danger-sign. Then the pulse gives warning if it be weak, irregular, and dicrotic after exercise. If the pulse fails to return to normal tension within an hour after any exercise, this failure indicates that such exercise is excessive for the particular stage in training which the recruit has reached.

This brief sketch only touches the fringe of a difficult and complex subject, but it affords some useful indications for the combatant who has to train recruits, and for the medical officer whose duty it is to supervise the effects of training on physique.

B. THE SOLDIER

So much for the recruit. One now turns to the soldier, the more or less trained man ; and having considered the means of getting the recruit fit for the front, we have to turn to certain factors which closely concern the health of our men when they arrive there.

1. Food

The first and most important is that of *food.* It takes less money and transport to feed the men adequately when you have them in the firing line than it does to replace men debilitated by underfeeding: ample rations represent ultimate economy.

(*a*) *Field Rations*

As medical officers will be consulted by commanding officers on many points concerning rations, it is advisable that they should know what the rations are, and particulars of the present field rations appear in the "Field Service Pocket-book."

In the South African War the *caloric value* of the ration was 3900 calories, as against 4300 allowed for the convict when undergoing hard labour. One may take it that the prison authorities are not likely to be too lavish in the ration of the convict, and further, one must consider that the convict's life of sheltered irresponsibility involves no stress comparable with that of the soldier during war.

Therefore this comparison alone suggested that the South African War ration was insufficient, and in that campaign there was from neurasthenia and debility a loss of efficiency which confirmed this view. This led, after the war, to the carrying out of experimental marches under war conditions. It was found as a result of those experimental marches that the men lost weight and girth, and became haggard and worn. Therefore it was clear that the caloric value was not sufficient for the demands of active service. In particular the amounts of fat and sugar were found to be insufficient, and the lack of variety was most trying. These experiments resulted in selection of the field ration of 1913, which is still in force. Its caloric value is 4855 calories; that of the French is 3064; that of the Russians is 4890; and that of the Germans is only 2801. The German ration is insufficient, and must have been supplemented very considerably: it is quite inadequate for war. You will notice that the only other ration which gives a higher value than ours is the Russian.

Our present ration provides the following amounts of proximate principles and energy per man *per diem*:

CORRECTION	Field ration	Reserve ration
Protein	175 grammes	180 grammes
Fat	218 ,,	80 ,,
Carbohydrate	515 ,,	326 ,,
Calories	4855 ,,	2800 ,,

Provision of so high a proportionate amount of protein enables the reserve ration to meet the needs of tissue repair, but the total energy of that ration only gives a bare subsistence diet for a man at rest and there is no margin for the demands of external work.

Without going into bromatological details, there are certain practical points which may be indicated briefly. The first is that the total energy provided in the field ration is ample. Supply of frozen meat materially improves the quality of the *protein* source. And it is worth noting that gingivitis, following consumption of hard bully beef by the unaccustomed, has been mistaken for scurvy.

As regards *fat*, this principle is valuable in that it has, weight for weight, two and a half times the caloric value of either carbohydrate or protein. It has therefore a very high cold weather value. Although doubt exists scientifically as to the extent to which carbohydrate and fat are interchangeable in a dietary, it is safe to say that they are probably interchangeable up to the point at which the inhibiting action of fat on gastric secretion adversely affects digestion. The fact that in Arctic regions explorers have for long periods consumed as much as ¾ lb. of blubber daily indicates that the limit of fat-consumption in extreme cold must be much higher than is generally supposed. It is obvious that in cold weather one should increase the amount of fat at the expense of the carbohydrate and to the greatest possible physiological extent.

Turning next to consider *carbohydrate*, sugar stands out as of interest from the fact that it is the most readily oxidized muscle-food available. This explains the craving of soldiers and children for sugar. Chocolate, which used to be given, has been found to be too concentrated a form of food to be digested readily, and it has the further objection that it induces thirst. If one wishes to increase the sugar ration, it is probable that jam, of which 50 per cent. consists of sugar, is the best form in which to give it. We have, however, to remember in this connection that jam is not an antiscorbutic.

Vitamines call for a passing comment. They are defined as nitrogenous, metabolic bodies which are unstable because of containing dissociated ions. Heat associates the ions, and so destroys the characters of the vitamines. For instance, cabbage-juice loses its vitamines at a temperature of 60°. Every deficiency disease is apparently in ætiological relation with some specific vitamine. As an example one may refer to the association between beri-beri and the vitamine contained in the outer layers of rice-grains. The only deficiency disease which concerns us on active service is scurvy, and that is dealt with by the inclusion in the ration of half an ounce of lime-juice a day, given, at the discretion of the medical officer, in the absence of fresh vegetables. This subject we shall return to when we consider sickness in war.

This brings us to the vexed question of *alcohol*. Two and a half ounces of rum are provided per man per day, again at the discretion of the medical officer. That raises for the medical officer the whole problem as to whether alcohol should be or should not be supplied to the men. On this matter it is essential that we should retain an open mind. As it is impossible at this strenuous time to scientifically investigate the claims and statements of the rival schools which respectively recommend alcohol or denounce it as unmitigated poison, all that can be here attempted is an impartial summary of the main arguments of the champions of these radically divergent views.

It is advisable to take first the *physiological data*. Two ounces of alcohol can be oxidized in the body daily without any being excreted in the urine as such. The $1\frac{1}{4}$ oz. of alcohol in the $2\frac{1}{2}$ oz. of rum ration is thus well within this limit. Energy is thus liberated at the rate of 7 calories per gramme, giving a total of 210 calories. This energy is available without the delay involved in making a fire, which military considerations may frequently render undesirable.

One important point to be considered is the encouragement to men on a trying march afforded by anticipation of the rum-tot awaiting them at its conclusion, and few things get a body of men along more effectively.

After ingestion, the first effect of alcohol is that of stimulation of the heart and dilatation of the capillaries. It is generally admitted that this materially aids gastric digestion, and it certainly produces a comforting sense of cutaneous warmth.

Later there ensues a mild hypnotic effect, to which the gastric adjuvant action materially conduces.

The dilatation of surface capillaries must obviously eventually lead to loss of heat from the body-surface.

Lastly, one may consider that alcohol has a depressing effect on the physiological resistance. One knows, for instance, that animals which are normally immune to certain bacterial infections will acquire the disease if given the same dose of organisms within a definite interval after administration of alcohol.

Now what are the *objections?* The first is that the caloric value can be better supplied to the men by means of soup and cocoa, which repair tissue-waste as well as affording heat, and that soup is a better gastric adjuvant than alcohol. Remembering the results of Pawlaw's work, that view I think is probably correct.

As to the loss of heat from the skin, following the dilatation of the capillaries, it seems to be immaterial whether the men's capillaries are dilated if they go to bed after they have had their rum and their meal, and take care to be thoroughly wrapped up in their blankets. They will not then lose heat from the body to any marked extent.

The mental effect of stimulation in ordinary individuals very rapidly passes into a lack of discipline in persons subject to that idiosyncrasy. Further, the hypnotic effect is, of course, undesirable in men who are detailed for guard duty.

There is no doubt that there is grave responsibility resting on those who decide on the issue of a rum ration, when one considers that alcohol is thus placed at the disposal of men who may have been fighting for years against dipsomaniac tendencies. This must result in there being thrust upon those men a temptation most difficult to resist under service conditions, which weaken intrinsic will at a time when extrinsic restraining influences are absent. That is a moral responsibility which must be very carefully borne in mind. It is no reply to say that we only give 2½ oz. of rum, because the teetotaller, who is not immune to sordid interests, will sell his drink to his comrade; and although a man is comfortable, efficient, and subordinate on 2½ oz., when he has consumed half a dozen other rations of rum obtained by these illicit purchases his condition is very different.

What would one make the *conditions of issue?* I think it should be stipulated that rum should only be issued when there is no suitable alternative available—I mean such alternatives as cocoa or soup or their equivalents. It should only be given in the specified amount, after the day's work is done, with the main meal, and just before the men can turn in for their night's sleep. Thirdly, commerce in rum rations should be made a punishable offence, both for the seller and purchaser, and dealt with with the utmost severity. Under those conditions one feels that the issue of rum is a thoroughly justifiable course, and when the men are unable, from military exigencies, to get any warm cocoa or soup, I should have no hesitation whatever in recommending that rum be issued to them.

To take now the next item that comes in the ration list—*tobacco*. Without going into the question of the various objectionable ingredients in tobacco, such as nicotine and the more harmful furfural, one may say that excess of smoking, particularly of cheap cigarettes, produces tachycardia, muscular relaxation, and diminution of visual acuity. These conditions result in "shortness of wind," which is of course bad for marching, and produce muscular tremor and loss of effective sight, which I need scarcely say are worse for shooting. The effects of smoking on the heart, and the quality of the pulse are well shown in this pulse-tracing. Tobacco, like alcohol, has certain compensating advantages. The mild narcotic effect of tobacco in moderation is not apparently attended by deleterious action on habitual smokers. Seeing that the allowance is only two pipefuls a day, it can do a man no harm to smoke one pipeful when he reaches camp and the other just before he turns in at night. The soothing effect is mentally most beneficial.

(*b*) *Tinned Rations*

We now come to the use of *tinned rations*. This is a matter which will come constantly under your attention, and it is therefore necessary to go into certain questions carefully.

The first point is the advisability of having an issue at least once a week of the tinned ration consisting of meat and vegetables all stewed together in one tin. This ration is well cooked and needs only to be warmed to render it rapidly ready for consumption. It is tender and appetizing to an extent which makes it very welcome to the men. The disadvantage that it weighs 30 per cent. more, for an equivalent caloric value, than does the ordinary ration of bully beef and potato is compensated for by the variety which it affords.

The matter of examination of tinned rations is so important and comes so frequently before the medical officer that it is advisable to give some notes on the points to which attention should be directed.

(1) *The Exterior of the Tin.* This should not show more than two solder-holes. It is popularly supposed that there should be but one, but some firms adopt a method which involves the presence of two such holes.

The tin should be painted or lacquered, and not labelled.

It should be legibly stamped with the date of canning, and this should not be more than one year prior to the date of issue for use.

The ends should be concave and should be dull to percussion. Small quantities of gas are best detected by opening the tin under water.

(2) *The Interior of the Tin.* The solder should not project from the seams. Solder consisting of lead, tin and sometimes zinc, the more soluble and toxic lead is apt to be taken into solution if an unnecessarily large surface of solder be exposed in the interior.

There should be no erosion of the tin which coats the iron of the case, and the following is a very useful method of testing for "pin-point" erosions: Remove the grease from the surface by strong alkali; wash; place in a solution of dilute hydrochloric acid (50 per cent.) with some strong solution of potassium ferrocyanide and leave for an hour. Minute erosions will stand out conspicuously of a deep blue colour after the plate has been gently washed free from the reagents.

(3) *The Contents.* Fat should amount to between 10 and 15 per cent. Gristle and fascia should not be in excess. The jelly should be semi-solid at ordinary temperatures. The meat should be of good colour and odour and not markedly alkaline. Preservatives must be wholly absent and tin should not exceed .03 per cent.

(4) *Blackening calls for separate and special mention.* It is the cause of much difficulty to the uninitiated, who are apt to regard all blackening of the tin interior as evidence of putrefaction of the contents.

There is an unobjectionable, slight, dark film—resembling "tarnish" on silver—which consists of tin (stannous) sulphide in small amount, precipitated in an acid medium. This is formed by sulphur liberated by the splitting up of proteid molecules in contact with the tin during the process of heating the can in cooking. It is known as "can-burn" by the contractors, who are prepared to make generous allowances for the amount of blackening due to this cause. It has, however, only to be suggested that, if there be no doubt as to the freshness of the meat, there is no reason for excessive heating.

Heavy blackening is caused by ferrous sulphide, which is thus formed: decomposition of the meat leads to formation of alkali and ammonium sulphide; this is converted into tin sulphide which, being soluble in alkaline solutions, is dissolved off the interior of the can as rapidly as it is formed; the iron underlying the tin is thus exposed and converted into ferrous sulphide, which is precipitated in alkaline solutions.

(*c*) *Cooking*

Certain details *re* cooking will be dealt with under the subject of "the March," but stress may be laid at this point upon the importance of securing variety and assimilability in the food of the soldier.

Variety is as difficult to secure on active service as it is important in view of the depressing effect of an unappetizing and monotonous diet upon gastric digestion and its initiation of the sequence of hormones.

Assimilability is more easily attainable when fresh meat is issued and is best obtained by the use of stew. The valuable influence upon digestion of the "appetite juice" which follows ingestion of soup, broth, or beef-tea should not be lost sight of.

A mincing-machine is a very important item in the equipment of camp kitchens, and the keen medical officer will insist upon its being kept both scrupulously clean and in good working order.

2. Clothing

The sartorial dictum that "clothes make the man" gives way in war to the more important view that clothes play so great a part in maintaining health and comfort that they demand more attention than is usually given them. The practical bearings can only be fully appreciated after an initial consideration of certain points of physics.

Clothing

Physics.

Maintenance of normal body temperature is the most important factor.

Air being one of the best non-conductors of heat, the more layers of air in the clothing the better will heat be retained in winter and excluded in summer. The importance of evaporation of water from the body surface will be fully dealt with under the Hygiene of the march. Here it may be noted that the high latent heat of steam is slowly taken up by water during evaporation—to the extent of 536 thermal units—but is abruptly given off in condensation. Colour is of some importance in that black absorbs and radiates heat most, while white serves these purposes least but reflects heat most.

Another function of clothing is that of *protection of the body from the action of certain rays of the solar spectrum.* The violet actinic, or chemical, rays are credited with having an irritant action on tissues, and a good deal of fuss has been made by the advocates of red clothing, the colour of which will absorb the complementary violet rays. Experiments conducted in India proved that a layer of blood one five-hundredth of an inch thick is impermeable to the actinic rays of the most powerful sunlight. The view formed from this observation has been confirmed by practical tests in Manila with companies of men clad in underclothing of red and of white respectively and kept under observation for a year as regards sickness and average weight. Those clothed in red actually compared disadvantageously with the control company. The red-clothing theory may thus be regarded as exploded, for whatever protection of this nature is needed is already afforded by the blood in the surface tissues.

Protection against Solar Rays

The matter of ultra-violet rays is more practically interesting, for these rays are known to have a destructive action on living tissue, which they penetrate. As bone tends to obstruct these rays, it appears probable that the relatively great thickness of the negroid skull is a protective adaptation. Two facts may be noted in this connection—one is that distress follows leaving the head uncovered in a tropical sun and the other is that imbrication of the vertebral laminæ protects the spinal cord from the action of rays which impinge obliquely on the spine and are thus filtered off by a long passage through bone. If men, who have suffered no ill-effects from long exposure while standing erect, lie down and thus expose their spines to the vertical action of solar rays on a hot summer day for any length of time, it will be noticed that many will suffer more on rising than is to be accounted for by the consequent abrupt alteration of blood-pressure.

British troops wearing " pork-pie " caps during the siege of Delhi suffered excessively from sunstroke, while the Guards who once went on duty in Egypt, taking their metal helmets, are said to have suffered proportionately little from this cause as compared with other troops not so protected. It is probable that these differences are to be accounted for by the fact that a thin sheet of metal is impervious to ultra-violet rays, and this leads to the suggestion that a thin sheet of aluminium in the lining of the helmet would be an effective means of protection during summer months and add little to the weight of the head-dress.

The effects of such influences upon fighting efficiency are not to be measured wholly by hospital admission rates.

Practical Application of these Data

Material. The fact that the universal covering of animals, from the arctic to the torrid zone, consists of hair raises many interesting points. The first is that of the structure of wool, the fibres of which are covered by scales, while they are transversely elastic. This structure confers several qualities, chief among which are retention of layers

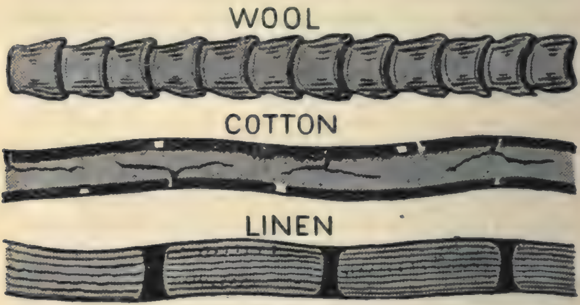


FIG. 1

of air and absorption of a considerable amount of water, which is slowly evaporated. While these properties are of obvious advantage in the retention of body-heat in winter, the value of wool as a clothing material in summer is not apparent at first sight. It becomes so, however, when one considers that a thin layer of wool affords no obstacle to cooling by evaporation when once it has become saturated by sweat, which then evaporates from the free surface of the garment and extracts heat from the body by conduction. This saturation is automatically the more rapid as the need of cooling is the more urgent.

Further, immediately sweat ceases to saturate the garment, and the outer layers dry, those layers fill with non-conducting air, and, as the need for cooling becomes less urgent, cooling of the body-surface is checked by the scales covering the still saturated deeper layers. This is of great advantage to the man when he reaches camp exhausted after a long march and with his clothes wet with sweat, the rapid evaporation of which would rob his body of heat which it then requires for recuperation.

One is thus forced to the conclusion that wool is the best material for clothing, both in winter and in summer, although in the latter it should be as thin as possible.

Cotton rapidly absorbs water by capillarity, clings to the body and extracts from it the heat necessary for rapid evaporation. The close adhesion of its fibres to each other eliminates the intervening layers of air.

Colour. The colour of clothing is determined by military rather than by hygienic considerations, but it may be noted that the negro—with his black skin and white shirt—has solved the problem of the best colours for extremes of atmospheric heat. Here, again, the advantage of the layer of black next the skin is not obvious at first sight. It is, however, apparent when it is realized that immediately the black skin is covered by sweat evaporation cools the air-layer between it and the shirt and then the pigment absorbs heat rapidly from the body and radiates it to the adjacent cold air.

Fitting. It is unnecessary to do more than point out that fitting should involve no constriction of the chest or limbs.

Puttees. Puttees are less satisfactory than smart and would be better rep aced by canvas leggings.

When dry they are apt to be put on too tightly and there is marked interference with circulation and marching when they subsequently get wet; when saturated they contract by 3 per cent. of their total length if made of ordinary serge. They are potent factors in production of "frost-bite."

Boots. Boots play so important a part in war that the desiderata for a suitable service boot are enumerated as:

(1) Strength without undue weight.

(2) Absence of "canoeing" of the sole, which should have moderately wide welts.

(3) Provision of a broad, low heel—brought well forward.

(4) An inner edge which is parallel to the line of greatest length of the boot.

(5) Easy flexion of the sole across the line of tread, with rigidity at the "waist."

(6) Pliability of the uppers.

(7) A broad, well blocked-up toe.

(8) Curvature of instep and heel to follow the natural lines.

(9) Waterproof stitching of all seams and sewing of the sides of the tongue to the uppers for at least two inches.

The commonest defects to produce sore feet are insufficient vertical space for the toes, and lack of sufficient curve at the back of the heel to prevent vertical friction between heel and boot. The fitting should allow of two pairs of socks being worn easily.

Waterproofing and pliability should be secured by filling the boots with oil (castor or cod-liver oil) for twenty-four hours. Excess oil can be removed, after emptying, by filling the boots with dry bran.

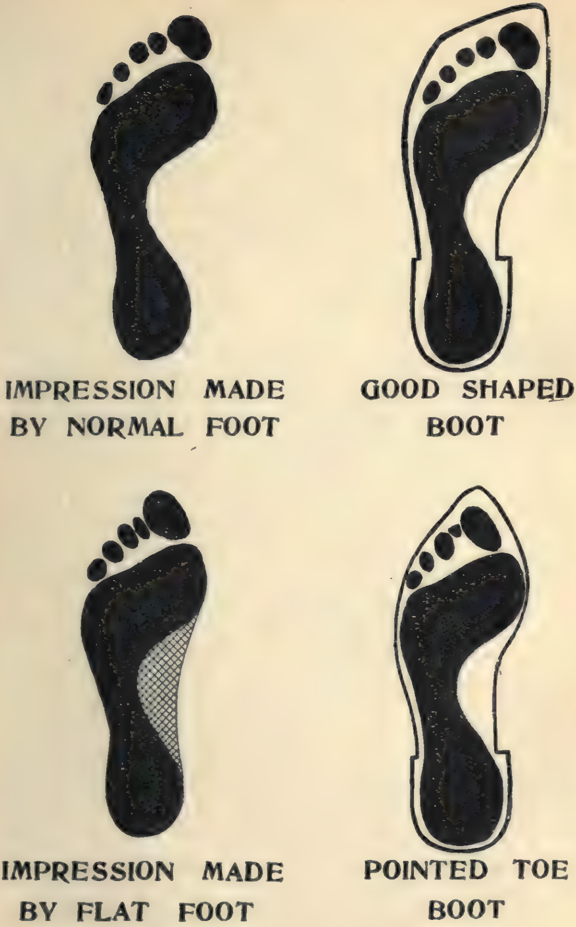

IMPRESSION MADE BY NORMAL FOOT
GOOD SHAPED BOOT
IMPRESSION MADE BY FLAT FOOT
POINTED TOE BOOT

FIG. 2

Frost-bite. This section on protective coverings would be incomplete without a reference to frost-bite, which during the present war put the equivalent of more than two of our infantry brigades out of action before the end of January, 1915.

The most important predisposing factor is tight puttees. The essential factor is prolonged contact with cold water, and it is probable that superficial areas of gangrene are produced secondarily by the mechanical obstruction to surface circulation by imbibition of water by the skin during prolonged standing in flooded trenches. Inasmuch as in a large proportion of cases the temperature has not been below zero, the term " frost-bite " is a misnomer.

The importance of the part played by wet is illustrated by the records of the Crimean War. In the winter 1854–5 there were 1924 cases and 456 deaths from " frost-bite." In the following year, although the temperature was similar, there were only 474 cases and 6 deaths. The essential difference in conditions was that in the former winter the men returned from the flooded trenches, to sleep in their dripping clothes, wrapped in wet blankets, on sodden ground, in leaking tents. The result was that large numbers were admitted for " frost-bite " before the temperature ever touched zero, and in some instances before it fell below 40° F.

The necessity for protecting the skin from direct contact with water is thus obvious, and the physics of the available means of protection have already been most carefully worked out, although it is inadvisable at present to discuss our proposed measures in detail.

Waterproofing. Two methods of rendering textiles waterproof may be mentioned :

(*a*) Waterproof sheets may be prepared by painting the material with hot, weak glue and 2½ per cent. alum solution.

(*b*) Clothing may be treated by dipping alternately in an emulsion of soap and a solution of alum.

Washing and Drying of Clothing. These notes on clothing may be concluded by reference to the important matter of purification.

The fouling of clothing is important because decomposition of the organic matter which they contain liberates organic vapour which, although freed from moisture and CO_2, is still lethal to mice in forty-five minutes. This product must therefore be noxious to larger mammals.

When the clothing has been loaded with organic matter by frequent saturations with sweat, it is desirable that a change should be provided for night use and fouling of the air of barrack-rooms should be avoided by drying the day-wear elsewhere. This is seldom practicable on active service but can be arranged for readily during training.

It is essential that, whenever possible, underclothing should be washed once a week, and a very practical point, not generally appreciated, is that laundry water rapidly becomes more foul than sewage—especially bacterially. Where, therefore, washing is done by the troops a constant flow of water should be maintained or periodical sterilization by chlorination should be secured, though this will largely increase the expenditure of soap and energy.

Objection is constantly made to the frequent washing of blankets, which become very foul and are liable to be infective on service, on the ground that washing causes heavy shrinkage and hardening. If a blanket be dipped momentarily in boiling water, rapidly washed in warm water, and rapidly dried without wringing, the total shrinkage in length need not exceed a quarter of an inch and non-sporing infective organisms will be destroyed.

The medical officer has to be on the alert to check the dangerous practice of drying clothing over charcoal braziers in barrack-rooms. Not only are large amounts of organic vapour thus rapidly driven off, but carbon monoxide from the burning charcoal is highly toxic.

Provision for drying damp clothing should be made, but this should be carried out in separate drying-sheds, apart from the rooms in which the men live and sleep.

3. Equipment

The maximum which a man can carry continuously without his fighting powers being sacrificed to burden-bearing is 30 per cent. of his total body-weight. In the average man this amounts to about 50 lb., and our infantry equipment weighs 53 lb. By the new web slings this is distributed so that it is carried without strain to maintain the body-balance and without constriction of the chest by bands. The use of vertical shoulder-slings permits of the clothing being turned back to freely expose the chest, and the whole equipment can be thrown off by a single movement. The distribution is arranged so that the men can discard, when going into action, those parts which are not actually needed during the engagement.

4. Personal Comfort

This relates to both physical and mental comfort, each of which has a very practical bearing upon fighting efficiency and therefore closely concerns the medical officer.

(*a*) *Physical*

Cleanliness is of the essence of comfort, and personal ablution is a matter which must be considered. By the use of rose showers, four times the number of men can get a hot bath in a given space and with one-quarter the amount of hot water which would be required if sitz-baths were used. Moreover, the objectionable practice of the same water being used by two or more men in succession is rendered impossible.

In the trenches braziers are used for heating of water in odd tins for ablution purposes.

This matter will be referred to in more detail when we come to consider the means of dealing with vermin.

Warmth concerns both the positive mental asset of physical comfort and the negative effect of cold in lowering physiological resistance. The latter is illustrated by the fact that fowls normally immune to a dose of infective organisms, will succumb to a similar dose if administered after they have stood for some time in cold water. Every effort should therefore be made to keep the men warm. In the trenches this has been done by excavating shelters in one face of the trench-side, keeping them free from water by low clay partitions, and placing in them stoves, around which the men not actually required to man the parapets can warm and dry themselves and on which they can heat their food and boil their tea.

The trouble involved in making these simple arrangements for the men's comfort is amply repaid by the increased efficiency which results. There has been enormous scope for energy and thought in devising measures to improve the conditions obtaining in billets. Many of these are obvious—as, for example, organization to provide an adequate reception for the men who come from the trenches exhausted after forty-eight hours of exposure to cold, wet, and danger.

(*b*) *Mental*

But there is one aspect which is less obvious, although urgently calling for action. It relates to the psychology of the quiescent interval between two spells of trench duty. To the educated man of highly strung temperament the tension of actual danger serves as a stimulus which carries him with éclat through the experiences in the trench itself. The inevitable mental reaction is proportionate to the temporary exaltation, and return to billets is followed by depression of which only the highly strung man knows the intensity. In the enforced inaction of the forty-eight hours' rest, before duty again calls the men to the trenches, scenes of horror which were only subconsciously perceived during the stress of action emerge with vivid persistence and the unceasing boom of the enemy's guns keeps memory perpetually alert. As the hours of respite from the imminence of violent death slip by, men who recall their own hairbreadth escapes and note the empty places of many a comrade can but speculate involuntarily upon the odds against their own escape from dangers constantly renewed. The higher moral courage carries the men through the effort of dissimulation, but the effort is a costly one in mental strain.

To what practical conclusion does this consideration lead ? That every effort must be made to provide our men with occupation which will fill this period of suspense so full of other interests that there will be no leisure for brooding or anticipation, while relaxation of all tension gives the opportunity for recuperative mental rest. Games, study, novels, handiwork—anything and everything which will serve this purpose—should be provided, and here is ample scope for energy which has found no useful channel hitherto at home.

That this is no imaginative sketch is known to those who have had the opportunity of watching, in invalids returned from the front, the effects of modern war. One knows of healthy and athletic men, among the last to be suspected of nerves and neurasthenia, who for days and even weeks after their return have suffered from recurrent nightmare repetitions of the sounds and sights of war. Night after night their sleep is broken by the sound of bursting shrapnel and the sight of wounds which daylight finds them only too reluctant to recall.

LECTURE II

ANTI-TYPHOID INOCULATION

GENTLEMEN,—Our topic for to-day, anti-typhoid inoculation, can only be approached by an initial consideration of certain facts relating to immunity which has been the subject of one of the most brilliantly successful laboratory studies. Unlike so many barren triumphs of the laboratory, this research has had an essentially practical bearing in that it has led to the evolution of anti-enteric inoculation—the most important contribution of preventive medicine to our means of safeguarding the lives of our men in camp and field. This method of prophylaxis is so much more applicable to the protection of aggregations of men than of individuals that it has not come under the notice of the civil practitioner to an extent which has led to his mastering its details as the military medical officer has had to do. The civilian practitioner, therefore, is at a disadvantage when he is faced by the most important duty of inducing men to come up voluntarily and avail themselves of this means of protection. It is a matter of keen regret that anti-enteric inoculation has not been made compulsory; and this regret is deepened by the obtrusion of the anti-everything busybodies, with their wonted capacity for misrepresentation, and a mischievous energy supported by funds which might have been used for a good purpose. The medical officer must, therefore, be fully informed as to the rationale of this method and be fully armed with precise data supporting its claims to success. It is for the purpose of placing that information at your disposal that a special lecture is devoted to this subject.

I propose to consider :—

(1) The general principles of active immunization.

(2) The application of those principles to the problem of protection against enteric fever.

(3) The scientific and practical results obtained by prophylactic inoculation.

A. THE GENERAL PRINCIPLES OF ACTIVE IMMUNIZATION

Beginning then with the general principles of active immunization, one defines immunity as relative insusceptibility to disease. Stress is laid upon the qualifying "relative," for immunity is seldom—if ever—absolute.

Immunity as thus defined varies according to :

(*a*) The number of invading organisms.

(*b*) The route of invasion—you will remember that cholera is intensely virulent in the intestine and innocuous in the blood, while tetanus conversely is harmless in the intestine but most dangerous if it gain access to a wound.

(*c*) The virulence of the organism. The importance of this factor is illustrated by hydrophobia, in which no case of recovery from the developed disease has ever been recorded.

(*d*) Physiological resistance—a subject to which we shall return in a moment.

Varieties of Immunity

There are two main varieties of immunity—the natural and the acquired.

(*a*) *Natural immunity* again may be racial or physiological.

(1) The racial is illustrated by the Barbary sheep in its insusceptibility to anthrax, which is so fatal to other species of sheep. Another striking difference is that between such closely allied species as the field mouse and the house mouse: one succumbs rapidly to septicæmia after a coccal injection to which the other is relatively indifferent.

(2) Physiological resistance plays a most important part in the difference in susceptibility of individuals of the same species. This difference is most strikingly demonstrated by an instance reported from India, where cholera dejecta carelessly thrown from a tent contaminated a camp water-supply. Of the 23 persons who drank from this supply on the following morning, only 8 developed cholera.

(*b*) *Acquired immunity* may be obtained naturally or artificially.

(1) If naturally acquired it follows, and results from, an attack of acute specific disease. In some instances—as *e.g.* influenza—the immunity is so short that an attack has even been supposed to leave increased susceptibility to fresh invasions by the same organism. It is generally recognized, however, that in the great majority of acute infective diseases one attack confers a high degree of protection against a second attack of that disease. In very rare cases a second attack has been known to occur even in diseases conferring so marked a subsequent immunity as scarlet fever or enteric. As such exceptions but prove

the rule and afford no argument that no immunity is thus conferred in general, so the rare instances of enteric occurring in inoculated men cannot be any more regarded as arguments proving that inoculation is valueless. It would be unreasonable to demand more protection from artificial methods than is given by the natural processes which they aim at reproducing.

(2) Artificially conferred immunity may be of the passive or the active variety.

The former is a curative and temporary result of the injection of protective substances ready-made. Its value is indicated by the fact that the use of anti-diphtheritic serum has reduced the mortality of diphtheria from 50 per cent. to 5 per cent.—which, in the United States alone, means an annual saving of some 30,000 lives. Unfortunately, for various technical reasons, this method is of only very limited applicability.

Active immunization, on the other hand, is effected by making the body manufacture its own protective substances, which are semi-permanent and prophylactic. The means adopted is that of injecting the stimulating material which produces that effect in the process of natural immunization occurring during an attack of the disease itself.

What measure of success has attended our efforts you shall shortly have an opportunity of judging for yourselves, but first it is necessary to study in detail the exact process of immunization as effected by natural means.

The mechanism of naturally acquired immunity

A sound grasp of this complex subject can only be obtained by a review of the properties and inter-relationships of the various bodies which take part in the production of immunity.

In endeavouring to present this difficult subject in a manner which is both simple and comprehensive, one is faced by three main difficulties. The first is that of the starting point—and, as lack of interest in matters bacteriological may have resulted in certain of my audience not having considered this matter previously, it appears desirable to err on the safe side and include all relevant factors, however simple. Next it is not easy to illustrate all points by the details of any single investigation or process. It is advisable therefore to present the whole of the facts as far as possible in one consecutive whole, without the distraction of breaking off constantly to explain that this or that fact is only relevant to one or other infection. And, lastly, it is impossible to avoid the use of technical terms, because any science which has advanced as far as this must of necessity possess its own nomenclature. Use of technical terms is not due to a desire to emulate the gentleman who would only refer to a bell as a "scintillating tintinabulator."

(1) First there is our old friend the *phagocyte*—the devourer (1 in the diagrams)—a polymorphonuclear leucocyte which will ingest any dead organism.

The actual lethal substance which kills the organism is contained in the serum and its amount as compared with the lethal power of normal serum—as unity—is known as the opsonic index. This is measured by the number of organisms phagocyted by each leucocyte after a bacterial emulsion has been exposed to the action of a serum for a given period, in the presence of leucocytes.

The phenomenon of chemiotaxis is closely related to that of phagocytosis. Living organisms exert repulsion on leucocytes which are thus driven

FIG. 3.

DIAGRAMMATIC REPRESENTATION OF THE BODIES CONCERNED IN, AND THE CONSECUTIVE STAGES OF, THE IMMUNIZATION PROCESS

1. Phagocyte.
2. Antigen.
3. Toxin.
4. Complement.
5. Fixed tissue-cell.
6. Anti-toxin.
7. Amboceptor.

FIG. 3*a*. Position at commencement of invasion

FIG. 3*b*. Production of, and lines of attack by, toxin (3). Phagocyte retreating

FIG. 3*c*. Production of anti-toxins (6)

Fig. 3*d*. Neutralization of toxins by anti-toxins; production of amboceptor (7)

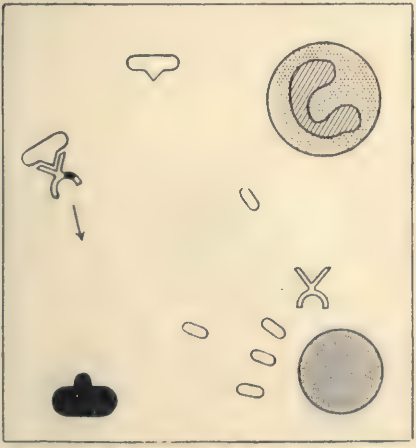


Fig. 3*e*. Excess anti-toxins after neutralization of toxins; amboceptor attached to complement

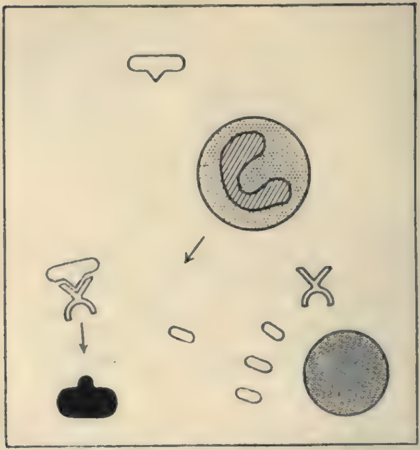


FIG. 3*f*. Amboceptor-complement molecule and phagocyte advancing to attack invading organisms

FIG. 3*g*. Amboceptor-complement molecule attached to invading organism

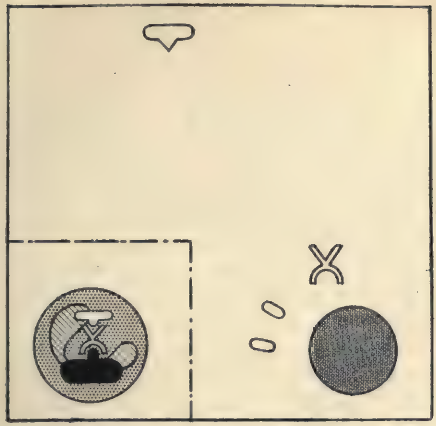


FIG. 3*h*. Phagocytosis of invading organism

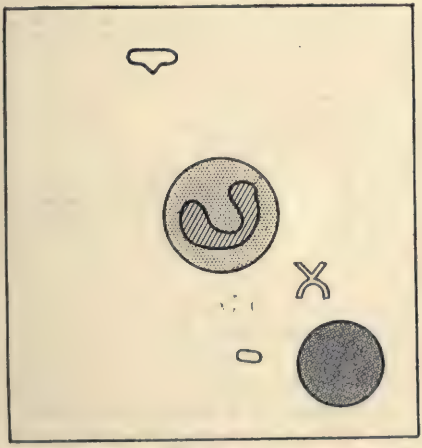


FIG 3*i*. Condition of subsequent immunity—available antitoxin and amboceptor remaining

away—negative chemiotaxis. Dead germs or dilute toxins aid phagocytosis by attracting leucocytes—positive chemiotaxis.

(2) Next comes the essential *antigen*—the former of anti-bodies (2 in the diagrams)—which consists of an extraneous animal substance introduced into the body. Unorganized proteins are concerned with the fascinating phenomenon of anaphylaxis, from which one is reluctant to turn without a word. The organized protein of the bodies of bacteria is the antigen which, when injected, leads to active immunization by stimulating the manufacture of protective substances.

As there is a quantitative relation between antigen or its toxins and protective substances, and the latter require to be standardized, this necessity has led to the working out of a standard known as the "M.L.D.," which is the minimal lethal dose of antigen which will certainly kill an animal of a given weight in a given period. The minimal amount of protective substance which will protect an animal against 100 "M.L.D.'s" is known as the "Immunity Unit."

It is assumed by Ehrlich that the affinity between antigen and protective substances is due to certain combining powers, which his "sidechain theory" represents by receptors, as shown in the diagrams.

(3) *Toxins*—or poisons (3 in the diagrams)—are formed by the antigen, and thrown off into the blood. They are ultra-microscopic and so potent that one fifteen-millionth of a grain of tetanotoxin is estimated to be enough to kill a rabbit. Being ultra-microscopic, they can be obtained in the filtrate from which organisms have been removed. It is presumed that to their action negative chemiotaxis is due, while their stimulus is credited with the power of making the fixed cells

produce the protective substances to be enumerated later. In larger amounts they destroy instead of stimulating the fixed cells to which they attach themselves. They can thus be filtered off with the cells with which they have combined.

(4) The next body to be considered is the *complement*—the unarmed defender (4 in the diagrams)—which is normally present, and capable of acting against any invading organism if provided with the suitable weapon. It is destroyed by heat.

(5) Then we come to the *fixed cells* of the lymphatic glands and marrow—the arsenals (5 in the diagrams)—which, under stimulus of the toxins, manufacture the protective substances.

Finally there are the defensive weapons—the anti-toxin and the amboceptor, numbered respectively 6 and 7 in the diagrams.

(6) The *anti-toxins* are formed by the stimulus of toxin or germs, living or dead. They combine with toxin, and the amount which neutralizes 100 M.L.D.'s of toxin is known as an "Immunity Unit." It is they which confer the passive immunity which follows injection of serum in which they have themselves been formed as a result of injection of dead organisms into living animals. By means of successive injections of a horse, the resultant diphtheritic anti-toxins can be so concentrated, *e.g.* that one dose of its serum contains enough anti-toxin to neutralize 400,000 M.L.D.'s of toxin.

The duty of anti-toxins is to protect the tissue cells from toxins while the cells manufacture the substances which will kill the invading organisms. Although they are always produced in excess, they are rapidly excreted. To this fact is attributable the evanescent protection which they give, while to their lack of action against the invading organisms is due the relative inefficacy of passive as compared with active immunity.

(7) Lastly comes the essential *amboceptor*—the immune body, anti-body, sensabilitrice, or fixateur—which represents the weapon supplied on mobilization to the unarmed defender, or complement.

Amboceptor is not normally present in the body and a special variety must be formed to deal with each different variety of invading organism. It is a remarkable fact that each is strictly "specific," *i.e.* will deal only with the organism which has led to its production.

The best illustration of the degree of this specificity is afforded by reference to anaphylaxis. It has been found that if an animal be sensitized by an antigen provided by the blood of the humped species of Egyptian bullock, that animal will react with a further dose of blood from a humped bullock but will give no reaction with blood derived from any other bullock. It has thus become possible to determine the identity of a blood stain—a matter of the utmost practical importance in criminal investigations.

Being unaffected by heat, amboceptor can be obtained separate from complement, which heat destroys.

Having been formed, and always formed in excess in cases which recover, amboceptor resists excretion and therefore remains in the blood for years—or for life—ready mobilized to repel a fresh invasion. Its precise rôle is to attach the complement to the organism and thus enable the former to destroy the latter by direct lethal action.

The term immune-body includes a group of substances, comprising among others agglutinins, bacteriocidins, bacteriolysins and opsonins. The method by which one of these substances is estimated will be described later.

Popular simile for the soldier

After a very considerable experience of the duty of persuading men to volunteer for inoculation, I have found that the surest road to success is to explain as far as possible how the method works and what it is supposed to do. If they can get hold of a general idea that is all that is necessary as long as there are one or two points of which they can see the proof for themselves.

The proofs are simply provided—*e.g.* one of the most effective is to show a hanging-drop of motile enteric organisms and beside it a hanging-drop agglutinated by immune serum. The former alone is one of the most effective methods of obtaining volunteers. A man comes up with a cheery smile to peer down the microscope; as he catches sight of the seething mass of motile organisms he blenches; and you have the satisfaction of seeing him pass straight on into the inoculation room.

The explanation of the process is less simple and matters must be put in a way which appeals to his imagination. There is no better way than by adopting the simile of the battlefield, somewhat on these lines. The organisms are the enemy invaders; the body the invaded country; the toxins the enemy's projectiles; the complement the unarmed population; the tissue cells the arsenals; the anti-toxins the defenders' projectiles; the amboceptors the bayonets of the defenders; the phagocytes the "body-snatchers."

With these pieces you fight a war-game for the men, illustrating it by models of which the diagrams in Fig. 3 are reproductions.

Invasion. Unarmed defenders driven back by gun-fire (negative chemiotaxis and toxins). Arsenals put out of action (toxins kill tissue-cells). Capture of lines of communication (blood vessels). Capital reached (heart). Surrender of defenders (death).

Rally. The invaders' fire checked (anti-toxins). Defenders armed (amboceptors). Defenders converge on invaders (positive chemiotaxis).

Battle joined. Invaders' fire smothered (toxins neutralized). Defenders getting in with the bayonet (complement and amboceptor).

Victory. Invaders penned and annihilated (abscess cavity). Dead of both sides (organisms and complement) being removed by body-snatchers (phagocytes). Invasion defeated.

Permanent mobilization. Defenders armed with bayonets which never become obsolete (the amboceptors—permanent). Ammunition for guns becoming obsolete (transient anti-toxins). Enough bayonets remain to enable defenders to crush any subsequent invasion before the enemy can develop gun-fire (permanent immunity by bacteriolysis before toxins can do any harm).

B. APPLICATION OF GENERAL PRINCIPLES OF IMMUNITY TO ANTI-ENTERIC PROPHYLAXIS

Having considered the general principles of immunization, we have now to deal with their application to the problem of protecting our men against enteric fever.

Initial difficulties were experienced in many ways.

(1) The immunity of animals to true enteric (a view since modified by experiments on anthropoid

apes) made it necessary for all experimental work to be carried out on man. This factor also made it impossible for passive immunization to be undertaken as a curative measure in developed human enteric: as immunized animals produce no amboceptors but only anti-toxins.

(2) In the case of *B. Typhosus* the toxins are endo-toxins—*i.e.* so intimately associated with the bodies of the organisms that they cannot be obtained free from the organisms by filtration. This made it necessary that the bodies of the organisms should themselves be injected as the stimulating antigen to promote formation of anti-bodies.

Auto-inoculation. This brings us to the point at which Sir Almroth Wright, in 1896, found progress barred along all other roads than that of auto-inoculation. It is with justifiable pride in our profession that we study the history of the advance along that perilous solitary road, and it is with a special pride in my corps that I recall the devotion to duty which led officers of the R.A.M.C. to offer themselves for this purpose. Without the possibility of a preliminary comparable test on animals, it became necessary for the officers experimented on to receive massive injections of dead enteric organisms, the effects of which could only be surmised by analogy.

As one can sympathize with the tension of this step in the darkness, so one can appreciate the satisfaction with which these officers found, in the subsequent development of protective substances in their blood, the promise of a brilliant outcome to their efforts. It is interesting to note that they received in a single injection three times the number of enteric organisms which are now given as a dose.

The methods now in use

(1) *The Emulsion.* As the term "serum" is wholly inaccurate and "vaccine" is often regarded as a term to be applied to a growth of living organisms, the fluid which is injected in this method is styled the anti-enteric, or anti-typhoid, emulsion.

The strain of organism used is one of very low virulence—as has been proved on two occasions when accidents with rubber connections have resulted in the laboratory personnel getting considerable intra-oral doses of the living culture.

The culture is a forty-eight-hour broth-culture at blood-heat and generally gives a concentration of about 3000 million organisms per c.c.

The dose is 500 million dead organisms in the first and 1000 million in the second injection. The reasons for this division of the dose are given later.

The standardization is obviously a matter of great importance in relation to the dosage. Various methods of determining the number of organisms per c.c. have been tried and successively abandoned for improved means.

(*a*) Weighing was regarded hopefully until it was found that 1000 million enteric organisms weighed only .113 milligramme. A useful datum for men who are alarmed at the 1000 million germs is that they only weigh $\frac{1}{600}$ of a grain.

(*b*) Next the technique adopted was to dilute the vaccine until one c.c. contained so few organisms that they might be counted as they grew into separate colonies on solid media, on which one c.c. of the diluted vaccine had been distributed. This means proved unsatisfactory owing to the tendency of the organisms to form clumps which, however many organisms they contain, produce only a single colony per clump. In any event the process of diluting 100 million times does not lend itself to extreme accuracy.

(*c*) The next procedure was that of counting the numbers of xanthocytes and bacilli in a stained smear made from a mixture of equal parts of blood and bacterial emulsion. As the blood is known to contain, with remarkable constancy, five million xanthocytes per c.mm., the proportion of bacilli to xanthocytes will be the proportion of the number of bacilli per c.mm. to five million in that amount.

(*d*) The method now in use is the simpler and quicker one of diluting the emulsion and making a direct count of the organisms on a hæmacytometric cell under dark-ground illumination.

Whatever the method of standardization adopted, it is always carried out by two observers working independently. If the results are so approximate that the difference is within the range of probable error, the mean is taken, but if there be any marked divergence, a third estimation is made as a control.

The laboratory precautions concern us closely because questions are often asked as to how the killing of all organisms is ensured.

The succession of precautionary measures speaks for itself, as to the security afforded by this chain of defences.

(*a*) Vegetative organisms are killed off by first heating the vaccine at 53° C. for seventy minutes and adding to the resulting emulsion, after it has cooled, 0.4 per cent. of lysol. Subjection to a higher temperature would destroy the efficacy of the emulsion.

(*b*) Samples of the emulsion are then plated to test for sterility under both aerobic and anaerobic conditions.

(*c*) Absence of spores is finally proved by inoculating animals with the emulsion and observing the effects for ten days subsequently. In order to afford an ample margin for considerations of massive inoculations, the animals get thirty times the proportional dose given to man.

(2) *The Injection.* There are certain important precautions to be observed when inoculating.

The bottle should be shaken—lest the organisms settle to the bottom and an excessive number pass into the last dose withdrawn.

The bottle should be opened aseptically, by passing its stem through the flame and breaking it with forceps similarly treated.

The whole syringe should be initially sterilized by drawing into its barrel oil heated to 130° C.—a temperature at which breadcrumb just browns when dropped into the oil.

Subsequently, only the needle requires to be sterilized after each successive inoculation, and this is effected by passing it through the hot oil.

It must be noted that, unless the barrel of the syringe be cooled before it is filled with emulsion, the properties of the latter will be destroyed.

The inoculation site should be painted with Tincture of Iodine. The infra-clavicular region, inside the braces line, is preferable to the level of the deltoid insertion. Adoption of the latter prevents the man from lying on that side at night and this site is more exposed to accidental pressure by day.

The best time for inoculation is the afternoon and the men should be directed to avoid alcohol and exercise for the rest of the day.

If, from previous experience or the result of the first inoculation, there be any reason to anticipate an excessive local reaction, it is advisable to give a dose of 30 grains of Chloride of

Calcium (or 15 grains of Calcium Lactate) just before injecting and to repeat the dose after six hours.

(3) *Besredka's alternative method.* Before passing on, it is interesting to note that Besredka advises the use of a true vaccine—one containing living organisms.

His emulsion consists of living culture sensitized by contact with highly immune serum the complement of which has been destroyed by heat, thus leaving only amboceptor.

The rationale of the method is that when the sensitized living organisms are injected, the amount of amboceptor present with them enables the complement of the inoculated person's blood to destroy the bacilli with speed and certainty and without any danger of infection resulting.

C. THE RESULTS OF ANTI-ENTERIC INOCULATION

We now turn to the results following this prophylactic measure, and they are best dealt with under the headings of (*a*) the early and (*b*) the remote.

(*a*) The early results

The most immediate, and in some ways the most practical, results are the *reactions* occurring in the inoculated. After considerable experience one can summarize the results as regards incapacitation as follows:

Incapacitated for 5 days, 1 per mille.
Incapacitated for 3 days, 3 per mille.
Incapacitated for less than 3 days, 996 per mille.

If due care be exercised, the danger of a reaction necessitating the man being admitted to hospital is almost negligible, and one force (I think it was the Canadian contingent) recently reported the inoculation of 27,000 men without a single hospital admission.

The constitutional reaction comes on usually about six hours after inoculation and consists of malaise, a slight temperature of perhaps 101°, with—in some cases—a tendency to faintness. If the man turns in early, he will probably sleep through the stage of constitutional reaction without being conscious of it.

The redness, tenderness and œdema around the inoculation site begin to subside after twenty-four hours usually.

It is safe to say that in 99 per cent. of cases the man is capable of carrying out his duties at the end of forty-eight hours, but for that period of grace he should be excused duty as a concession to his temporary inconvenience and as a generally understood routine.

The *blood changes* follow later and are of both scientific and practical interest, seeing that upon them depends the efficacy of the protection conferred by this method of prophylaxis.

The essential change is an increase in the amount of protective substances of the amboceptor group. It will serve if one substance of this complex group —the agglutinin—be used to illustrate both the degree of immunity conferred and the methods of estimation.

Agglutination is the phenomenon by which motile organisms in the presence of agglutinins first lose their motility and then collect together in groups, as if for mutual protection. Hanging-drops demonstrate the initial motility and the complete agglutination which has followed admixture with immune serum diluted one thousand times. The reaction is regarded as complete if at the end of half an hour no separate motile organisms can be seen. The concentration of agglutinins in a serum is measured by the extent to which the serum can be diluted without losing its power to " clump " a culture in half an hour.

As normal serum has a slight agglutinative power which seldom exceeds that represented by a dilution of 1 in 10, that amount is taken as the basis of comparison. We are now in a position to follow on our chart the effects of inoculation on the degree of this reaction. *Vide* Fig. 4.

On the day of the first injection the agglutination power is charted at the 1 in 10 level. There it remains until the eighth day, when there appears a rise which progresses to its maximum of 120 times the normal on the thirteenth day, after which it begins to fall.

It was hoped at first that increase of the single injection dose would give a proportionately higher rise in the curve, but it was found that increased injections gave little better results, even if pushed to an amount which caused considerable constitutional disturbance, while massive doses of vaccine may produce an initial " negative phase." The effect was then tried of giving a second moderate injection ten days after the first, so that the second stimulus might be summated upon the first. The effect is shown by the wave sweeping up to 300 times the normal. A succession of doses at ten-day intervals would give still further protection, but a balance must be struck between the attainable protection and the inconvenience involved both to the individual and to the unit in the midst of its training. It is considered that the double dose strikes a happy mean.

The need for, and interval between, the two

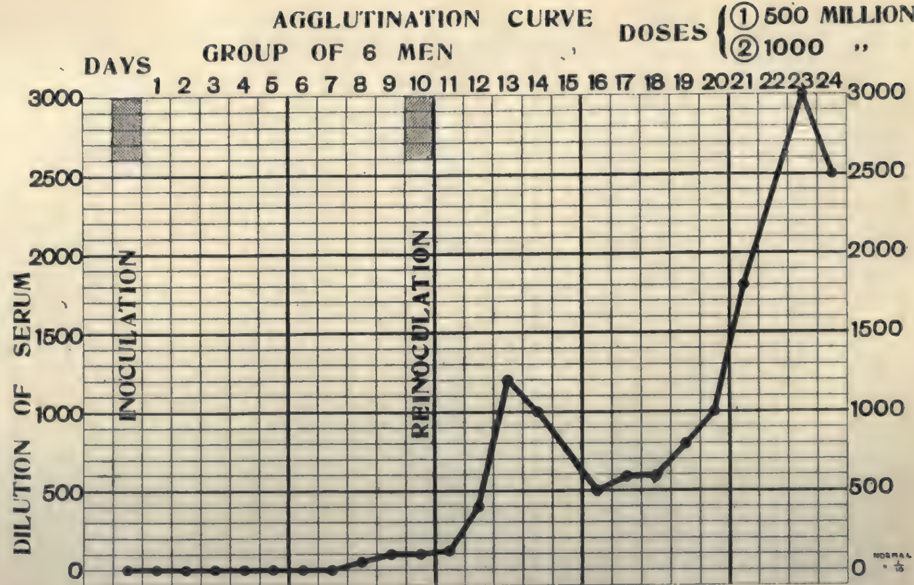


FIG. 4. Chart showing production of agglutinins as a result of anti-typhoid inoculation

injections has been dealt with fully, because of the many questions which are constantly being asked about it and because of the great utility of this chart when hung up in the re-inoculating room. There are very few men indeed who refuse their second dose when the chart has been shown them and fully explained.

After the third week there is a slight but rapid fall for a few days and then the agglutinative power slowly recedes to the normal during a number of years. It is probable that normal is not reached for five or six years, but it is considered that protection should not be regarded as effective after the end of the second year, at which time it is advisable that men should be re-inoculated.

This has an important bearing on statistical data, as will be seen when we come to consider whether a man who has been inoculated more than two years previously should be included in the protected or the unprotected groups.

(*b*) **The remote results**

The remote effects of inoculating upon enteric incidence can only be estimated by statistical methods, with regard to which one factor calls for preliminary comment.

It is that—just referred to—of the classification of partially protected men, *i.e.* those who have had only one injection or who have been fully inoculated more than two years since. To include them among the fully protected would raise the enteric incidence in this group, while to place them among the wholly unprotected would reduce the enteric incidence in *that* group—either of which does injustice to the results of inoculation in the comparison of relative incidences.

The only sound course is to place these men in a group by themselves.

With this initial remark one turns to the available statistics, and these have now become so numerous that only a few of the more striking or interesting can be discussed. Three, of an increasing relative importance, are selected as indicating the results which have been obtained in our own army.

(1) *The Meerut outbreak.* A cavalry regiment at Meerut (India) had 200 inoculated and 300 uninoculated men. Sixty cases of enteric occurred in an outbreak among these men, all living under apparently precisely similar conditions in barracks. The cases were distributed among the groups as follows:

Fully protected	Partially protected	Wholly unprotected
Nil	2	58

Of the 58 cases among unprotected men, 10 died and 2 had to be invalided out of the Service as permanently incapacitated.

(2) *Twenty-four test units.* Special medical officers were attached to twenty-four units for twenty months, with instructions to record the incidence of enteric in relation to prophylactic inoculation. The data thus obtained refer to a number of men equivalent to a whole division, living—as regards the groups in each regiment—under similar conditions for a considerable period. They therefore afford evidence on a scale which cannot be regarded as dominated by co-incidence.

The relative incidences are shown in Fig. 5. If the wholly-unprotected-group data be compared with data from a group comprising all the other men—whether fully or partially protected by inoculation—the former give 5.6 times as many cases and 10.7 times as many deaths from enteric as the latter.

The most effective way of presenting these facts to the men is to state them in terms of sporting odds, thus: If two men of similar physique and

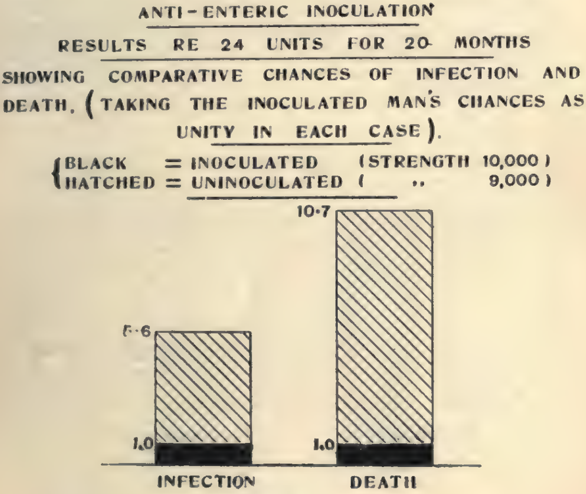


FIG. 5

age—one protected and one unprotected—are exposed to similar risks of enteric and one is going to get it, the odds are 5½ to 1 that it will be the uninoculated man, while if one of them is bound to die of it, the odds lengthen to 10½ to 1 that it will be the unprotected man.

That does not state the full value of the comparison, for if the partially protected be excluded altogether the results are more striking.

(3) *Data of the whole British Army in India during ten years.* The figures derived from the returns of enteric in the British troops in India from 1903 to 1913, cover a still wider field. The chart is shown in Fig. 6.

Here the following tabular comparison may be made between the enteric figures for the year in which inoculation was reintroduced, 1905, and the latest figures available, 1913, when 90 per cent. were inoculated.

	Admissions	Deaths
1905 . .	1146 ..	213
1913 . .	85 ..	16

In comparison the data for the Indian troops for these years may be contrasted. If it be urged that improving conservancy is alone responsible for the reduction in enteric among British troops, then the better sanitation of the cantonments of Indian troops should produce a corresponding decline in their incidence rates. Owing to native prejudices, prophylactic inoculation was not urged upon Indian regiments until 1911 and the numbers inoculated were inconsiderable.

	Admissions	Deaths
1905 . .	130 ..	35
1912 . .	243 ..	62

What are the practical results of this reduction in enteric in the eight years since prophylactic inoculation was reintroduced? Two hundred lives saved annually; 250 less hospital beds; 103,000 days of sickness less in the year—or the equivalent of the whole British Army in India being out of action for a day and a half. In deaths and medical expenses alone this probably represents

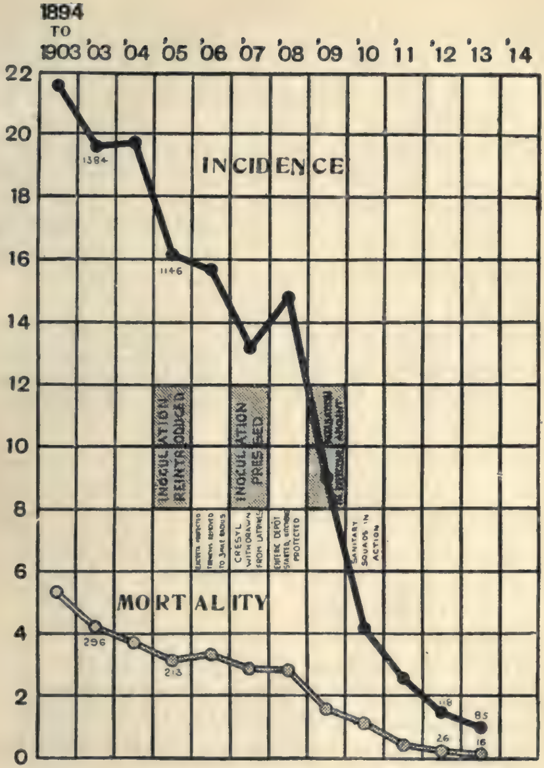


FIG. 6

Reduction of Enteric among British troops in India from 1903 to 1913.

an annual economy of £50,000 a year or a loan of over £1,500,000 at 3 per cent. interest.

I think that these results are sufficiently brilliant to justify the officers of the R.A.M.C. in looking back with satisfaction on the results of their collective efforts of the last ten years.

(4) Striking as these figures are, we get figures more striking still if we turn to the *statistics of the army of the United States*, which has given us a lead in making anti-enteric inoculation compulsory and thus afforded an indication of the results which would follow adoption of a similar course.

To first take the contrast afforded by two divisions of similar strength (about 20,000 men) living in camp on United States territory in 1898—when no men were inoculated—and in 1911—when 100 per cent. of the strength was compulsorily inoculated.

The former division was camped at Chicamauga for ten months and the latter on the Mexican frontier for four months.

	Enteric admissions	Enteric deaths
1898 (ten months)	1729	248
1911 (four months)	1	nil

That the freedom from enteric in the latter instance was not due to absence of sources of infection is shown by the fact that the uninoculated civilians in and around the camp had 47 cases and 17 deaths.

The results of the introduction of voluntary inoculation in the United States army and then of making inoculation compulsory are shown in Fig. 7, which speaks for itself. The only note to be added, as strengthening the case, is that from 1908 to 1913 there was no death in this army

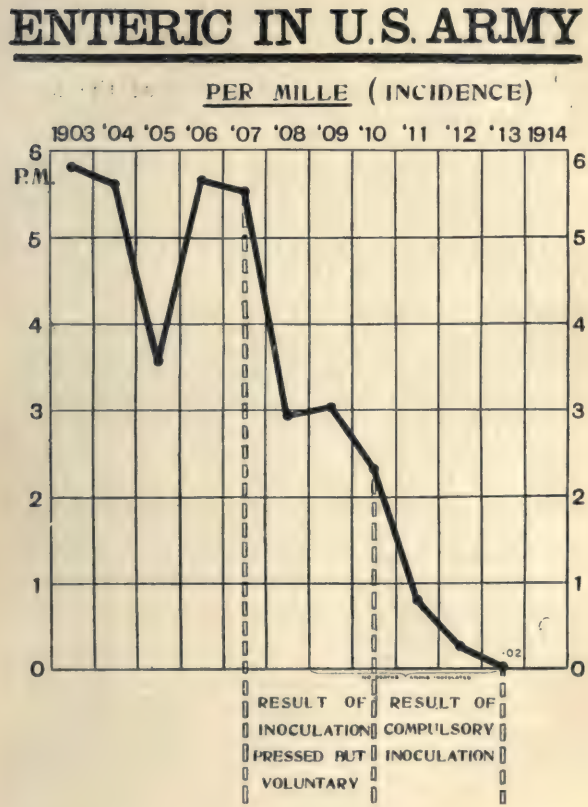


FIG. 7

Results of anti-enteric inoculation on enteric in the U.S. Army.

from enteric fever and in 1913 the army of 90,000 strong only gave three cases of enteric during the year.

(5) Finally we may just glance at the latest published figures bearing on the incidence of enteric upon our men at the front.

Out of 606 cases only 18 per cent. have been among inoculated men, while of the 50 recorded deaths only one has been an inoculated man.

In face of the overwhelmingly convincing mass of statistical proof of the value of this means of protection, one can only look eagerly for the day when our men will be saved from their own vacillation and rescued from the sinister influence of the anti-everything busybody by having prophylactic anti-enteric inoculation made compulsory. Meanwhile the medical officer—already overtaxed by duties sufficiently strenuous—must undertake the thankless task of persuading men to voluntarily adopt a measure which not only protects themselves from a grave danger but protects the whole army in the field from the risk thrust upon it by the obstinacy of the recalcitrant whose sole argument against acquiring protection is the parrot cry of "I don't hold with it."

LECTURE III

THE MARCH

Gentlemen,—Having dealt with the selection of a healthy recruit and considered his physical training, his protection against enteric, and certain of his needs when converted into a soldier—we now come to the march which carries him from the rail-head into the firing-line.

The relevant facts fall naturally under three heads—the physical, the physiological and the practical, but before taking them up in detail it is useful to pause for a moment to grasp the importance of the soldier's ability to march.

That importance is related to the dominant part played by marching power in securing the preponderance of numbers at the critical time and place which determines victory, and it is indicated by Napoleon's dictum that "More battles are won by strength of leg than by force of arms." Further emphasis is found in the records of two other celebrated commanders whose successes were won rather by sweat than by slaughter.

In Fortescue's "History of the British Army" there is an illustration from Marlborough's campaign in the Low Countries in 1711. It is there set out that, by a march of forty miles in eighteen hours, Marlborough's force captured the strongly fortified town of Bouchain under the eyes of the outmarched Villars and thus brought this campaign to an abruptly victorious end at the expense of trivial loss.

Colonel Henderson, in his life of Stonewall Jackson, remarks that "His victories were won rather by sweat than by blood, by skilful marching than by sheer hard fighting. The marches which strewed the wayside with footsore and weaklings won his battles. The enemy, surprised and outnumbered, was practically beaten before a shot was fired and success was obtained at a trifling cost."

Jackson himself remarked, "I would rather lose one man in marching than five in fighting."

We, as medical officers, are concerned to prevent the loss of even that one man in marching and this can only be achieved by infinite pains and attention to a host of details each trivial in itself.

PRELIMINARY DATA

(*a*) Distance

For large bodies of men marching continuously day after day, the daily distances covered are at first sight surprisingly small. Twelve miles a day is fair going, fifteen miles is good and twenty miles a day continuously is regarded as "forced marching."

Roberts' march of 318 miles from Kabul to Kandahar took twenty-three days. Friant's Division covered seventy-eight miles in forty-six hours, and at Austerlitz on the following day lost 40 per cent. of its surviving strength.

I think the record march is that of the Light

Division to Talavera—sixty-two miles in twenty-six hours.

(*b*) Speed

The ordinary quick time is that of 120 thirty-inch steps a minute. This gives us the round figure of 100 yards a minute, which is so important a datum in the calculation of distances when the commander of a unit has to get his force at a given point at a given time, to take its allotted place in a column of march.

If halts be allowed for, this works out at just under three miles an hour, but the larger the force the more slowly it marches and two and a half miles an hour for a brigade or two for a division is a good average.

(*c*) Duration

It will be seen that the average fifteen-mile march (and we are taking averages throughout) will take a brigade six hours and a division eight hours. When you realize that a division, with all its impedimenta in column of march, covers a length of fifteen miles of road, it is much easier to appreciate the difficulties which occur when a wagon breaks down and blocks a narrow way near the head of the column. At the best, the rear-guard, at the end of its fifteen-mile march, can only reach the point from which the advance-guard moved off in the morning and the normal eight hours which the rear-guard should occupy on its day's march will be increased by every delay which checks the weary column ahead as it gradually breaks down the road along which it slowly labours on its way.

(A) PHYSICS

Having disposed of these preliminaries, we now turn to certain relevant matters of physics.

(*a*) The unit of energy

The unit of energy—the calorie—is the amount of heat needed to raise one gramme of water through 1° C. A kilo-calorie is a thousand times that amount and is the unit used in bromatology, as indicated by the term Calorie spelt with a capital "C."

(*b*) Energy distribution

Three thousand Calories should be provided by the diet of a man at rest. When it is realized that a steam-engine is only capable of utilizing for useful work 13 per cent. of the energy value of its fuel, it will be appreciated that man—as an internal combustion engine—works comparatively economically in utilizing 20 per cent. of the energy value of his diet for actual work. The 80 per cent. balance goes in production of heat which must be dissipated if the body temperature is to be kept constant. There are thus 2400 Calories of heat to be dissipated daily by the man at rest—*i.e.* 800 Calories in eight hours. Vide Fig. 8, column A—the scale being shown in column B.

When the man is marching this is obviously much increased. A march of fifteen miles on an undulating road, when fifty pounds of equipment is carried, involves 350 foot-tons of work. This needs 254 Calories of energy as work, which can only be provided at the expense of a production of 1016 Calories of useless heat. If the march occupies eight hours, this 1016 Calories must be added to

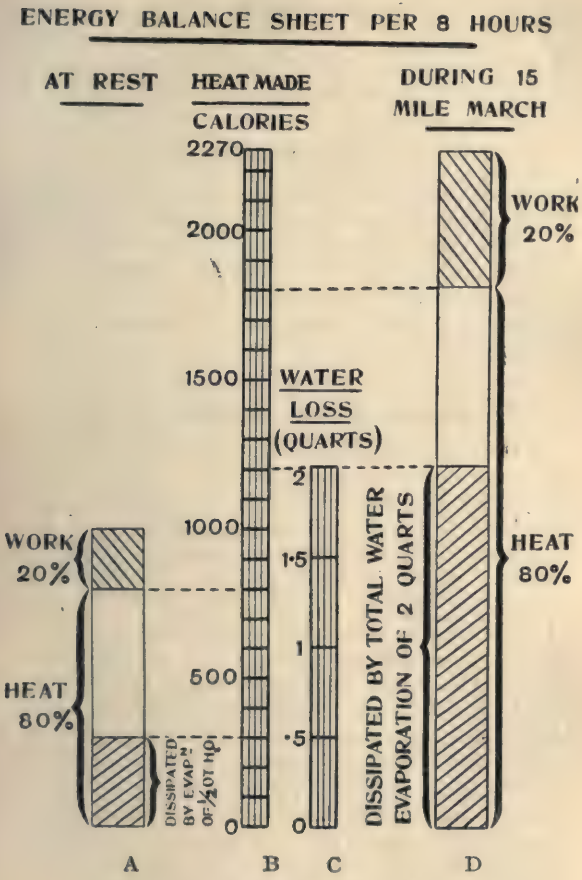

ENERGY BALANCE SHEET PER 8 HOURS
AT REST
HEAT MADE
CALORIES
DURING 15 MILE MARCH
2270
2000
1500
1000
500
0
WORK 20%
HEAT 80%
WATER LOSS (QUARTS)
2
1·5
1
·5
0
DISSIPATED BY TOTAL WATER EVAPORATION OF 2 QUARTS
WORK 20%
HEAT 80%
A
B
C
D

FIG. 8

the 800 Calories which must be disposed of by the man when at rest—making a total dissipation of 1800 Calories in the eight hours of the march. Vide Column D in relation to Column B in Fig. 8.

(*c*) Heat dissipation

The principal factor in the dissipation of heat is evaporation of water, and this makes it necessary to note that each gramme of water absorbs .5 Calorie during its vaporization. Converted into terms of our fluid measures, this represents a loss of 600 Calories for every quart of water evaporated from the body.

(*d*) Attitude of best mechanical advantage

Mathematical calculations show that in marching the best mechanical advantage is obtained by a stride the length of which is six-sevenths that of the leg. With regard to the best attitude there has been some difference of opinion. There was recently much interest aroused by the French suggestion of the " Marche en flexion " by means of which it was claimed that men could cover long distances at the surprising speed of six miles an hour. The knees were kept flexed and the body was inclined forward at a greater angle as the desired speed increased—the effect being that of a continuous falling forward. It was found on investigation that the results were due rather to the training which the exponents of this method maintained than to any inherent advantages in the method itself and that the continuous strain on the quadriceps extensor caused proportionate exhaustion. This method was soon abandoned, although Himalayan experience of the natives' method of knee flexion when walking downhill shows it to be valuable in descents.

There are obvious objections to adoption of the rigid pose of the smart soldier on the parade ground to the conditions of a war march, and many rules have been made regarding the position of head and limbs best suited to the latter. These are difficult to apply simultaneously, when the man has one rule for his head another for his arms and so on, so that there is merit in a single phrase which summarizes them all and needs no effort to remember or apply. One such phrase is—the position assumed when about to ascend a flight of stairs. That attitude puts the head, back and arms in the most advantageous positions and you will appreciate the hint if you adopt the attitude towards the end of a long march.

(B) PHYSIOLOGY

The physical data lead naturally to the correlative physiological interests, the first of which is :

(*a*) Heat equilibrium of a man at rest

Rest in this sense does not mean absolute quiescence, but the quiet of a loafing day. Under these conditions the body needs about 3000 Calories of energy, and of this, as seen, 2400 Calories go to the production of heat. If this heat were allowed to accumulate, hyperpyrexia would ultimately result. It is disposed of by the abstraction of heat from the body by radiation, conduction, convection, in urine, and by the evaporation of fluid. It is calculated that when at rest roughly 30 per cent. is dissipated by the last means, the major portion being lost by evaporation from the respiratory tract.

(*b*) **Heat equilibrium of a man when marching**

(1) The physiological optimum temperature is 100.5°, the human machine—like all internal combustion engines—working best when warmed up.

(2) The physiological maximum is 102°, at which temperature pathological indications begin to be noticeable. Swaying and tremor mark the onset of inco-ordination due to the waste products of too rapid metabolism affecting the nerve-endings. The flushed, sweating face and open mouth proclaim the need for increased evaporation. The gasping respiration indicates stimulation of the respiratory centres by accumulating carbon dioxide in the blood.

The range between the physiological optimum and the pathological temperatures is thus only 1½° and this narrow safety margin indicates alike the delicacy of the adjustment mechanism and the importance of every means of aiding that adjustment.

(3) This adjustment—in contrast to the case of the man at rest—is mainly effected by evaporation, and whereas in the resting man this is chiefly due to loss from the respiratory tract, the great excess required to be evaporated during the march has to be disposed of by the skin.

We have already seen that the total heat which must be lost during an eight-hour march of fifteen miles is 1800 Calories (*vide* Fig. 8, columns B and D). The proportion of this which must be dissipated by evaporation amounts to 1300 Calories; and as the evaporation of one quart of water takes 600 Calories, the total water which must be lost in this eight-hour march is two quarts, or one quart in seven and a half miles (*vide* Fig. 8, columns B, C and D).

The importance of free evaporation from the skin is well illustrated by the case of a man who suffered from the extraordinary defect of congenital absence of sweat glands. He was only able to work during hot weather if his shirt were kept saturated by water.

(c) Effects of water loss

Fig. 9 shows in graphic form certain important points bearing upon the water loss and water needs of marching men.

It is seen that water forms 66 per cent. of the total body weight. This proportion is a hundred pounds, or ten gallons, of which the loss of one gallon involves danger and loss of one and a half gallons causes death. In this connection it is interesting to note that death results from asphyxia, which is probably due to the increased viscosity of the blood retarding its circulation through the pulmonary capillaries of one two-thousandth inch diameter.

The one gallon which represents the maximum which can be lost without danger is shown enlarged in the right-hand column, which indicates the effect of loss of separate successive quarts.

One quart can be lost without inefficiency resulting, so that at the end of seven and a half miles marched without water the men should be quite fit.

During the loss of the next quart slight inefficiency gradually appears and at the end of fifteen miles there is a genuine "necessity thirst," but still there is but slight inefficiency.

During the loss of the third quart inefficiency becomes marked, if no water has been drunk, and after the loss of four quarts during a thirty-mile waterless march the man's condition is becoming dangerous.

These data are of the utmost practical im-

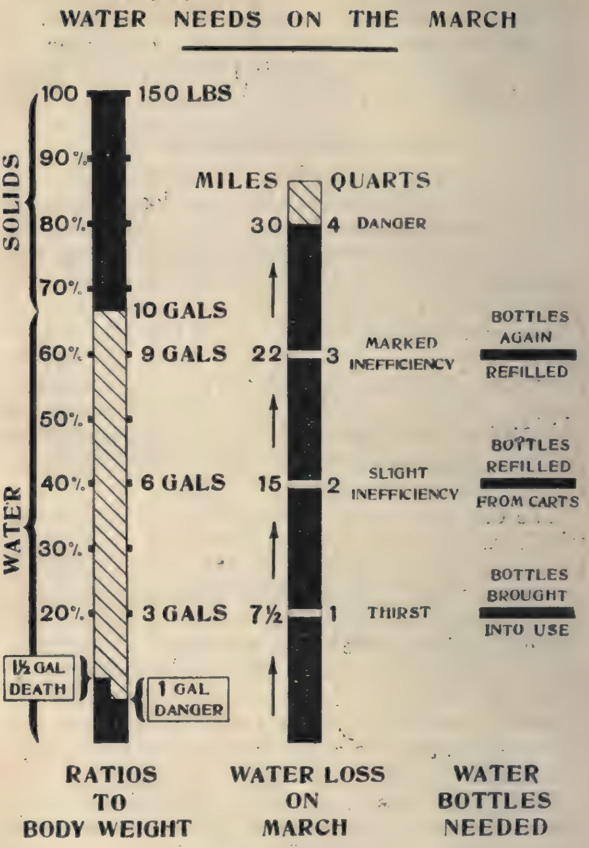

WATER NEEDS ON THE MARCH
100
150 LBS
90%
80%
70%
10 GALS
60%
9 GALS
50%
40%
6 GALS
30%
20%
3 GALS
SOLIDS
WATER
1½ GAL DEATH
1 GAL DANGER
MILES
QUARTS
30
4
DANGER
22
3
MARKED INEFFICIENCY
15
2
SLIGHT INEFFICIENCY
7½
1
THIRST
BOTTLES AGAIN REFILLED
BOTTLES REFILLED FROM CARTS
BOTTLES BROUGHT INTO USE
RATIOS TO BODY WEIGHT
WATER LOSS ON MARCH
WATER BOTTLES NEEDED

FIG. 9

portance in that they enable us to determine at what stages of the march the necessity of drinking the water-bottle contents arises. On the right of the Table are shown the periods and distances of the march at which the water-bottles should be taken into use (and need to be refilled) to ensure that not even a slight inefficiency may result from lack of water. They indicate that on a fifteen-mile march the contents of the water-bottle should not be touched until the half-way point is reached and that then the contents of the water-bottle (one quart, or, more precisely, one pint and three-quarters) should suffice to take the men into camp without the bottle being refilled, or inefficiency being experienced.

The precise data thus obtained afford invaluable aid in the maintenance of water discipline, the enforcement of which has been made less firm by the fear of the combatant officer that strict discipline in this matter might inflict genuine distress on the men.

Owing to uncertainty as to the precise point at which " habit thirst " becomes " necessity thirst," no definite orders have been laid down.

It is fully recognized that the data given are only averages and that allowance must be made for the increased sweat occurring on hot days, but it is to be remembered that in the Table given there is a margin of a quart of water always between the man's needs and the onset of even slight inefficiency due to loss of fluid.

Two aspects of this question may be mentioned as showing the value of these calculations—which are confirmed by the actual average daily water consumption by a body of men marching continuously under war conditions. (*a*) Men can without fear of causing them genuine hardship, be prevented from drinking water taken from any wayside source—however liable to pollution. (*b*) The danger of slack water discipline is illustrated by an incident in the first Zulu war when our force, advancing on a strongly held enemy position, came unexpectedly upon a sunken watercourse, and at a shout of " water " practically the whole skirmishing line threw down its weapons and dashed for the river. Only failure of the enemy to take immediate advantage of this gross breach of discipline saved the force from annihilation.

(*d*) **Marching rhythm**

As the optimum length of stride bears a definite ratio to the length of leg, it is obvious that adoption of one rhythm of marching will place the tall and short men at a mechanical disadvantage. On the other hand walking is so automatic an action that it is said to be the only exercise which can be continued during sleep. It must therefore be largely under subconscious control. Any factor which increases this subconscious control diminishes purposeful mental effort and thus economizes mental strain. Marching in rhythm—and especially to music or singing—is a valuable aid to subconscious control in marching and probably more than neutralizes the loss by mechanical disadvantage which results from maintaining an uniform length stride for men of different heights.

(*e*) **Digestion**

Digestion is interfered with by the vascular demands of muscles at work; the men should therefore have only a light meal before a long march, but this light meal is most important.

Exhaustion also retards digestion ; there should therefore be an interval of half an hour after arrival in camp from a trying march before the main meal is served. That meal must be very digestible if the exhausted man is to gain the full benefit from it. In this connection there are two important physiological points—one is that meat extract (beef-tea or soup) taken before the main meal increases the digestive capacity by 20 per cent., owing to the consequent flow of "appetite juice"; the other is that the man gains the greatest absorption of protein from slowly stewed meat.

It may again be mentioned here that sugar is the most rapid muscular restorative, in view of its rapidity of digestion and oxidation.

(C) PRACTICAL CONSIDERATIONS

These may with advantage be epitomized into the form of notes.

(1) *Marching hours.* An early start is desirable, in order to get the march over before the heat of the day.

Night marching is to be avoided if possible: owing to the loss of sleep which ensues it is unprofitable.

(2) *Speed.* Increase of speed beyond the average of two and a half miles an hour (including halts) increases the energy expenditure in greater proportion than the speed.

The start and finish of the march should be slow, as every horse-master knows.

(3) *Rhythm.* The men should alternate between marching in step, marching at ease and marching to song.

(4) *Order.* The men should march in open order, half on each side of the road. This lessens the tax on the last men of marching into a reek of odour and water vapour, the latter of which limits their

power of sweat evaporation. The centre of the road is thus left free for transport.

(5) *Clothing.* The chest should be bared. The new web-pattern equipment makes this easy. This effects a reduction of half a degree in body temperature, which is a third of the margin between the optimum and pathological temperatures.

If the clothing be not thrown open, the shirt may absorb as much as a pint of fluid and this will evaporate after arrival in camp with a consequent abstraction from the body of 300 Calories of heat which is then badly needed.

Marching "shorts" are excellent in warm weather.

(6) *Halts.* Five minutes should be given in each hour and thirty minutes when the half-way point is reached. Longer halts make the men stiff.

The men should throw off their equipment and lie down. It is a great assistance if they massage each other's legs.

The first halt should be called soon after starting, in order to allow the men to relieve themselves and adjust their loads.

A halt of one day in seven is biblical and otherwise sound. It enables the men to wash themselves and their sweat-soaked clothes thoroughly, to darn their socks, and to get the regimental chiropodist to attend to their feet.

(7) *Conservancy.* Strict regimental discipline is most necessary, for the line of march to-day will be the line of communication to-morrow.

Each man should be made to use his trenching tool to bury his excreta, so that the roadside may not be fouled. Failure to carry out this simple measure of great importance to the health of the troops should be made a disciplinary matter and severely dealt with.

(8) *Contra-indications.* Alcohol should be forbidden on the march: it lowers blood-pressure and causes rapid heat production without corresponding tissue repair.

Smoking should be forbidden; it causes thirst, tremor and tachycardia.

(9) *Food.* A light meal should be provided just before the start.

If the march be a long one, light food should be provided when two-thirds of the distance has been covered. Each man carries the remains of his bread-and-cheese ration issued on the preceding evening.

The main meal should be served after arrival at the end of the march. The desirable interval of half an hour for rest is generally unavoidable. If the force arrives in good time, tea may be served as soon as possible—within half an hour usually—and the main meal later. This is advantageous, as by dinner-time all work is done and the men's minds are free. The moral and physical effects on the men of long delay in getting their main meal are very marked. They are apt to lag on the march or to go to sleep on arrival in camp and not bother about the food when it is ready at last.

These are most essentially matters for the regimental medical officer to interest himself in.

(10) *Cooking.* Under old conditions not only did the cooks' wagons and rations not arrive for a very considerable time after the unit reached the end of its march, but the meal took the cooks two hours to prepare after they were able to get to work. Meanwhile the men had to do the best that they could with their mess tins, and those who have attempted to cook with mess tins know the unsatisfactory nature of the products. More-

over, until the wagons arrived, there was generally nothing to cook.

The first improvement was that camp kettles were brought into the load carried by the first line of transport. That calls for the definition of first line of transport as transport which follows the unit as closely as possible and carries everything that is absolutely essential for the troops if they are to continue fighting. The second line of transport travels with the baggage train at the rear of the force and carries the items which the men can temporarily dispense with.

The first line of transport follows immediately after each unit,* and the camp kettles should arrive a few minutes after the unit itself so that the main meal should—at the worst—be ready within two hours after men reach the camp or bivouac.

Still more modern advances have evolved the travelling kitchen, which calls for a brief description.

That now in use is of the "heat-retaining" type (*vide* Fig. 10), which gives *en route* no smoke which might draw the enemy's fire. It consists of ovens and hot-jacketed boilers arranged around a central furnace, all contained in the body. The limber contains hot-jacketed receptacles, compartments for rations, utensils, fuel, etc. It can be detached from the body and, being drawn by one horse, is used for food distribution while the body continues cooking. The whole is drawn by two horses; weighs twenty-four hundredweight, and cooks for 250 men and their officers. It travels with the first line of transport.

The apparatus is worked on the following lines.

* "Field Service Regulations," Part i, page 30; "War Establishments—Expeditionary Force," page 146.

The food is placed in the receptacles and the furnace vigorously stoked for one and a quarter hours before the force marches out, when the fire is drawn or damped right down before the kitchen follows at the rear of the unit, behind the ammunition and with the water-carts. Cooking proceeds on the

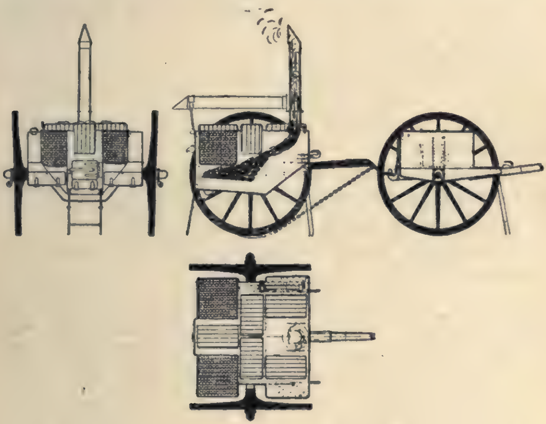


FIG. 10.
Travelling kitchen.

line of march, owing to retention of heat by the non-conducting jacketed receptacles, and is sufficiently advanced for a complete meal to be served one and a half hours after the start. The meat is better cooked and more tender the longer it is exposed to this moderate heat.

By this means the whole unit can be supplied with its main meal on arrival in camp. This is a great advantage to the pickets, who can get their dinners before they go on duty or else may be supplied later by the limber coming round to distribute hot food to outlying posts.

It is obvious that provision of this apparatus conduces to the maintenance of a high degree of fighting efficiency by securing that the men are adequately nourished, and it has, moreover, the additional advantage of keeping the men in good humour—on the principle that "a hungry man is an angry man."

(II) *Fluid ingesta.* Consideration of the practical bearings on this matter has been simplified by previous discussion of the physical and physiological data.

(*a*) The normal *average requirements* are that the men should get one quart of water at the end of every seven and a half miles marched.

Allowance must be made for high speed, increased weight carried, and high atmospheric temperature or humidity.

In order to reduce the temptation to men to drink the contents of their water-bottles before they have reached the end of the first seven and a half miles certain precautions should be taken.

The first is that the men should have a large amount of hot tea or coffee before they start on the march. In view of the indicated value of sugar, this should be freely sweetened.

Then it is a useful measure to advise the men to suck a bullet or pebble on the march. It has been urged that the consequent flow of saliva quenches thirst, which reminds one of the problem of the community which made a living by taking in each other's washing. The value of sucking a bullet lies in the fact that it keeps the mouth shut and therefore moist.

With these simple precautions, the old campaigner will march all day without having recourse to his water-bottle. The difficulty is with the young inexperienced soldier, who starts pulling at his water-bottle before he has marched two or three miles. This further promotes " habit thirst " and the man wants to refill his empty bottle from the first heavily-contaminated wayside source that he passes. The actual needs bear repetition: the water-bottle should not be taken into use until seven and a half miles have been covered, and the contents should then take the man to the end of the fifteenth mile. The bottle should be refilled at the end of the fifteenth mile and at the end of every seventh mile subsequently. This will prevent the men suffering from " necessity thirst," and there will always be a quart of water between each man and any inefficiency from loss of fluid.

(*b*) The *water-bottles* hold approximately a quart of water each. They should be filled overnight either with chlorinated water or with weak, sweet, boiling tea. The bottles are thus sterilized and in the morning they are full of cold sterile liquid. Tea is a better thirst-quencher than water.

The corks need dipping in boiling water, for they become very foul and coated with a layer of bacterial slime.

The cavalry are supplied with aluminium bottles which withstand the acid of the sterilizing tabloids which each cavalryman is provided with. Two tabloids will sterilize the contents of one bottle in half an hour. Immediately the bottle is emptied it should be refilled and the tabloids added so that they may have time to act before more water is drunk.

(*c*) The *water-carts* hold 110 gallons each. The two supplied per battalion therefore supply 880 quarts, *i.e.* enough to refill the water-bottles of the average battalion in the field.

They should be filled and the contents chlorinated overnight by addition of bleaching powder, so that they are full of sterile water and ready to take their place in the first line transport when the unit moves off in the morning.

When the bottles need replenishing, this should be done at the half-hour halt, the carts being brought close up for the purpose. Supervision is needed to see that there is no waste or there will not be enough water to go round. The carts should then be refilled at the first opportunity and the contents chlorinated in readiness for the next replenishing of the bottles or for the supply of pure water for making tea and cooking when the unit reaches camp.

As the carts can only travel three and a half miles an hour when full, or five miles an hour when empty, they cannot keep up with cavalry. This is why cavalrymen are supplied with the sterilizing tabloids. It would be a great advantage if portable clarifiers and sterilizers for water were supplied to cavalry units in a pack-saddle form which would ensure their keeping up with, or following close after, each unit.

(*d*) The *personnel* per battalion available for water duties consists of one N.C.O. and four men of the R.A.M.C. In addition the M.O. can apply to the C.O. for two men per company for special work in connection with the purification of water. As this is not generally known and is only laid down in one obscure regulation, the reference may be useful. It is found in "Field Service Regulations," Part i, para. 46.

(12) *Care of the men's feet.* This brings us to the last, but by no means the least, of the practical considerations relating to the march with which we can find time to deal. The importance of

this matter in its effects upon the progress of campaigns has been dealt with, but it may be emphasized by noting that 25 per cent. of troops suffer from some disability due to their feet during the first ten days of a campaign. In the Franco-Prussian War the Germans had 30,000 men incapacitated from this cause in "the early part" of the war.

The view that men suffering from sore feet have no claim to sympathy is unfair to them. Blistered feet make the sufferer bring into play untrained and inco-ordinated muscles and this increases the work done by as much as 20 per cent. This in turn raises the temperature by one degree, and thus absorbs two-thirds of the margin between the physiological optimum and the temperature at which pathological effects appear.

The features of good marching boots have been mentioned and the methods of preparing boots for the march have been described. It is probable that—contrary to general belief—the majority of cases of disability from sore feet are due to defects in the socks rather than in the boots. Those defects are—undarned holes of which the edges ruck up into ridges, and bad darning which has drawn the edges of the hole together in a lump. It is advisable that two pairs of socks be worn: even if the outer pair be only of cotton, they take the friction of the boot off the woollen pair which should be worn next the feet.

When the socks are worn into holes they may be replaced by substitutes which are quite satisfactory. The first is a triangular piece of thin soft textile, such as linen. The man places his foot on it, with the toe towards the apex so that the material can be brought up around and wrapped over the foot. If of the correct size, the apex in front and the opposite edge behind will both reach just to the top of the boot. The material, being soft, adapts itself to the spaces around the foot, without puckering into the ridges which one would expect to form and chafe the skin. In the absence of suitable textile material, thin greased paper may be substituted.

The *daily routine for care of the feet* is as follows: On arrival in camp the men should remove their boots, clean, dry and dubbin them so that they keep waterproof and pliable.

They should wash their feet in cold water, rubbing them with alum or spirit lotion to harden the skin if there be any tenderness. Clean socks and camp shoes should be put on, and the consequent sense of comfort alone is well worth the trouble.

Finally the socks worn on the march should be washed and kneaded until perfectly soft and then dried ready for the morning, when socks and boots will be clean, soft and comfortable.

While it will often happen that the whole of this routine cannot be carried out daily, it should be adhered to as far as possible and the consequent reduction in disability from sore feet will be surprising. If the M.O. instructs the regimental chiropodist in his particular methods, the latter will relieve him of a considerable tax on his time when it is most valuable.

There are various devices for lessening the friction between the foot and the sock. The time-honoured one is that of soaping the inside of the sock, so that when the foot gets wet with sweat the lather serves as a lubricant. Another method—applicable to cold weather when there is little sweat—is to dust the inside of the sock freely with talc (magnesium silicate, which is insoluble) with 10 per cent. boracic acid and 3 per cent. salicylic acid added.

A simple and most useful adjunct is a leather strap and buckle. The strap is passed as a figure-of-eight under the foot, over the instep, around the top of the boot and buckled off over the inner malleolus. This so lessons friction that a man with blistered feet can often march in comfort.

The *treatment of certain conditions* may be indicated. Blisters should be pricked and, after the fluid has been squeezed out, painted with Tincture of Iodine. Finally the blistered area is protected by a piece of adhesive rubber plaster, in the centre of which is cut a small hole to allow discharge to escape.

Corns should be treated by the regimental chiropodist at the weekly halt. There is no more efficient method than that of paring down with scissors, curved on the flat, and subsequently extracting the "core" after the latter has been hardened and rendered opaque by painting daily for a few days with salicylic paint consisting of:

Salicylic Acid, 60 grains
Ext. Cannabis Indica, 8 grains
Collodium Flexile, 1 oz.

This keeps better if a little rectified spirit be added.

Bromidrosis is best treated by soaking the feet on alternate days with a 2 per cent. solution of formalin or applying 2 per cent. salicylic ointment.

Men who are liable to tenderness of their feet may apply 1 per cent. formalin on alternate days with advantage.

With these hints on the care of the men's feet, the section dealing with the march must be concluded—not that the tale is fully told but because the available time has come to an end.

LECTURE IV

SICKNESS IN THE ARMY

Gentlemen,—It is alleged—with what basis of truth I leave you to judge—that among the spectral archives of human effort there is a tome which embodies the record of each individual. If that be so, the record of the sanitary officer might take the form of a balance-sheet which sets out on the one side the increased efficiency due to his efforts and on the other the losses which he might have prevented. The successful sanitary officer's final balance-sheet should show a substantial item on the credit side.

Hitherto we have dealt only with credit items relating to the getting of fit men into the fighting line; to-day we turn to the debit page and consider the losses of that fighting capital by sickness.

Owing to the sex, age, and careful selection of the personnel of a striking force, the army sanitarian has little concern with such causes of ill-health as degeneration, neoplasms, and functional failures. Disease, on the other hand, has hitherto caused an overwhelmingly large proportion of losses in war. Its causes in the field are almost wholly bacterial and largely preventable, and herein lies the appeal which excess sickness makes to the energy of the sanitary officer who would that his record might not show an adverse balance.

This negative aspect is best approached by a survey of the indications afforded by (*a*) the data of sickness in armies in normal peace times and (*b*) the losses by disease in war.

A. SICKNESS IN THE ARMY DURING PEACE

Sickness in the army during normal peace times is studied in the hope that thereby we may be able to extract some indications as to the best means of preventing sickness in war. There are three main questions to be answered. First: Has success attended sanitary efforts in general? Secondly: If so, to what special measures is that success mainly attributable? Thirdly: What are the practical outcomes of research into the etiology of those diseases which so largely determine the high sickness incidence of war?

1. The success of sanitary efforts in general

We may consider the progress of a half-century and that of the most recent decade of which the full statistics are available.

(*a*) To take first the improvement in the health of the whole of our army at home and abroad, a comparison is made between the returns for 1855 and 1905. In that half-century the death-rate fell to 33 per cent. and the total sick-rate to 48 per cent. of the levels of 1855.

(*b*) For the results of a decade of sanitary progress it is better for our immediate purpose to turn to the figures relating to the British troops in India, where our men live constantly under conditions which more resemble those of active service than do those which obtain at home.

From 1903 to 1912 the following results were obtained, as shown in Fig. 11:

The enteric death-rate	fell to 8·8	per cent.
The invaliding rate	,, 23	,,
The total death-rate	,, 35	,,
The constantly-sick-rate	,, 46	,,

In the figure the shaded portions of the columns indicate the reductions which have been effected.

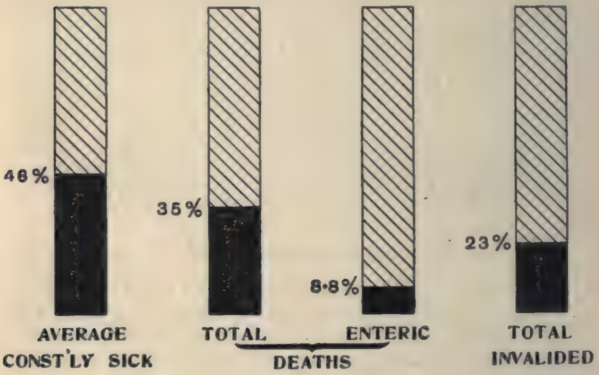


FIG. 11

Result of ten years of sanitary effort in the Army from 1903–1912

The progress may perhaps be better realized from the actual numerical savings.

Annual Saving

600 less deaths.
1,500 less invalided out of the service.
2,300 less average strength sick in hospital:

70,000 less days sickness from enteric, *i.e.* the equivalent of the whole of the British troops in India being kept out of hospital for one day.

(*c*) Another interesting comparison is that between the death-rate for the whole British Army and that of civilians of corresponding age and sex. In 1855 the military rate was 85 per cent. more, while in 1905 it was 22 per cent. less, than the civil rate. Against the fact that a certain number of sick men are annually invalided out of the service to swell the civil death-rates may be placed the effects on health of the difficulties of sanitation in foreign stations.

I think that you will agree with me that this series of figures indicate results which may be regarded with satisfaction by military sanitarians who pause to take stock of the fruits of their labours, and I am sure that no more generous recognition will be accorded that that given by their *confrères* in civil practice.

2. The relative importance of special sanitary measures

In considering evidence bearing upon the question of which measures have had the greatest influence in the production of these results, it is advisable to turn to data from India, where conditions are the most similar to those of active service. The indications may best be followed by considering the relation between various sanitary measures and the reduction in the incidence of cholera and enteric on British troops. In drawing inferences from these statistical returns, the *post hoc propter hoc* method of deduction is the only one available and must be adopted despite its frankly admitted liability to fallacy.

(*a*) *Cholera*. In Fig. 12 there is shown, by decades, the mortality from cholera between 1863 and 1912 in British troops.

During the first decade the mortality was so great that in 1869 alone 972 British soldiers died from this fell disease; in 1912 the deaths amounted to only fourteen. It is generally considered that this most striking reduction is mostly due to the protection of water from contamination. Measures taken for this purpose by the pioneers were steps in the dark, but the discovery by Koch, in 1884, of the *Spirillum Choleræ* gave the necessary scientific knowledge which has led to the saving of so many valuable lives.

The rapidity of reproduction and the high motility of the vibriones explain the speed and extent of infection of water to which infective organisms have gained access, while native habits explain the relative incidences of cholera upon troops and natives at the present time. When the native goes into the village pond to wash, he first wades out into the middle of this collection of foul surface drainage and thoroughly stirs up the mud; then he washes himself thoroughly; then he cleans his teeth with a finger and expectorates freely; finally, when he dies of cholera, the best that his friends can do for the community is to throw his corpse into the nearest stream. On the other hand the sepoy, living in a halo of infected villages and often mixing freely with the villagers, but having a pure water-supply in cantonments, escapes. Even in hill stations where every year the wave of infection sweeps up to villages, within a half mile of barracks, the Indian troops escape, and in my

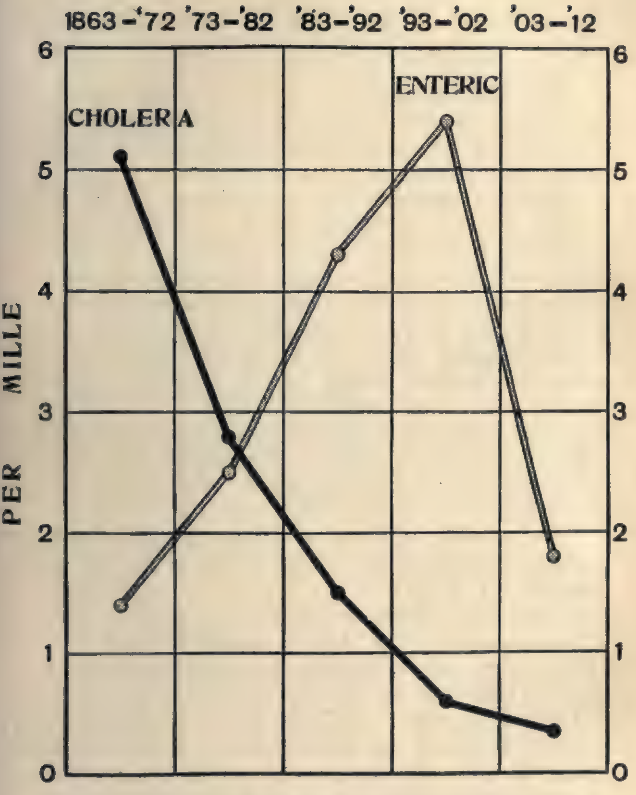


FIG. 12.
Mortality from Cholera and Enteric among the British Troops in India.

six years' experience of a division in India there was but one small outbreak of cholera among 12,000 Indian troops, while the native population of the province died at a rate of 83,000 in a single year.

Both the outbreaks with which I had personal acquaintance—the only two outbreaks in the division in six years—were undoubtedly water-borne and present features of interest.

The first was in a hill station from which two native women, driven by an unavoidable lack of water in the camp, went down to a village to bathe. That village was subsequently found to have lost over thirty of its inhabitants from cholera in a short time, without the fact having been reported, and the corpses had been thrown into the stream which fed the bathing pond. The disease thus introduced into the camp was rapidly stamped out, but not before a medical subordinate paid the death penalty for going from attending the sick to his meals without washing his hands.

The other outbreak was one among British troops marching down from the hills. It was traced, by a process of exclusion, to a native contractor's mineral-water factory sited between the rest-camp and a heavily infected native town. The water was stored in an open bath in the street, the surface of the water being covered thickly with dust. The water was certainly being filtered through an apparently sound Berkefeld filter, but on demanding to see the filter candle it was found that the candle had been broken and replaced by a dirty portion of the clothing of the coolie in attendance.

(*b*) *Enteric.* What was the course of enteric incidence while this remarkable diminution was

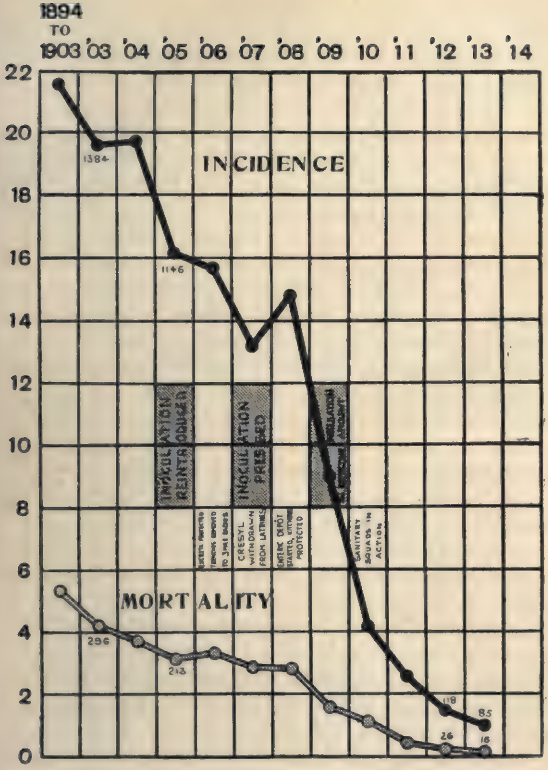


FIG. 12A.

Reduction of Enteric among British Troops in India from 1903 to 1913 taking place in the cholera death-rate? The two death-rates are charted together in Fig. 12 for comparison and it is seen that—in spite of the effects of protection in water-supplies in reducing cholera—the enteric mortality was actually increasing at a similar rate up to the year 1903. It was therefore obvious that, however important the provision of pure water may be, it certainly is not the predominant factor in the prevention of enteric and the most important factor, or factors, remained to be sought. The enteric incidence of the succeeding decade throws considerable light upon the search, and the relation of certain measures to the curve is shown in Fig. 12A, although that relation is not necessarily one of cause and effect. The association between certain measures and enteric incidence can be followed from the chart, and it will be sufficient in general to simply state here in chronological order the principal measures which were adopted.

1905. Anti-enteric inoculation was reintroduced as a voluntary measure.

1906. It having been noted that stations which trenched filth close to cantonments had 30 per cent. more enteric than those which trenched filth three miles beyond cantonment boundaries, it was directed that the trenches should be sited at not less than that distance from barracks. Disinfectant solution was placed in latrine receptacles in order to keep flies off.

1907. Anti-enteric inoculation was pressed, but no considerable number of men availed themselves of this means of protection. The use of disinfectant solution in latrine pans was discontinued.

1908. Latrines and kitchens were systematically fly-proofed. Post-enteric "carriers" of enteric organisms were isolated at the Naini Tal depot, and were invalided out of the service if found to become permanent carriers.

1909. The proportion of men inoculated against enteric became, for the first time, sufficient to have an appreciable influence upon the incidence rate in general.

1910. The Sanitary Squad personnel came into action and exercised a very excellent effect upon conservancy methods in cantonments.

1913. The proportion of inoculated men reached the high figure of about 90 per cent. for the whole of the British troops in India.

From the statistical standpoint it is unfortunate that the evidence should have been obscured by the introduction of so many measures which might stand in causal relation to the 90 per cent. reduction in this decade in the incidence of enteric fever upon British troops.

To the unprejudiced mind, the importance of the part played by enteric inoculation is obvious, but it will doubtless be objected by the anti-inoculation faction that the decline in enteric rates is due to other measures introduced during this period. However unfortunate for the Indian troops, it is fortunate that in our endeavour to get at the truth we are aided by the fact that native prejudices delayed the commencement of voluntary anti-enteric inoculation of the sepoys until 1911. We are thus able to compare the enteric incidence on Indian troops protected by sanitary measures, energetically pressed during this period, with the incidence on British troops protected by both sanitary measures and inoculation. The striking fact emerges that enteric among Indian troops actually shows an increase during this period of so marked a diminution among British troops.

Enteric among Indian Troops.

	Cases	Deaths
1905 ..	130 ..	35
1912 ..	243 ..	62

It must, however, be remarked that a considerable difference existed between the efficiency of sanitary measures in the respective barrack areas.

Among the measures carried out for British troops two must be regarded as specially effective and therefore most interesting in our present study. The first is that of dealing with enteric "carriers." The second is the group of improvements which were designed to prevent infection being carried from excreta to food by flies. Both these factors will be dealt with in detail later, but it is interesting to note here that the decline in enteric between 1905 and 1913 is only broken by one year, *i.e.* that in which use of antiseptic in latrine pans was discontinued. It is probable that considerable effect was due to both these measures before the numbers of inoculated men began to produce the marked fall in the curve between 1908 and 1913.

3. Relevant results of research into ætiology

It is necessary that we should keep in touch with research if we are to avail ourselves of the indications afforded by the facts which are thus brought to light.

(*a*) The Numbers and Longevity of Infective Intestinal Organisms

There are certain facts which are valuable not only because they enable us to get clearer ideas ourselves, but because they enable us to state in definite terms matters which it is of the utmost importance that our subordinate personnel should grasp fully. They also add point to the explanations that we may wish to give to combatants regarding our recommendations.

The data relating to *Bacillus Typhosus* are usually taken as illustrative of bacteriological facts relating to organisms of the typho-coli group.

(1) *The numbers* of excretal enteric bacilli :

In fæces there may be 16 million per grain.

In urine there may be 1000 million per c.c. and 25 per cent. of enteric cases excrete *B. Typhosus* in their urine. This fact is of great value in impressing upon men the danger of infective urine, a point which they are usually as slow to grasp as they are ready to believe that fæces are objectionable.

(2) *The persistence* of *B. Typhosus* is most variable under saprophytic conditions and is largely dependent upon the type and number of active saprophytes with which the more delicate parasites have to battle for existence. The following are estimates advanced by various authorities :

In fæces and soil	Three days.
In water	From three days to three weeks.
In textiles	Two months.
In butter	Four months.

It by no means follows that failure to recover *B. Typhosus* after these intervals proves their absence, and improved technique may lead to the view that far longer persistences are usual.

(*b*) Human Infection-Carriers—Ratio of Carriers to Population

The most extended data available are those which were obtained by Klinger from a study of 8486 cases of enteric occurring among a population of 2,390,000 in a given area.

(1) There are first the cases which have suffered from an attack of true enteric fever—*the "post-enterics."* About 2% per cent. of these excrete virulent *B. Typhosus* after recovery from the acute disease and remain "carriers" for an average of four years, while some continue to be infective for the rest of their lives.

The organisms live in enormous numbers in necrotic patches of the mucosa of the gall-bladder. The mucosa, being necrotic, is avascular and hence the anti-bodies in the blood are unable to get at and destroy these organisms. They are further protected by the fact that the bile-salts neutralize certain of the anti-bodies which might otherwise be excreted and attack the organisms by that route. In this safe retreat the enteric bacilli multiply and may remain for months at a time without sufficient numbers escaping in the fæces to be detected. The occurrence of diarrhœa with profuse biliary discharge may then sweep vast numbers into the intestine and infectivity of the excreta results.

(2) Then there are *the "contact-carriers"*—persons who appear to have had no disease corresponding to typical enteric fever and who are in apparently perfect health. Possibly they may be liable to auto-infection from their own foci. Their number among the whole population depends upon the extent to which enteric is prevalent, and hence upon the facilities afforded

for acquiring these undesirable alimentary guests. The proportion may vary from .03 per mille (Germany) to 3 per mille (United States).

(3) For *the whole population* the post-enteric and the contact carriers are estimated by Klinger to amount to a total of .1 per mille of the total inhabitants.

Among our troops from stations giving so high an enteric incidence as India, the proportion would, of course, be very much greater. In any case one would not be far wrong in thinking that the majority of our units in the field at the beginning of a campaign have a carrier among their number. This is a view the practical importance of which cannot be over-estimated, for the excreta of every unit must be regarded as potentially infective, by the presence of enteric organisms even if other infective bacteria be absent.

(c) Carrier Potentialities

The relation of carriers to enteric infections has been proved in instances which have now become so numerous that they cease to be of interest enough to record. The following illustrations are useful, without any claim to being the most striking available.

(1) One hundred and ten cases and six deaths from paratyphoid followed the eating of pies made by a cook who proved to be a carrier. Such startling epidemics lead to early detection of the infected person.

(2) The infections are far more difficult to trace when they occur as sporadic cases which mark the way of the cook carrier of less degree, *e.g.* one cook in six years was responsible for twenty-eight cases and two deaths from enteric.

(3) Nor is the infectivity solely confined to those who handle food. The instance of the fo'c'sle hand who infected thirteen other men with enteric in eighteen months is most interesting, because it indicates the importance of the part played by infected hands apart from food considerations. In this case all the fo'c'sle inhabitants handled the rungs of the ladder by which they reached their quarters.

Point is added to this last view by the results of an experiment carried out in the enteric depot at Naini Tal. A bacilluric carrier, taken without warning, was made to stroke with his fingers the surface of a culture plate. Five colonies of pure enteric organisms subsequently developed on the surface of the plate.

(*d*) Difficulty in Detecting Chronic Carriers

It has been mentioned that enteric fæces may contain as many as 16 million enteric bacilli per grain. There are, however, some 70,000 million other organisms in that weight of fæces and the *B. Typhosus* are therefore outnumbered by 4000 to 1. The odds against finding *B. Typhosus* in any given examination of the fæces of a chronic carrier are enhanced by the fact that there may be intermissions of three months or more between the periods when infective organisms are being passed. It was once calculated that the total odds against the detection of a carrier by a single examination were 360 to 1. This is a sufficient reply to those critics who ask why medical officers do not make a determined attempt to discover and weed out all carriers before the army departs over-seas on active service.

Although the whole personnel cannot be examined for carriers, those who are concerned with preparation and service of food may—and in view of their potentialities should—have their medical histories investigated and their excreta examined if possible, while they should be kept constantly under observation subsequently.

One more point calls for mention. It is the suggestion that agglutination reactions afford a certain and simple means of carrier detection. While there is a certain amount of support for this view as far as persons carrying paratyphoid "A" bacilli are concerned, the method is inapplicable to the discovery of carriers of true enteric.

It must not be inferred from the fact that the enteric carrier has been used to illustrate the foregoing points that he is the only infective human agent with whom we have to deal. The dysentery carrier is extremely important, and the cholera carrier is possibly even more dangerous under given conditions. It has been calculated that, in areas where cholera is markedly endemic, no less than 80 per cent. of the apparently healthy population may be thus infective.

The diphtheritic carrier you are already unpleasantly familiar with, and I fear that you will have the carrier of cerebro-spinal meningitis as a sinister disturber of your peace of mind during this war.

(*e*) Insect Carriers

Insect carriers of infection will be dealt with fully later, as of sufficient importance to require a section to themselves. They are here mentioned as adjuncts to the human agent.

One has but to realize fully the mass of infective organisms which may be excreted in the numbers indicated, to appreciate the part which can be played by insects in bridging the gulf between the human carrier and his victim.

B. SICKNESS IN ARMIES ON ACTIVE SERVICE

1. Historic losses from sickness in the wars of the past century

From the mass of available records certain may be selected to illustrate both the part which sickness has played in the course of campaigns and the diseases which have been chiefly responsible for the high incidence of sickness on armies in the field during last century.

Yellow fever carried off 50,000 out of 58,000 men in the San Domingan expedition of 1802.

Typhus so decimated a Bavarian army in 1812 that, when it had run its course, the force could only muster 3000 out of 28,000. By the same scourge the Russians lost half their strength of 120,000 men after Plevna.

From cholera the Allies lost 10,000 men in the Crimea in 1854, and it has been stated that the Turks at one time during the last Balkan War were losing upwards of 500 men a day.

Plague in 1828 took a toll of 6000 lives in one month from the Russian army in Turkey. From all causes that army, which left Russia 100,000 strong, left 85,000 dead on Turkish soil and had half its total strength in hospital at one time.

Dysentery caused 1342 deaths and 38,000 cases of sickness during the South African war.

Enteric in 1870–1 was responsible for 73,000 cases and 6900 deaths in the German army.

From the same disease in the South African War we suffered a loss of 57,000 men infected—one-third the striking force at the commencement of the present hostilities—and over 8000 deaths—the equivalent of two brigades.

In our wars of the past thirty years, for every one man killed by act of the enemy we have had forty hospital admissions and lost 4.8 lives from disease, while in the South African war sickness was responsible for a loss of 86,000 men by death and by invaliding.

In the presence of figures such as these, the historian cannot be accused of hyperbole in saying that sickness has "so ravaged armies, victorious in the field, that the surviving hale have scarce sufficed to bury their dead and care for the dying."

2. Factors determining the high sickness incidences of war

The first fact which arrests attention in considering these losses is that the diseases responsible are practically all of two main classes: (*a*) those of the infective intestinal type—enteric, dysentery, and cholera, or (*b*) those conveyed by vermin—typhus and plague.

The diseases and their specific organisms being the same as those met with in peace, the high sickness rates of active service must be due either to lowered resistance of the troops or to increased facilities for infection.

The French view (Kelch and Calmette) is that infective organisms lie latent in numbers of persons, pending favourable conditions of lowered physiological resistance which will enable them to develop. We know that this is so in the case of many "carriers," and the effects of lessened resistance have already been admitted. On the

RATIO BETWEEN SICKNESS & CASUALTIES IN BRITISH WARS OF LAST 30 YEARS

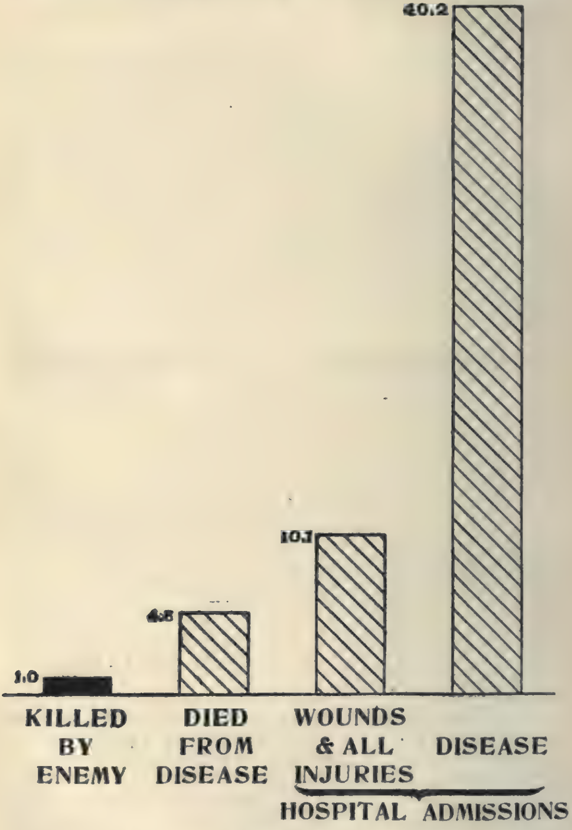


FIG. 13

other hand, we also know that there is on active service a marked diminution in the number of cases of such infectious diseases as the exanthemata in general. This suggests that the excessive incidence of other infective diseases in war depends more upon increased facilities for spread of infection by carriers than upon auto-infection of "contact carriers" as a result of lowered physiological resistance.

These increased facilities are obvious. Improvisation of measures to supply pure water and dispose of excreta; overcrowding of tents to an extent (500 per acre) which is five times that obtaining in the worst civil rookery; absence of suitable means of isolation and disinfection; unavoidable insanitary conditions inseparable from the stress of war—all play their part in the causation of these deplorable sickness rates of war.

3. Diseases of the infective intestinal type

These may be considered here, leaving until later the diseases conveyed by vermin. Again enteric is taken to illustrate the facts relating to this group of diseases, which in South Africa caused 42 per cent. of the total death-rate.

Enteric has hitherto broken out in expeditionary forces towards the end of a month on service, despite every care in excluding men who are under suspicion of being in the incubation stage. The early sporadic cases have been followed by outbreaks assuming epidemic proportions about a fortnight later. The experience may be quoted of the American camps established for concentration of troops about to proceed to Cuba; every camp was infected by enteric within seven weeks, and to this cause was attributable 80 per cent. of the total deaths, while 20 per cent. of the total personnel in the camps got typhoid.

For long the attitude towards this inevitable occurrence of enteric after a month in the field was that it either showed the medical examination of the personnel before departure to have been slip-shod or that it proved the spontaneous development of specific disease. Discovery of the "carrier" solved much of the mystery. It gave rise to the view that the chain of events is: The force includes carriers; their specific organisms are of low virulence; "passage" of these organisms through the bodies of a series of men exalts the virulence; the men with lowered resistance provide the early sporadic cases; the outbreak assumes epidemic proportions after the interval required for development of secondary infections.

It is thus unnecessary to invoke the unproved hypotheses of spontaneous development of specific disease or the mutation of organisms.

This leads us to consider what are the modes by which these secondary infections are caused in war.

(*a*) Contact Infections

The extent to which this means is responsible was realized during the Hispano-American war, when 66 per cent. of enteric cases were traced to infection by other men in the same tent. It was a striking fact that certain tents in heavily infected camps remained free from cases throughout, although their occupants mixed freely with the rest of the personnel and used the same latrines, kitchens, and water.

Or, again, the 5000 Boer prisoners in Ceylon had 700 cases of enteric, while their guard of several hundred men had no single infection. Apart from contact among the prisoners, both bodies of men lived under similar conditions, and at that time the enteric rate for British troops in India was twenty per mille.

(*b*) Ambulatory Enteric and Premonitory Diarrhœa

It has been constantly noted that outbreaks of enteric have been preceded by epidemics of apparently non-specific diarrhœa. It is possible that this fact is related to the gradual exaltation of the virulence of specific enteric organisms by passage, and that this initial diarrhœa represents a stage at which the organisms, while incapable of causing hæmic infections, can give rise to intestinal irritation. This was considered to be fully established by the Reid Board of American experts, who found that in 1898 those who had suffered from the initial diarrhœa were less liable to subsequent attacks of clinically typical enteric.

Whether these cases be regarded as mild cases of enteric or not, outbreaks of diarrhœa on active service are of great practical importance. Diarrhœa should be carefully watched for and reported by latrine orderlies to the medical officer, to whom the onset of marked prevalence should be a warning that even more stringent precautions are required.

Ambulatory typhoid has long been recognized, but its prevalence is still perhaps not fully appreciated. The Reid Board considered that the diarrhœa cases gradually merged into ambulatory typhoid and, after a most careful analysis of the records, estimated that only 46 per cent. of the cases of genuine enteric were diagnosed as such.

(c) Infectivity of Enteric at various Stages of an Attack

Coming now to clinically typical enteric, a most important point to which attention is drawn is that infectivity is marked in the incubation stage. It has been thought that if cases were detected at the earliest stage of the developed disease, and promptly isolated, there was little probability of harm having been already done. Some 812 cases of contact infections definitely traced to previous cases have been analysed, and the results of this analysis are shown in graphic form on Fig. 14. From this analysis it appears that during the second week of incubation, the infectivity is little less than that of the first fortnight of the developed disease and is responsible for more than double as many infections as were traced to the convalescent period.

(d) Dust and Mud

There is one other infective agency which is in danger of being overlooked or underestimated and that is dust. While it is admitted that the infectivity of dust is short-lived, it must also be admitted that it is apt to be intense, and it is only necessary to recall the enormous numbers of enteric organisms in bacilluric urine to appreciate this fact.

Those who have messed with a South African "dust-devil" as attendant need no reminder of the geophagism which marked the experience.

A time-honoured service habit which must be checked resolutely is that of scouring kitchen utensils with mud taken from anywhere near the kitchen. This mud is apt to be fouled in

812 CASES OF ENTERIC FEVER TRACED TO DIRECT PERSONAL INFECTION SHEWING STAGE AT WHICH INFECTION WAS CONVEYED

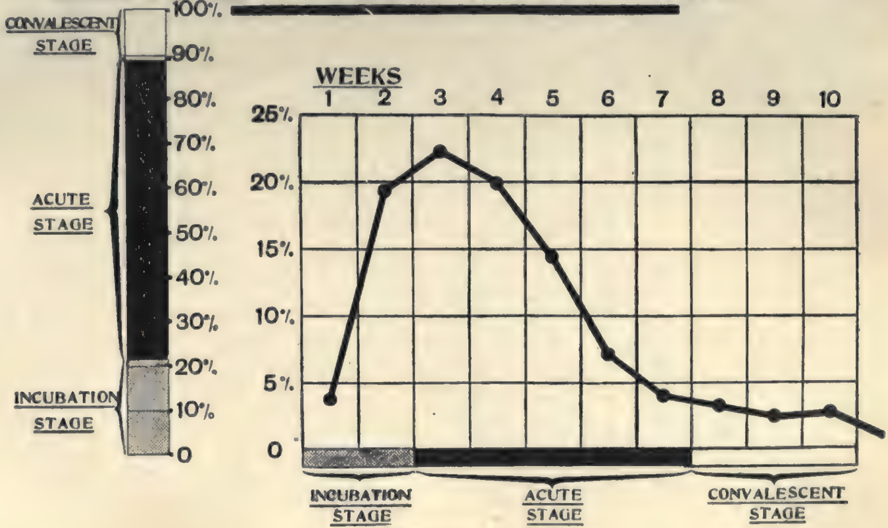


FIG 14

many ways, not the least obvious of which is that the path may lie on the direct road of men passing to and from latrines and urinals. The store of wood-ash which is supposed to be kept for this purpose is seldom forthcoming on investigation.

(*e*) Responsibility for Sanitary Personnel

This section would be incomplete without a reference to the special responsibility of medical officers for the safety of their subordinate personnel, who are subject continually to the special dangers already indicated. It is one of the clearest duties of the sanitary officer to impress upon his staff the absolute necessity of precautions, upon which he should instruct them personally and in detail. The following incident is of value as a means of forcing matters home upon their minds: Five boys proceeded to the Aldershot sewage farm and mischievously disconnected the troughs by which effluent was distributed. Four hardened sinners returning to barracks in time to wash their hands before tea paid no penalty. The usual Nemesis followed the one repentant, who stayed behind to make the mischief good; he got back late for tea, did not wash his hands, and came down with enteric twelve days later.

(*f*) Other Diseases of the Infectivc Intestinal Type

Attention has been concentrated upon enteric, firstly as the most important disease of this group, and secondly because, having been more thoroughly investigated, it better illustrates facts applicable to the other members of the class.

Most of what has been said of enteric is equally applicable to its next important ally—dysentery

—and to that most alarming cause of field epidemics—cholera—which is so fixedly endemic in the territory of certain of our present and prospective Allies that it assumes an importance unusual in our campaigns.

4. Other diseases of practical interest

(*a*) Other SPECIFIC INFECTIVE DISEASES of interest in the present war are so fully described in text-books as to call for only cursory notice.

(1) *Cerebro-spinal meningitis* has been introduced among the troops at the front and may cause some anxiety, both from its high mortality (70 per cent. in untreated cases) and from the fact that 40 per cent. of contacts are said to become temporary carriers by a naso-pharyngeal infection which persists for some thirty days on the average.

(2) *Typhus* has in historic times been the most dreaded scourge of besieged forces. Its immediate associations are famine, filth, and vermin. Having been for centuries endemic in South-Eastern Europe it has an importance which is emphasized by the fact that the infection-carrying vermin—lice—are so difficult to deal with at the front. It only needs the introduction of the infective organism to light up an epidemic in trenches and billets, the dread of which is spurring us to strenuous endeavours to deal with the vermin difficulty at the earliest possible date.

(3) *Plague*—another vermin disease, conveyed by fleas—must be guarded against, seeing that we have troops serving who come from the home of endemic plague, whence so many epidemics have commenced their sinister course.

(*b*) The only DEFICIENCY DISEASE with which we are concerned is scurvy—another product of the siege. At Port Arthur, *e.g.*, 83 per cent. of the garrison suffered from this disease.

There are two practical points which may be noted. One is that gingivitis, following the use of hard rations in the early experience of unhardened units, has been mistaken for scurvy. The differential diagnosis is readily made owing to the fact that in true scurvy the normal alkalinity of the blood is reduced below the equivalent of decinormal acid diluted three times. The test is easily applied by mixing in a pipette equal parts of the diluted acid and of blood and dropping the mixture on to the surface of litmus paper.

The other point is that, on the recommendation of the medical officer and in the absence of fresh vegetables, half an ounce of lime juice may be issued with the rations daily. This issue will effectually prevent the occurrence of scurvy.

(*c*) The diseases grouped—perhaps unscientifically—as Exposure Diseases and the disability due to Dental Caries—which was one of the most powerful causes of invaliding from South Africa—come under the ken of the medical officer in relation to the questions of clothing, rations, and cooking.

(*d*) Neurasthenia is a common result of the stress of war.

MEASURES FOR DEALING WITH DISEASE IN WAR

The measures available for dealing with sickness in war are as complex and varied as are the diseases with which they are designed to deal. All that can be attempted here is to indicate their general scope.

Diagnosis and Statistics

1. Indications of need for action

There are two essential methods of obtaining the necessary information upon which the need for any action must be based.

(*a*) The first is accurate diagnosis, which determines what are the special diseases which have to be dealt with.

Accuracy in diagnosis presents great, but not insuperable, difficulties in the field—difficulties which have been enhanced by the growing tendency in practice to rely upon laboratory assistance, to the detriment of direct clinical observation.

This difficulty has been partly met by the novelty of travelling motor laboratories being provided for each army at the front. These laboratories are provided with full equipment for such diagnostic work as may be needed, and it is hoped that eventually one such may be provided for each division. Already the work done has been excellent and important. In the first three months, in addition to diagnostic work, two enteric carriers were detected—one being a cook who had already caused five secondary infections in his unit.

(*b*) The second basis is accurate statistical record of the prevalence of those diseases which call most urgently for remedial action. The importance of this work is both immediate and remote—the latter in relation to the subsequent compilation of statistical returns which will throw invaluable light upon the problems of preventive medicine and guide us in our preparations for the next great conflict.

Upon the sanitary officer falls the duty of keeping the statistical records of preventable disease and maintaining close touch with the progress of the remedial measures for which they indicate the need.

The form on which infectious cases are reported is reproduced, and will appeal to those who have had experience of public health administration.

2. Preventive measures

Disease prevention is the essence of effective sanitation. The inception and execution of measures requisite to check the incidence of preventable diseases make great demands upon the army sanitarian both as regards his qualities and his strength. He admittedly holds one of the most responsible appointments in the army overseas, for upon his knowledge, driving power and executive ability depends to a very large extent the maintenance of the fighting strength of the force. Failure on the part of the medical staff may involve heavier losses of personnel than even the ablest dispositions of the higher command can compensate.

The detailed measures are better dealt with under the appropriate headings.

3. Remedial action

Next in importance to prevention is prompt detection of wastage in the fighting strength and removal of its cause. Herein lies the value of statistical returns, which should be available sufficiently early to make action effective at the onset of any sickness excess. The diseases should be so grouped as to indicate the presence of certain defects, *e.g.* disease of malnutrition in relation to rations and cooking, or exposure diseases in relation to clothing. Comparison of the returns of the larger formations will indicate to what extent the causes of high incidence are remediable, while comparison of the returns of units will indicate the possibility of their being due to individual inefficiency.

The acute infective diseases are the most urgently important and demand prompt isolation of the patient and equally prompt destruction of the *materies morbi* by disinfection.

(*a*) *Isolation of infective cases.* While matters relating to care of the sick in hospital come under the definition, and within the scope, of sanitation, they are not under the direct care of specialist sanitary officers, and hence will not be discussed in detail here. There is, however, one link in the chain of disposal of infectives which calls for discussion. It is that of the responsibility resting upon medical officers of units when faced by the alternative of either sending all suspicious cases to hospital at the earliest opportunity or of risking keeping infectives in the unit by treating mild suspicious cases themselves. In trench warfare the decision is of less consequence; upon the march it affords scope for high qualities of professional ability and readiness to accept responsibility. The first course involves rapid decrease in strength; the latter involves a risk which is only justified by a well-founded confidence in diagnostic ability. The hour is 4 A.M.; the force is about to move off; by flickering candlelight the medical officer of a unit sees around him a body of perhaps twenty or thirty men. They have all to be examined and decisions must be made as to the disposal of each within a few minutes. A temperature of 100 degrees; slight tendency to diarrhœa; no other signs or symptoms—what is to be done with such cases? The keen medical officer will take a certain amount of risk upon his own shoulders and let the man come along with his unit, but he will also take steps to reduce that risk to the minimum. The first danger is that of carriage of the blanket of such patients with the rest of the regimental blankets, all thrown together. The blankets of possibly infective cases which are taken along should be carried on the Maltese cart which takes the medical equipment. First they should, however, be soaked in antiseptic which can be made up in a ground sheet lining a hollow dug for it. At night these blankets, having dried *en route*, are served out to the suspicious cases, who bivouac around the medical centre. On the following morning—or perhaps that night—it is possible to form a final conclusion as to the nature of the case and dispose of it accordingly. By these means—not recognized officially—the keen medical officer will reduce by perhaps 50 per cent. the hospital admissions of slight cases, which choke the advance accommodation for patients.

(*b*) *Disinfection in the field.* While it is unnecessary here to undertake a detailed description of the apparatus provided and the methods adopted—which are dealt with by the printed instructions supplied—a word may be spared for this subject. A large number of portable Thresh's steam disinfectors have been supplied and are being added to.

They are of the low-pressure, jacketed variety, the temperature being raised a few degrees above 100° C., by the use of a concentrated saline solution. They give space for sterilization of some sixty blankets—or the equivalent—at one working. Exposure and drying each take thirty minutes.

There is also supplied a jacketed wooden box for steam sterilization, steam being led into the box from a separate metal boiler. The weight is 400 lb. and the effective capacity is twenty-five blankets per charge. The apparatus registers an uniform internal temperature of 100° C. at the end of two and a quarter hours from the cold and after one and a quarter hours at subsequent refillings. *B. Coli* is killed after thirty minutes' exposure to this maximum temperature, but the period can apparently be reduced to five minutes if six tabloids of paraform be added to the boiler contents for each sterilization of a fresh charge of blankets.

The apparatus has the disadvantage that there is no provision for drying the sterilized textiles.

Experiments are being energetically proceeded with in many directions and, as a result, the apparatus has already been much improved.

(*c*) For the benefit of those who have no experience of military work a final note may be added *re* the disinfectants provided in the field. The stock concentrated disinfectant is Liquor Cresoli Saponatus, with a carbolic coefficient of twelve. This forms a stable and excellent emulsion and is used in the proportion of $1\frac{1}{2}$ ounces to the gallon of water.

Carbolic acid and formalin are also supplied, and are used in the proportion of eight ounces of either to the gallon of water.

Form for Investigation, Report, and Record

Cases of Infective Disease in the Field

Disease...............................

Arm ....
Division ....
Brigade...
Unit ....
Regimental Number...................................
Rank..
Name ....
Age ....

DATE OF :

Onset of sickness...................................
Reporting sick......................................
Admission to Medical Unit ....
Investigation.......................................

Clinical Features of Illness

Character of onset—
  Whether definite or obscure.
Character of illness—
  Whether acute, sub-acute, or chronic.
  Whether typical or atypical.
Method of diagnosis—
  Whether by clinical or laboratory differentiation.
Other notes ....

Epidemiological Features

If any similar cases :	Date of	If within incubation period*	
In the company, or equivalent	....	Yes.	No.
In the unit................	....	Yes.	No.
In the brigade	....	Yes.	No.
In the division	....	Yes.	No.

* See page 118.

Form for Infective Disease

Employment of individual on, or shortly before date of onset of illness :

On food issuing	Yes.	No.
On food preparation	Yes.	No.
On water duties	Yes.	No.
On sanitary duties	Yes.	No.

Probable source of infection . . . .

Probable place of infection . . . .

If food or drink obtained from any unusual source . . . . . Yes. No.

Source, if any. . . . .

Other notes . . . .

Sanitary Features

At probable place of infection :	Method	If efficiently conducted	
Disposal of fæces . .	. . . .	Yes.	No.
Disposal of urine . .	. . . .	Yes.	No.
Disposal of refuse . .	. . . .	Yes.	No.
Disinfection . . .	. . . .	Yes.	No.

Prevalence of flies—
If marked, slight or medium.

Condition at time of inspection of :

Latrines	Day urinals	Night urinals	Kitchens	Lines
. . . .	. . . .	. . . .	. . . .	. . . .

Precautions taken :

	Date	Method
Disinfection of kit, &c. . .	. . . .	. . . .
Isolation of patient . . .	. . . .	. . . .
Segregation of contacts . .	. . . .	. . . .
Measures to deal with sanitary defects noted . . .	. . . .	. . . .

If applicable

Inoculation against Enteric Fever :
If completely protected (two doses within two years).
If partially protected (only one dose, or not within two years).
Wholly unprotected (never inoculated).

Form for Infective Disease

Vaccination against Small-pox:
Character of marks—whether good, faint or absent.
Number of years since last vaccination.

Signature of M.O..................

---

*

Disease	Usual number of days of: Incubation period	Segregation period
Cholera	3 to 6	12
Chicken-pox	10 to 16	20
Diphtheria	2 to 10	12
Erysipelas	3 to 10	12
Influenza	3 to 4	5
Measles	10 to 14	16
Mumps	10 to 20	24
Plague	2 to 8	21
Scarlet fever	1 to 4	10
Small-pox	12 to 14	16
Enteric fever	10 to 14	23
Typhus fever	5 to 14	14

LECTURE V

THE ROLE OF INSECTS IN WAR

GENTLEMEN,—To-day I propose to deal with the interesting and essentially practical matter of the part played by insects in the conveyance of infection to man.

It has only been in comparatively recent times that the facts have been fully established and the importance of this phase of insect activity has been realized. Formerly the fly was classed, without question, among the friends of man, and it was even described by one poetic enthusiast as "A dipterous angel dancing light attendance upon Hygeia."

More recently the unmasked traitor has been denounced by Sir John Lubbock as "A winged sponge flying hither and thither to fulfil the foul behests of Contagion." This latter view is supported by no less an authority than the Book of Exodus in which we read that, after a due interval presumably for incubation, the plague of flies was followed by death of the firstborn.

The subject naturally resolves itself into consideration of (*a*) the *Muscidæ*, (*b*) the *Apterous ectoparasites*, and (*c*) the *Lepidoptera*.

A. MUSCA DOMESTICA

The first culprit to be haled before the judgment-seat is *Musca domestica*—the common house fly—the interesting points about which may be thus grouped :

(1) Relevant facts concerning the morphology and habits of flies.

(2) The relation of those facts to the problems of fly-borne infection.

MORPHOLOGY AND HABITS OF THE FLY

As it is impossible in the time at our disposal to deal with so great a subject satisfactorily, the best procedure is to briefly discuss such aspects of fly life as have a practical bearing.

1. Morphology

Metamorphosis : The fly develops, by metamorphosis, through successive stages so dissimilar as to suggest wholly different forms of life. The stages and their durations in temperate climates are :

	Duration in days.
Ovum or egg	½ to 1
Larva or maggot	5 to 8
Pupa or chrysalis	3 to 5
Imago or young adult	
Total	9 to 14

In hot climates the average period is reduced and the minimal period may be as short as seven days.

The ovum must be kept warm if it is to develop, and it is therefore laid in decomposing organic matter, the rapidity of chemical change in which supplies the needed heat.

The larva has no digestive glands, and is therefore dependent upon predigested food—another reason for the fly ovipositing in fæces. Its most interesting habit is that of burrowing. It does so first to reach the moister areas of its habitat; if disturbed it hides with great speed; finally, in the prepupal stage, it burrows into the ground beneath the filth to a depth of two or three inches. Having reached this haven it defæcates freely enough to draw its body away from its exoskeleton, thus forming the pupa and pupa-case.

The pupa remains without food for four days while developing into the imago.

The imago escapes from the pupa-case by the device of inflating its frontal sac, which forces the lid off. The young adult then emerges and struggles to the surface. It will escape through a depth of six inches of loose soil and even through six feet of dry sand—the latter being a truly heroic effort.

The adult provides the following points of anatomical interest (*vide* Fig. 15):

It is provided with a non-piercing, retractile proboscis through which food is sucked by the powerful pharyngeal muscles.

The salivary glands are large and saliva is freely expectorated on to sugary foods which can be dissolved prior to ingestion.

The alimentary tract is provided with no other digestive glands, and the fly—like its larva—is dependent for protein upon predigested food derived from decomposing organic matter. In addition to the stomach it has a large crop capable of holding a four days' food reserve.

The hairiness of body and legs is remarkable, as indicated in the diagram. The feet are provided with hairs, terminal claws and adhesive pads. The latter consist of surfaces covered by multitudes of fine hairs and moistened by a glairy

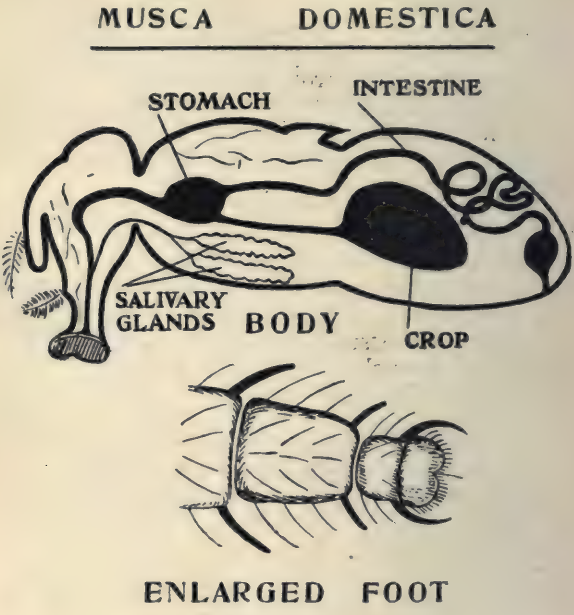


Fig. 15

sticky substance, by means of which the fly maintains its foothold when inverted. For the conveyance of organisms in vast numbers, it would be difficult to imagine a more suitable apparatus than the fly's foot.

2. Feeding habits

Having had no food for four days, the emerging imago is so hungry that it seeks the nearest feeding ground, and gorges up to 70 per cent. of its weight at a single meal.

Its preferences for certain foods are dictated by anatomical considerations. It must get either soluble carbo-hydrate or predigested protein; the former from kitchens and swill-tubs, and the latter preferably from fæces. When both sources are available the latrine and the kitchen are frequented alternately.

When resting, the fly can often be observed to regurgitate its crop contents until there is suspended from the end of its proboscis a drop nearly as big as its head. This fluid is drawn in and out with gusto so long as the fly is undisturbed, but is dropped if alarm leads to hasty flight. A cropful of fæcal fluid may thus be deposited on the surface of food ready for human consumption.

Well-fed muscidæ defæcate about once every five minutes.

3. Flight

One is constantly asked what is the average normal range of flight. This depends upon the food-supply: well-fed flies seldom travel more than 1000 yards. On the other hand, a hungry fly has a range expressed in terms of miles: one entomologist reports that a fly maintained its position alongside a ship for 104 miles between noon and sundown, when it was lost sight of. It is presumed that this fly had to find its way home again, after having said farewell to the departing entomologist.

4. Reproduction

The potentialities for reproduction are enormous. As 150 ova are laid every ten days of the six weeks of adult female life, each female might possibly live to see 2500 of her progeny.

If, further, we take the number of generations in a normal season to be nine, a single fly might conceivably produce a number represented by five followed by twenty-nine noughts (5×10^{29th}). Although fly mortality must reduce this huge number to figures more easily grasped, this datum is worth quoting as an incentive to all antimuscid measures, and especially to those which are instituted before the onset of spring.

There are two means by which continuity of the species from one warm season to another is secured. One is that, in warm kitchens, flies will continue to breed throughout the winter—though at only half the normal speed. The other is that the sudden onset of autumnal cold causes the fertilized females to pass into a hibernating state until the ensuing spring. It is to these means that attention should be most energetically directed before the advent of spring has afforded the necessary facilities for oviposition.

The material suitable for breeding must possess two properties—it must provide heat for the ovum and predigested food for the larva. Flies therefore oviposit in fæcal matter, which provides both needs better than any other material; they prefer horse-droppings because of its freedom from the continuous caking of the surface which occurs with bovine fæces. In 90 per cent. of cases stable litter is chosen by the ovulating fly, and one pound of litter has produced 455 larvæ. Human fæces are the next most common choice, and in India 480 flies were actually hatched out from one deposit. Other fermenting or putrefying organic matter will also serve, but it is not generally known that—as a last resource—ova may be deposited on damp rags and even on paper.

5. Natural enemies

It is interesting to consider the natural enemies of muscidæ, in the hope that they may be utilized to keep the number of flies down.

Ova are almost immune from attack, save by a certain species of ant which, unfortunately, is peculiar to the Philippines.

Larvæ are attacked, voraciously at times, by fowls, but this appetite is an unreliable one.

The enemies of the *adult* are numerous, but only call for enumeration and brief comment.

Empusa musca is the most effective. Its spores enter the fly stigmata, and the mould then develops and grows through the body of the fly until its terminal fibrils pierce the surface, as can be seen in specimens under the microscope. Certain of these fibres attach the fly to fixed objects, and others form conidiaphores which contain sticky spores. The conidiaphores remain quiescent until the moist warmth of spring bursts the sheath when the spores are projected in all directions, some finding their way into the stigmata of other flies, thus completing the cycle.

In America the clover weevil has been dealt with by the use of a similar mould, but so far a suitable medium has not been found for the culture of *Empusa musca*.

Acari are occasionally found parasitic on flies, but usually they only use the fly for getting a free ride to their feeding grounds.

Spiders kill a certain number, by webs during the day and by attack on sleeping flies at night.

Certain *centipedes—e.g. Scutigera forceps*—are very active and leap upon the unsuspecting fly, which they enclose with their legs like a hen caught in a coop.

Occasionally a *pseudo-scorpion* will hang on until a fly drops exhausted, and then suck its life-blood.

Gall-flies are most effective. The female may be seen walking over fly pupæ, selecting a suitable spot for oviposition. The muscid pupa is devoured by the gall-fly larvæ which hatch out in its interior, and 90 per cent. of pupæ may be thus killed, one gall-fly having been observed to attack twenty-two pupæ in succession. Unfortunately only one small family of the gall-flies has this most commendable habit.

Finally there are *birds*, but it is surprising to find that, of 9000 birds' stomachs examined, flies were only found in two although there were numerous lepidoptera present.

It is thus evident that we are not likely to get much assistance from the natural enemies of the fly in our endeavours to keep the numbers down.

BEARINGS OF THE FOREGOING FACTS UPON THE PROBLEMS OF FLY-BORNE INFECTION

1. The fly's skatophagism and capacity for germ carriage

As flies alternate between human fæces and human food, the fact that one grain of the former may contain sixteen million infective organisms, with a life of at least three days, becomes of obvious importance. It must be considered in the light of the capacity of the fly for carrying those infective organisms and depositing them on food.

The crop of a fly may contain some 200 million organisms. By the ratio of 4000 to 1—already quoted—that mass of bacteria may contain 5000 enteric bacilli or probably a similar number of other intestinal infective organisms. A large part of the crop contents may—as described—be regurgitated on to the surface of food within a few minutes of ingestion.

The numbers of organisms conveyed by *the feet* is illustrated by a culture plate upon which a fly has been allowed to walk: parallel lines of growing colonies show every footprint.

The total number of organisms and the proportion of coliform representatives among them are represented in graphic form in Fig. 16.

The great increase in the numbers of organisms in proportion to the foul nature of the habitat needs no emphasis, but attention may be drawn to the increase in the relative proportion of coliform representatives. In the three groups of flies examined this proportion increases thus: 3 per cent., 7 per cent., 27 per cent.

The aptness of the simile of "a winged sponge" is now apparent and it needs little imagination to appreciate the effect on the bacterial content of milk in which two or three such saturated sponges have struggled while drowning.

It only remains to add that the most delicate intestinal infective organism that we know—the *Spirillum choleræ*—is capable of living at the very least for eighteen hours under the most adverse conditions to which it would be exposed on the fly's foot.

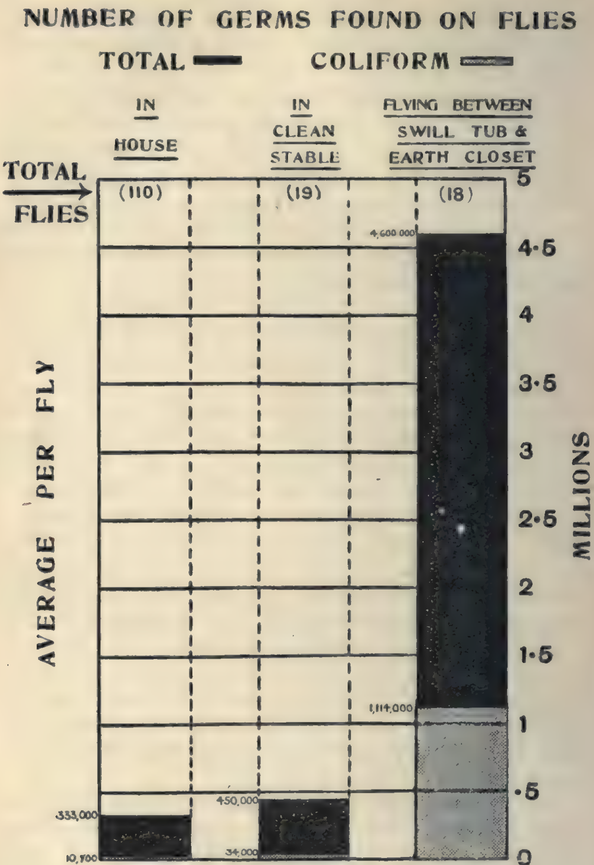

NUMBER OF GERMS FOUND ON FLIES
TOTAL
COLIFORM
IN HOUSE
IN CLEAN STABLE
FLYING BETWEEN SWILL TUB & EARTH CLOSET
TOTAL FLIES
(110)
(19)
(18)
AVERAGE PER FLY
MILLIONS
5
4·5
4
3·5
3
2·5
2
1·5
1
·5
0
4,600,000
1,114,000
450,000
333,000
34,000
10,700

FIG. 16

2. The actual isolation of infective organisms from flies

The question now arises as to how far these presumptive calculations have borne the test of actual proof. Much work has been done and some of the results have been criticized adversely, but three of the typical results obtained may be mentioned.

Spirillum choleræ was recovered from the first fly examined in a post-mortem room in Hamburg during an outbreak of cholera. *Bacillus typhosus* was recovered up to the twenty-third day, from the legs of flies which were infected by pure culture of that organism. *Bacillus tuberculosis* was found in four of the first six flies examined after collection from a consumptive patient's room.

3. Evidence of the relation between fly prevalence and disease incidence

The chain of argument can only be considered complete if specific instances can be produced which prove the presumptions to be correct. For the most conclusive piece of evidence of this nature we are indebted to the records of the sister service.

In the year 1850 H.M.S. *Superb* was stationed in the Mediterranean for some months, visiting various ports and having sporadic cases of cholera among the crew.

Then she put to sea for two months, and there was no case of cholera after the fifth day out. This practically eliminates carriers from the list of possible infecting agents, and similarly frees from suspicion the ingesta on board.

Next she put into Malta for a few days, during which there was no communication whatever with shore save that flies from the cholera-infested port swarmed on board. After the usual incubation period of three days, cholera again broke out—to again disappear when the ship had been five days at sea.

During the following winter the ship was in and out of Mediterranean ports constantly, but there were no flies and there was no cholera.

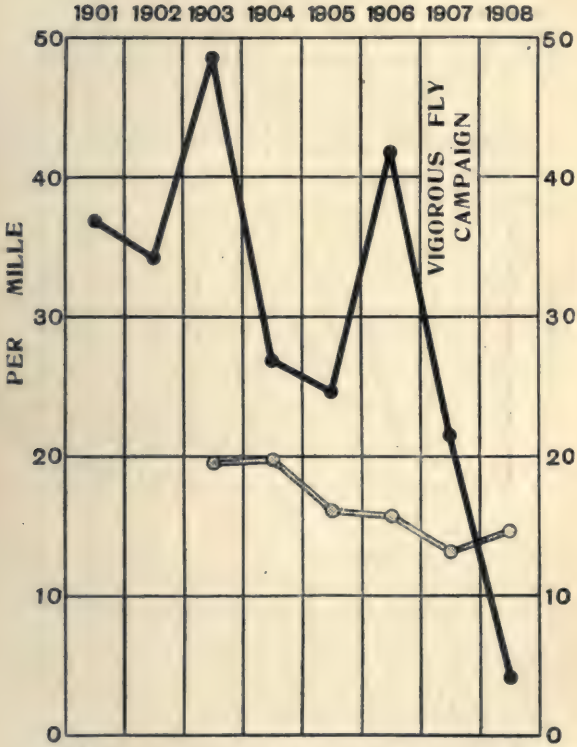
There are few conditions conceivable on land which could afford clearer evidence as to the part played by flies in the conveyance of infection than is afforded by the outbreak on this ship while lying off Malta.

There is also some interesting evidence from our Indian records, and especially those from Mhow and Poona.

At *Mhow*, as shown in Fig. 17, the enteric rate was for years much above that for the whole of the British troops in India. A most vigorous anti-muscid campaign was instituted in 1907, and there immediately followed a fall in enteric incidence to about one-third that of the whole of the British troops in India. This abrupt fall is more than can be accounted for by the wider fluctuations of individual stations, and it is particularly noticeable that it preceded the date at which anti-enteric inoculation had been adopted by a sufficiently large proportion of men to materially lower the enteric rate.

Poona is a station in which the climate is damp and warm throughout the year, and hence one in which flies are numerous at all times. In Fig. 18 are shown the relations between curves indicating the number of flies present, the incidence of infantile diarrhœa and the incidence of enteric.

ENTERIC AND FLIES AT MHOW



ENTERIC FOR ALL INDIA SHOWN

FIG. 17

The first is based on the number of flies caught daily on pieces of tanglefoot of similar size exposed at fixed sites. The incubation period of infantile diarrhœa is very short and the chart shows that the curve of infantile diarrhœa incidence followed that of fly prevalence with the utmost regularity,

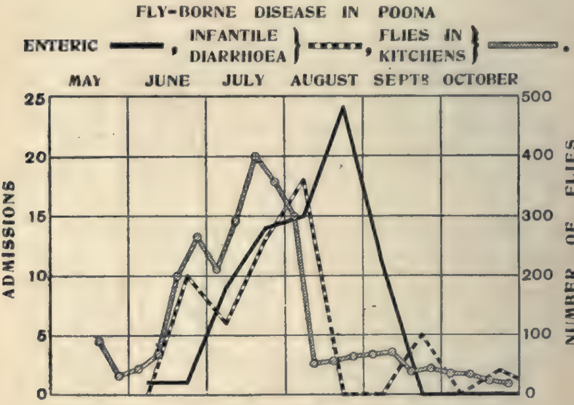


FIG. 18

and at precisely the short interval of delayed response which would be expected if the causative relation were established. Allowing for the longer incubation period of enteric, there is a similar correspondence between the curves, the delay in the final fall being attributable to the incubation period of secondary infections.

Finally one can turn to evidence obtainable nearer home and consider certain *Nottingham* records extending over a period of ten years. Nottingham is divided into three districts according to the method of conservancy adopted—w.c.

houses, houses treated on the bucket-removal system and houses with middens. The possibilities of flies gaining access to human excreta are obviously least in the w.c. houses and greatest in the houses with middens. The available statistics state the enteric incidence upon the occupants of these classes of houses during the ten years under review, and do so in terms of the number of houses which it took to provide one enteric case. The data are :

w.c. houses	one enteric case	from	420 houses.
Bucket-removal houses	,,	,,	151 houses.
Midden houses	,,	,,	42 houses.

This gives the ratios of enteric liability of the occupants of these three classes of houses as 1, $3\frac{1}{2}$ and 10 respectively.

Anti-muscid measures are discussed in the last section of this lecture.

B. APTEROUS ECTO-PARASITES

The apterous ecto-parasites of man are—as the name indicates—wingless insects. As a result of their parasitic habits they have suffered certain penalties and gained certain compensating advantages. Among the former are the loss of wings—by disuse atrophy—and, in some species, inability to withstand loss of food for more than a short period. Among the latter is the power of self-protection by colour mimicry, which is illustrated by body lice acquiring the colour of the skin of the human race infested. They also get free rations for life.

Insects have one common feature of practical interest. It is that the class respires through

Phylum .	ARTHROPODA				
Class . .	Insecta				
Orders .	*Siphonaptera*		*Hemiptera*	*Anopleura*	
Families .	*Pulicidæ* (fleas)		*Cimicidæ* (bugs)	*Pediculidæ* (lice)	
Genera .	*Xenopsylla*	*Pulex*	*Cimex*	*Pediculus*	*Phthirius*
Species .	*X. cheopis* (rat-flea)	*P. irritans* (human flea)	*C. lectuarius* (bed-bug)	*P. capitis* *P. vestimenti* (lice)	*P. inguinalis* (crab-louse)

a series of stigmata, which may be occluded by oil droplets with consequent asphyxia of the insect.

Another practical point is that man and animals usually have distinct parasitic species, which normally are seldom ready to exchange the human for the animal host or *vice versa*.

No detailed description of the various species can be attempted in the limited space available, but a few facts of interest or practical importance will be noted concerning each species. The means of their destruction will be summarized in the succeeding section. Before passing on to individual species, it will perhaps be found useful to tabulate the biological classification of the various insect ecto-parasites with which we are now concerned.

1. Fleas

The female flea at each ovulation lays ten ova, which hatch in from five to ten days. The resulting larva, after twelve days, develops into the nymph, which takes twelve days to mature into the adult. The complete development takes four weeks in summer and six weeks in winter. Ova are dropped at any convenient spot—on or off the body of the host—and are not attached to adjacent surfaces.

Apart from the irritation to which fleas give rise, their importance in the present war lies in the fact that they convey the *B. pestis* of plague from the rat to man. *B. pestis* lives and multiplies in the stomach of the flea for seven days and is passed in its fæces, whence it is rubbed into the flea-bite by subsequent scratching. In view of the facts that plague is endemic in India, that most European epidemics have had an

Eastern origin, and that so many Indian troops are at the front, this is a matter which we cannot afford to lose sight of. There is further the consideration that plague is now endemic in Tripoli and therefore liable to obtain a footing in the forces of our Allies.

2. Bugs

Fifty ova are laid by each female, and the ova hatch out in seven days. The larva takes about eleven months to develop into the adult, moulting five times during the process. It feeds once between each pair of moultings. The adult lives for four months and inhabits mattresses or cracks in bedsteads, walls, and floors, only coming out at night to suck blood. It can subsist on organic filth, but likes a meal of blood before each of its four ovulations. The period of subsistence without blood-sucking is ten weeks.

The parasite, beside being passively conveyed in bedsteads and mattresses, has considerable migratory powers and finds its way from house to house by means of walls and gutters.

It is said to have invaded Germany in the eleventh and England in the fourteenth century.

Its objectionable characters are not confined to the characteristic smell from the metathoracic glands and the intense irritation to which its bite gives rise; it has been regarded as a means whereby relapsing fever is conveyed from man to man.

3. Lice

P. capitis. Some fifty ova are laid and they hatch in a week. They are covered by chitin—which is most resistant to acids and alkalies—and are attached to the hairs by stalks which also resist most acids, but are soluble in 10 per cent. acetic acid. The emerging young resemble the adults and mature so rapidly that ovulation occurs three weeks later.

P. vestimenti. The female lays from three to five eggs daily during the twenty-five days of its mature adult life. The eggs hatch in from three to eight days, producing young which resemble the mature adult and reach sexual maturity a fortnight later. The total life of the adult is six weeks, and in that time the female may see some 8000 of her progeny.

Blood is sucked twice a day, and the newly hatched adult dies of starvation in one and a half days if unfed, while the mature adult will only survive four or five days without food.

The special habitat of the body louse is under folds of the clothing, those next the trunk being the favourite haunts. There the female spends most of her time and there the ova are deposited. It requires the strictest search beneath all folds of the clothing before absence of this parasite can be definitely ascertained. The ova are tiny ovoid white bodies, protected by chitin and attached to the clothing by stalks. They are as relatively resistant as the adults are delicate, and "sterilized" clothing will continue to yield young adults for a week after treatment, as the ova successively hatch out. Hence the problem of freeing an infected regiment from lice is a most difficult one. One most useful measure is that of smearing the inside surfaces of all seams with grease so that the young are asphyxiated as they hatch by the grease occluding the respiratory stigmata.

The body louse has always been a pest in the Near East and was particularly so among the

Russian troops in the Crimea. To it is attributed the rôle of infection carrier in typhus, which is decimating the Serbian army and civil population at the present time and which constitutes so great a menace to all armies at the front, should the infective organism be introduced among forces infested with lice. The view has been advanced (Dutton) that the body louse is also capable of conveying the infection of enteric. In view of these threatened dangers, every effort is being made to rid our troops of lice, and it is hoped that we are on the eve of evolving a practicable method which will go far towards solving the problem.

Phthirius inguinalis. This is an alias of the familiar *Pediculus pubis*, of which it need only be said that it resembles the body louse in most points of its life history, but is seldom found in clothing.

Before leaving this section to consider remedial measures, it is only fair to the army and to medical officers that a word should be said as to the conditions which have led inevitably to extensive vermin infestation of troops, billets, and trenches at the front.

Under normal conditions the British soldier of the present day is extremely cleanly. When the war broke out men were crowded to the utmost capacity of tents in camps in which the normal routine of examination and the customary provision of bathing facilities were impossible under the stress of unprecedented demands. Among the men who occupied these camps at an early stage were many reservists called to the colours, in some cases from sordid and verminous surroundings. This aggregation of men led to direct personal transference of lice and to infection of the tents which were used for successive bodies of men assembled prior to being sent abroad. The available supply, and speed of manufacture, of steam disinfectors was for many weeks wholly inadequate for our requirements, and hence many units left this country with considerable numbers of the men already verminous. The rolling stock overseas, the billets, and the trenches were thus all infected in turn and the continuous subsequent overcrowding has rendered it impossible to eradicate the pest hitherto. It is obvious that it is necessary to disinfect the clothing of whole units in the same day and the practical difficulties in the way of achieving this at the front are enormous. Even when this has been done, the unit has had to occupy billets only that morning evacuated by the troops which have relieved them in the trenches—billets which it would be most difficult to free of vermin even in peace time with every appliance readily available. The inherent difficulties of such a problem are only fully appreciated by those who have been called upon to provide a practical solution, but enough has been said to indicate the nature of the problem and the alertness of the medical authorities to its importance as a factor facilitating epidemic outbreaks and causing inevitable loss of efficiency by insomnia consequent upon continuous irritation.

C. LEPIDOPTERA

The part played by moths in war requires but brief comment. Weevilly biscuits have figured prominently in foc's'le yarns and in the accounts of many an old campaign, but the most striking record is that of a British force in Jaffa which had to consume its biscuits at night, when the maggots could not be seen!

Investigation has shown that the maggots are the larval stage of moths, which ovulate on the surface of biscuits during the drying process.

This difficulty has been met, first by screening the doors and windows of the drying rooms and secondly by making smaller biscuits which, by more rapid drying, reduce the opportunity afforded to ovulating moths for deposit of their ova.

PROTECTIVE MEASURES

(a) Against fly-borne infection

The protective measures at our disposal may be thus classified:

1. The destruction or protection of infective material.
2. Anti-muscid measures.
3. Protection of food.

1. The Destruction or Protection of Infective Material

It is obvious that the potential menace of the fly as a carrier of infection can only become an actual danger when the fly has access to infective material. The responsibility for precautionary measures relating to *materies morbi* of a pathological nature—as, *e.g.* the vomit of a cholera patient or the exudate from small-pox pustules—lies with the medical staff of hospitals. The measures for disposal of excreta, which may be infective when derived from persons suffering from disease, are the responsibility of the sanitary officer but will be better dealt with under the section devoted to conservancy.

It only remains to point out here the obvious generalization that the best methods are those which effect the earliest destruction of the infective organisms, with the least possibility of flies gaining access to the infective material meanwhile.

2. Anti-muscid Measures

(a) *Checking fly-breeding*

This is the most radical and important measure, in that it aims at the root of the difficulty. The statement of relevant facts concerning the breeding and habits of flies has already indicated the lines of procedure.

Stable litter and horse dung. These, being the commonest breeding materials, demand the most attention and provide the greatest practical difficulty. The amounts which are apt to collect in the vicinity of mounted units' lines are enormous, and it is calculated that the average to be disposed of daily is 8 lb. per animal. There is no doubt that incineration is the only really satisfactory method of disposal, and it is equally certain that this work is seldom overtaken if once accumulation be permitted.

As imagines will struggle to the surface through a considerable depth of loose soil, burial is not a sound method of disposal, apart from the enormous labour which it involves. If, however, it be unavoidable, there are certain practical points to be noted. The first is that, as larvæ hatch in five days, removal must be carried out not less often than twice a week. The second is that, as larvæ burrow, the collection pits should be lined with impervious material, or—failing this—after emptying, the floor of the pit should be freely treated with larvicide, such as lime.

Various methods have been proposed for

treating manure heaps with some poisonous material, such as kerosene, lime, or permanganate. The cost of such methods is prohibitive, the weight of the toxic material is great, and the difficulty of saturating the huge litter heaps is considerable. Later proposals for treatment of manure heaps are the application of (*a*) crude borax —1 lb. per 15 cubic feet, or, (*b*) tar oil—1 gallon per 500 cubic feet. The former has not succeeded in our tests, the latter is promising (Lefroy).

Swill-tubs and refuse-bins. These accessories of fixed camps call for attention because larvæ remain attached to the sides when the receptacles are emptied and duly develop later. It has been suggested that the receptacles should be provided with grid bottoms and placed over water : larvæ, attempting to burrow, drop into the water and drown in large numbers. It is also suggested that gauze fly-traps should be inserted in the lids of refuse bins, holes being made in the sides of the bins to afford ingress to flies.

(*b*) *Destruction of adults*

This measure is important at all times. During the winter the females breeding constantly in warm kitchens and those hibernating through the cold weather should be attacked. Measures should precede the spring increase in the fly production.

Only field service methods call for notice here.

Poisons. Fly-papers are the most familiar means and act by the arsenic which they contain. Its presence is indicated by a brick-red colour (arsenate) or yellow colour (arsenite) on adding silver nitrate to water in which the fly-paper has been soaked. As the Maybrick case focussed popular attention upon the fact that fly-papers contain so powerful a poison, it is undesirable to supply this article on active service when neurasthenia is so prevalent.

Formaline is a better alternative. Three per cent. is added to sweetened milk or beer, and the mixture—which is non-toxic to man—is exposed in a saucer in the kitchen at night, all other fluid being removed. Efficacy is proved by the large number of flies found dead in the morning and dying during the day.

Fumigation is best effected by burning a mixture of equal parts of camphor and phenol, which forms dense irritating fumes. Four ounces per 1000 cubic feet is an effective amount.

Mechanical methods. "Tangle-foot" is familiar and may be simply made by mixing sugar and cream in equal proportions. Knowing the attraction of settling points for flies, the Japanese adopted the ingenious device of making "hedgehogs" by sticking matches into large potatoes. These were dipped into the improvised tanglefoot before suspending them at suitable heights.

Traps can be improvised by inserting paper funnels in the necks of bottles, which are placed on their sides after a little sticky fluid has been placed in the bottles and a track of it laid in the funnels. It is alleged that 2000 flies have thus been caught in a day.

Finally burning may be tried. In South Africa the mess-tent ropes hanging from the interior of the roofs were so covered by flies at night that they were just fly-festoons. Torches were made of brown paper and the flame was run rapidly and carefully along the festoons. Enormous numbers of flies fell on to spread newspapers and were killed by the assistant treading on them. This method is possibly one of the most humane and not the least so—as it appears at first sight.

3. Protection of Food

The last link in the chain of defence is that of preventing flies from gaining access to food. This is the most difficult and the least satisfactory means at our disposal in the field. It can only be applied in billets or permanent camps where buildings are available both for cooking and messing. It should, however, be attempted when, as Theobald Smith says: "We fight for our food with myriads of flies, alert, persistent, invincible." One has seen a man's food so covered with flies, while he stood to attention during the passing of an inspecting general, that the nature of the meal could only be guessed at.

Fly-proofing of kitchens and messing-rooms by coarse butter muslin is cheap and effective to a certain extent, but it is difficult to induce men to undertake the necessary co-operation. Food should be covered by muslin both during storage and during conveyance from kitchens to mess-rooms.

All the foregoing methods can be used for freeing rooms of their fly population. Useful results follow covering of the windows with blue translucent material—flies disliking blue. By smearing kerosene on window-panes and placing trays of water beneath, we may achieve the happy result that flies, stupefied by the kerosene fumes, fall into the water. Both kerosene and dry lime in the open will keep flies at a distance, but the attraction of the window light overcomes that repulsion in enclosed rooms. It is claimed that borax exercises a similar repellent action.

While it is impossible to free camps wholly from flies, it is possible—with so many cheap and effective means at our disposal—to reduce their numbers enormously. The one essential that is most commonly lacking is energy to undertake the necessary organization of preventive measures. The keen sanitary officer wages one long unbroken battle with the fly hordes and only keeps the ascendant by perpetual energy and attention to a mass of apparently trivial details. His first difficulty is that of arousing intelligent interest and enlisting the essential co-operation of the rank and file: when that has been surmounted the battle is already half won.

(b) Anti-vermin measures

This matter is so important that no excuse is needed for the following list of measures which, while making no pretence of being complete, afford alternatives suitable for all conditions and supplied by even the most meagre of equipments. Rather is an apology due for the fact that lack of space prevents any attempt to do more than list the remedies which appear the most useful.

Pediculus capitis

A mixture of kerosene and olive oil, equal parts, rubbed on the head and washed off after twenty-four hours.

Kerosene and all volatile hydrocarbons applied neat.

Ten per cent. acetic acid (or vinegar) and fine-tooth combing.

Four per cent. formaline solution.

Ammoniated mercury ointment.

Five per cent. of oleate of mercury in ether.

The Germans have adopted the method of shaving the head, which is as radical as most of their methods, and is merely a reversion to the days of our forefathers, who shaved their heads and wore wigs less from foppery than from a desire for sleep at night free from cephalic irritation.

Pediculus vestimenti

The body louse presents a distinct problem, owing to the fact that it lives in the clothing. There are two methods of attack :

(*a*) To kill both adults and ova forthwith. Of the many means vaunted, only steam sterilization has so far borne the test of practical trial in our hands. It is difficult and very expensive to apply on the requisite scale. Hot ironing of the seams of clothing has not been successful.

(*b*) To kill the adults forthwith and to smear all the interior seams of clothing with grease which will asphyxiate the young as they hatch out from the ova. It is obvious that by this means cure will only be complete when the last batch of eggs hatched, which may not occur for six weeks. Meanwhile, however, comfort is assured and laying of more eggs is prevented.

The adults are best killed by powders, of which the following have been proved effective, in conjunction with grease on seams of clothing, in the following order :

(i) A powder of 2 per cent. each of iodoform and creasote, with 96 per cent. of naphthaline. Two ounces per man should be dusted on the interior of all clothing once a week.

(ii) Zinc oxide and French chalk (magnesium silicate) 25 per cent. of each, with 50 per cent. of ammoniated mercury.

(iii) Keating's powder (pyrethrum).

For asphyxiating the young as they hatch, the most suitable grease is a jelly of crude mineral oil 9 parts, soft soap 5 parts and water 1 part. This is known as " vermijelli " and is recommended by Professor Lefroy. If two ounces per man be smeared once a week on all interior seams of the clothing, it has been found effective in conjunction with the above dusting powders.

Benefit has also been derived from wearing around the neck, waist, and calves worsted fillets smeared with unguentum hydrargyri.

Other much advertised methods have proved far less useful than the above forms of treatment, and thus do not call for detailed mention here, the majority being quite ineffective.

Pulex irritans

(*a*) Fleas may be dealt with on the body by :

Pyrethrum powder (Keating), which must be fresh.

Iodoform sprinkled on the clothing. From personal experience in the flea-infested stations in the Himalayas one can confirm the statement that sprinkling of iodoform under the doormat is most effective in keeping fleas out of quarters.

(*b*) For killing fleas in the floors of infested rooms we have the methods proved to be effective in the treatment of plague houses in India, such as :

The burning on the floor of a six-inch deep layer of straw is applicable to native huts with mud floors and walls. Fleas—which can only jump about four inches—are burnt.

Saturating of floors by an emulsion in water of 5 per cent. cresol, with or without 20 per cent. of soft soap solution, gives excellent results.

Cimex lectuarius

As the bug lives mostly in cracks in walls and furniture it must be attacked there. That leads to the mention of various fumigation methods, which are also applicable to other vermin.

Sulphur dioxide may be used—one pound per 1000 cubic feet.

Camphor and phenol, equal parts—four ounces per 1000 cubic feet.

Fresh pyrethrum powder—five ounces per 1000 cubic feet.

When any of these substances is used, it is necessary that the exposure be as long as possible and it is further desirable that the vermin—many of which are merely stupefied—should be promptly swept up and burnt.

Hydrocyanic acid gas is lethal, but is too dangerous for practice.

Rats

This section would be incomplete without some reference to the means of destruction of the *Mus decumanus*, seeing that this is so important a part of the prophylaxis of plague which is conveyed to man by the rat flea—*Xenopsylla cheopis*.

The early successes claimed for various bacterial poisons have not been confirmed.

The safest poison is phosphorus, which is made up into pills containing 4 per cent.

Sulphur dioxide is effective if it can be concentrated and confined.

* * * * *

This section may be concluded by a brief description of a *modus operandi* which achieved marked success at the front. The buildings were those of a large clothing factory, which proved most suitable for the purpose. One regiment was dealt with per diem and marched from the trenches to the premises where batches of the men were dealt with at a time. They first shed their outer clothing, which was removed on lorries to be dealt with as will be presently described. The men then passed into the old soaking-room, where there were three huge vats filled with hot water. The underclothing was thrown off and put into tubs of strong disinfectant, while the men got into the vats—ten at a time—and washed themselves thoroughly with soap. As considerations of time, space, and facilities for heating water did not permit of fresh water being provided in the vats for each lot of men, two lots had to use the same water in succession, and in the interim the vat contents had to be chlorinated to reduce the impurities to reasonable proportions. On emerging from the bath the men rubbed themselves with the lysol soft-soap lather, and then rapidly got into clean underclothing left over from the regiment treated on the preceding day and meanwhile sterilized and washed. While the men bathed, an army of women were employed in an adjacent room in hot ironing the inner seams of the men's outer clothing, into which some of the lather was subsequently rubbed. The men then donned their serge and marched off to their billets. Such men as specially required it got their hair cut and soaked their heads in the mixture of kerosene and olive oil.

One regiment could just be run through this cleaning station in a day, and then the men had to occupy billets vacated that morning by the unit which had just relieved them in the trenches. Lack of quarters made this Box-and-Cox arrangement unavoidable. The condition of the billet, thus in permanent occupation without an interval for treatment—even had any means of treatment been available—rapidly undid what benefit had been achieved, but it was something to know that the whole unit had at least been clean and vermin-free for an interval, however brief. There being only the one building large enough and capable of being spared for this purpose for a division of 20,000 men, it follows that continuous work at the maximum capacity only enabled each unit to be dealt with once in twenty days.

This description serves two purposes—it indicates something of the difficulties which were experienced at the front and something of the energy and ingenuity which were expended by our medical officers in the attempt to cope with those difficulties.

As rapidly as they could be supplied by the makers, steam disinfectors were dispatched to the front, but apparatus of ordinary capacity can only skirmish with a problem of the dimensions indicated. Our principal hope is that we may be able to evolve some means whereby vermin can be deterred from infesting the men, and to this end experimental work is being conducted with the utmost energy, both with the old remedies and with new products—synthetic and simple.

LECTURE VI

MEDICAL ORGANIZATION AND ADMINISTRATION IN THE FIELD

GENTLEMEN,—Having dealt with certain desiderata and dangers of active service, we now turn to the organization and administration by means of which field sanitation is controlled.

Although—in its widest interpretation—sanitation concerns all medical officers and all medical organization, we may not now discuss matters relating to the care of sick and wounded, save as regards measures for dealing with cases of specific infective disease.

Before proceeding to detailed descriptions, there are certain prevalent misconceptions which make it desirable to define the precise rôle of the medical service in relation to war.

(*a*) *The essential duty of the medical officer.*

The essential duty of the medical officer is the first point to be considered. It is clearly enunciated by Sir Evelyn Wood, after a long and varied experience of the staff, in the following quotation: "Medical officers are trusted staff officers whose duty it is to guard the troops against disease, with the object of increasing fire effect by raising the fighting value of the troops and reducing hospital transport and establishments."

The primary duty of the medical officer is thus identical with that of every other member of the force, *i.e.* defeat of the enemy in the shortest possible time and with the smallest national loss.

(*b*) *Humanitarian considerations.*

How far is this primary duty compatible with humanitarianism ? Colonel Melville tersely summarizes his opinion on this interesting problem thus : " The price of success in war is human life and suffering and it is for the commander to decide on the terms of payment. He may decide to pay the price in exhaustion and disease or in terms of bayonet and gunshot wounds."

The matter is thus taken out of the hands of the medical service and humanitarian instincts may only be afforded scope when they do not interfere with the essential end of bringing the war to a successful conclusion with the minimal ultimate loss.

A moment's thought shows that this view is in accordance with the generally accepted tenets of all medical practice : the first aim of the practitioner is not to remove pain but to remove the cause of the pain. As the cause of suffering in war is the state of war itself, victory is the one remedy for both the disease and the suffering which it occasions. No individual considerations—whether of suffering or death—can be permitted to retard the prosecution and progress of the national cure.

Further study however indicates that the matter is not merely a physical one, to be expressed in terms of so many lives lost : in balancing results we have also to weigh psychological effects on fighting efficiency. This aspect of the problem demands careful consideration when a decision is being made as to the extent to which the medical officer is justified in jeopardizing his own life.

On the one hand loss by the unit of its medical officer at a critical juncture is a serious disaster. On the other hand the sense of security afforded to the men by the assurance that medical aid is close at hand in case of urgent need is a psychological factor the value of which in the fight may far outweigh the risk of loss of medical personnel. It is interesting to note that the most common apprehension among men going into action is that of death from hæmorrhage, which they firmly believe that the medical officer can always arrest if only he can reach the wounded man in time.

Personally one holds the view that the medical officer should be near his unit in all engagements and it is certain that thereby he will enormously enhance his influence with men who know that he has shared their dangers in order to be at hand to render prompt aid in the event of their dire extremity.

This instance is illustrative of many in which psychological factors justify the exercise of humanitarian instincts which it would otherwise be our duty to repress.

Fortescue in his " History of the British Army " gives an account of Marlborough's last campaign and a description of one remarkable forced march. That account contains the following sentence : " Hundreds dropped and many died there and then, but they were left where they lay : . . . each regiment pushed on with such men as still survived." To the humanitarian of keen imagination there is something inexpressibly callous in this bald narrative of the leaving of dying men by the wayside, but to the combatant all is justified by the fact that the force of this relentless human wave swept it on to almost immediate victory which was thereby purchased at a comparatively trivial cost.

(c) *Professional interests*

To turn for a moment to professional interests, it must first be realized that medical knowledge and sanitary art have but one value in the field, which is gauged by their effect on the massing of rifles at the decisive point and moment. The ultra-scientist who wastes time and money on refinements unsuitable for active service conditions is of far less value than the rule-of-thumb practitioner who can carry on with practical energy and meet the demands of the hour.

The medical officer who regards the campaign as an expedition for the furtherance of medical knowledge, regardless of all military considerations, forgets that conservation of all national resources is essential and that economy is one of the dominant factors in success—economy of money, of time and of transport.

(d) *The relation of the medical to the combatant branch*

It is the duty of the medical officer, as regards matters beyond the immediate professional care of patients, to advise only. If he carefully frames his advice in accordance with the foregoing principles and on lines of practical common sense, he will establish a reputation for soundness and secure the combatant officer as his best ally. The more able is he to put matters in a light which will enable the combatant to understand the scientific reasons for the measures advised, the more likely is his advice to be followed.

On the commanding officer rests the whole responsibility of either accepting or rejecting medical advice. If he accepts it, he accepts also the responsibility of providing for its being carried into effect. The commanding officer alone is in possession of full knowledge of the purely combatant considerations which must determine whether the suggested measures are practicable and expedient, and in some cases it is undesirable or impossible for him to explain precisely to the medical officer why his suggestions cannot be carried out.

The medical officer who takes it as a personal affront, and sulks when his advice is not adopted is not only guilty of gross insubordination but is liable to proceed to a grave dereliction of duty by abstaining from tendering further advice which it is his duty to give. The only correct attitude for the medical officer under the circumstances is to assume, with a smile, that combatant exigencies are responsible. He should renew his advice—if he still considers it sound and important—in another form or at a more opportune moment.

A. COMBATANT ORGANIZATION IN THE FIELD

1. Formations and distribution of the force

To the civilian practitioner coming into touch for the first time with military formations, the classifications appear puzzling and Fig. 19 may prove useful.

This Table and the definitions given in the Field Service Pocket-book should make the general classification clear, but one or two points may be noted.

Lines of communication defence troops form part of the field army because they may be concentrated at any point on, or even leave, the lines of communication at the discretion of the commander responsible for defence of a section. They are thus not immobilized as are permanent garrisons and coast defence troops.

Administrative units are those whose primary

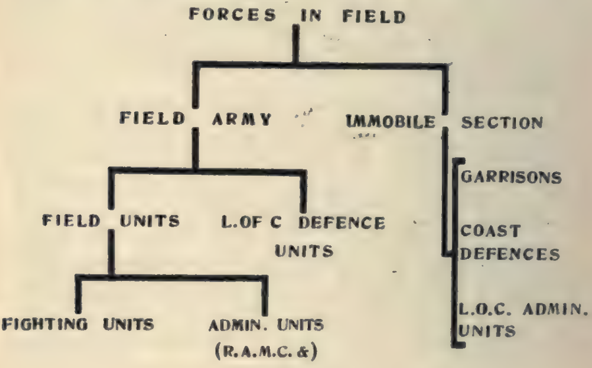


FIG. 19

function is to maintain the fighting efficiency of the true fighting units. In some cases they are armed and prepared to give a good account of themselves in an emergency. Some are permanently immobilized on the lines of communication and others form integral parts of the field army, but in either case the personnel comes under the definition of "troops."

The relation of various formations, units and personnel of the forces in the field to the lines of communication, from base to firing-line, is shown in the Frontispiece, which also indicates the channels of supply. Attention is directed to the footnote.

The composition of these forces is stated in detail in War Establishments (Part i, Expeditionary Force) and summarized in the Field Service Pocket-book. It thus calls for no discussion here, but a few remarks on the distribution of these formations in relation to the lines of communication may prove useful.

Whenever possible, the main line of communication is a railway, in connection with which a base and an advanced base are located respectively as near as is convenient to the overseas port and the zone of active operations. The most advanced points on the rail to which stores can be sent are known as the "rail-heads" and it is most desirable that each army should be supplied through a separate rail-head of its own.

The point at which the main line divides into branches feeding the several armies is known as the "regulating station" and it is in the neighbourhood of the regulating station that the advanced base is usually located. Here too the commander-in-chief may have his headquarters, whence he can control both the lines of communication and the fighting formations spread out fan-like before him. This general headquarters is the centre of the great web and on its staff are the heads of all the administrative services.

Behind the commander-in-chief is the next most important officer of the force—the inspector-general of communications (the "I.G.C."), who controls the whole lines of communication up to the refilling points to be described later. This officer has upon his staff the second senior officers of the administrative services.

The normal positions of these most important headquarters are indicated in columns abreast of the plate (frontispiece).

This preliminary sketch clears the way for detailed notes on certain matters which more particularly concern the medical service.

2. Supply channels

The channels by which the forces are supplied are indicated on the left-hand side of the Frontispiece. This was formerly a matter of great medical importance because the empty returning supply transport was used to bring back the sick and wounded. It may still be so used and a brief description of the procedure is therefore advisable.

From the rail-heads supplies are conveyed by motor-lorry supply columns to "rendezvous" arranged in advance by the headquarters of armies. There the columns are met by divisional staff officers who conduct them to "refilling points" where the supplies are transferred to divisional supply trains and where the sphere of control of the I.G.C. ends. The supply trains then carry the loads to their divisions. This procedure constitutes the daily routine, both the supply columns and trains making the double journey to and from the refilling point each day. The sick and wounded used formerly to be carried by the wagons of the supply train as far as the refilling point, where they were transferred to the columns and by them conveyed to rail-head. The difficulties of this procedure were great. One of the most trying duties of the medical service was that of getting patients at odd hours, often at night, to uncertain and constantly-changing starting points for the wagons, which were frequently missed, waited for, or delayed. The jolting in rough, unfitted supply wagons inflicted much suffering on the patients, while night travel made it most difficult for the medical personnel to adequately attend to their needs. It was impossible to disinfect the wagons after they had carried infective cases and before they were again used to carry food to the troops—a most insanitary alternation of use.

The provision of light motor transport has made it possible to give separate vehicles for use of patients, to their great gain, to the relief of the medical service and with an actual reduction of traffic congestion on the roads. Motor convoys for sick and wounded, fully fitted and equipped for the comfort and care of patients, now travel at their own time and speed. It is probable that the success which has attended this innovation will prevent reversion to the former unsatisfactory system of utilizing supply wagons for sick convoys.

3. Staff organization

The organization of the staff is popularly regarded as a matter which the newly-joined medical officer finds it difficult to grasp, hence it calls for attention.

The general staff overseas is responsible for the whole conduct of military operations. For this purpose it is organized in three branches, the first of which retains the name of "general staff," and controls the actual fighting, while the other two branches take over responsibility for all matters accessory thereto. The responsibilities of the branches—as far as they concern the medical service—are summarized in the following Table.

Branch	Responsibilities
1. "General Staff."	All matters concerning the actual operations of war.
2. The Adjutant-General's	Care of sick and wounded—accommodation, casualty lists, invaliding, burial of the dead. Medical equipment. Supply and discipline of medical personnel. Sanitary measures. Reports and returns.
3. The Quarter master-General's	(*a*) Director of Supplies. Food, forage, fuel, light and disinfectants. (*b*) Director of Ordnance Supplies. All non-medical stores, clothing and equipment. (*c*) Director of Transport. All non-railway transport. (*d*) Director of Railway Transport. Railway transport. (*e*) Director of Works. Buildings and camps on the lines of communication.

These three branches have their representatives—either in a separate or in a combined capacity—on all headquarters down to those of divisions. It is most important to realize that, quite rightly, these staff officers insist that matters concerning their staff branches should pass through their hands. Any attempt, therefore, to short-circuit the established channels of communication—by direct application to higher authority over the heads of the staff officers of the formation concerned—must necessarily lead to friction and, in the long run, to delay. This aspect is particularly commended to the attention of the newcomer.

The medical service is under the control of the general staff branch with regard to tactical dispositions, but for all other purposes is under the adjutant-general's branch.

B. MEDICAL ORGANIZATION IN THE FIELD

The medical organization in the field may be dealt with under the following heads:

(1) Personnel of medical officers.
- (*a*) Administrative (Staff) officers.
- (*b*) Executive officers.

(2) Medical units.
- (*a*) Non-sanitary.
- (*b*) Sanitary.

(3) Duties.
- (*a*) Of officers.
- (*b*) Of units.

1. Personnel of Medical Officers

The sanitary officers with the forces in the field may, for our purposes, be grouped as (*a*) Administrative and (*b*) Executive; although this classification is not official it is convenient. Before proceeding, it must be pointed out that the conditions met with in the present war have necessitated adaptations in our organization. Although the information embodied here is schematic, and may prove transitional, it conveys a sound general idea. It is set out in the Frontispiece.

(*a*) Medical Staff Officers

(1) **The Director - General of Medical Services Overseas** is attached to the Adjutant - General's branch of the Commander-in-Chief's staff—*i.e.* General Headquarters, 1st Echelon.

On the personal staff of the Director-General is the Assistant Director of Medical Services (Sanitary).

(2) Next in seniority are the **Directors of Medical Services.** Formerly the senior medical officer with the expeditionary force was the D.M.S. of the force, but it has been found necessary in the present war to have several D.M.S's. and create the higher appointment of Director-General.

There is thus a D.M.S. attached to the staff of the I.G.C. and this officer should have on his personal staff a Deputy Assistant Director of Medical Services (Sanitary).

For the Field Army it has been found necessary to have other D.M.S.'s and it will probably prove ultimately necessary to provide one such officer for each army.

(3) The next senior medical-staff appointment is that of **Assistant Director of Medical Services,** there being one A.D.M.S. for each division, each base and each advanced base, and an A.D.M.S. (San) on the staff of the D.G. There is a D.A.D.M.S. attached to each divisional A.D.M.S. to assist him in general staff duties and supervise the divisional sanitation.

That brings us to the end of the staff officer personnel, for brigades are medically controlled by the divisional staff and only in case of a brigade being detached will its senior medical officer undertake staff duties.

(*b*) Sanitary Officers

In general it must be considered that every medical officer is a sanitary officer, but practice and nomenclature have led to certain officers being regarded as having special sanitary duties.

The sanitary staff-officers have already been designated, but they may be recapitulated.

The A.D.M.S. (Sanitary) at General Headquarters.

The D.A.D.'s.M.S. (Sanitary), one at the Headquarters of the I.G.C. and one in charge of the rail-head area and beyond.

The D.A.D's.M.S. on the staff of each division.

In addition there are certain Specialist Sanitary Officers who are distributed one to the base, one to each advanced base, one to each rail-head—where they are in touch with the headquarters of the army served by the rail-head concerned—one acting as C.O. to each Divisional Sanitary Company and one to each of the sanitary districts constituted as such by the Director-General. Finally each officer in medical charge of an unit is essentially a sanitary officer to his unit.

It will conduce to clarity if the duties of the medical personnel of the forces in the field be considered later separately from their distribution.

2. Medical units

The medical units in the field may be divided into those whose duties are (*a*) principally sanitary and (*b*) those whose duties are principally non-sanitary; with the latter we are not now directly concerned, but it may be useful to simply enumerate them and state their accommodation for patients, seeing that this information is not concentrated at any one point in existing regulations.

(*a*) Medical Units without Special Sanitary Duties

The division is the basis of military calculations, for it is an army in miniature, with every arm and service represented, and is capable of wholly independent action. Consequently the basis of calculation for a force, as regards medical units required, is the number of units needed per division in the field. Those units are indicated in the frontispiece, with the approximate positions which they may occupy on the lines of communication.

Per division in the field

Unit	Number	Each unit gives Accommodation for patients
*Field Ambulances (Infantry)	3	40 lying or 120 sitting up
†Casualty Clearing Station	1	200
Stationary Hospitals	2	200
General Hospitals	2	520
Ambulance Train	1	100

* The Cavalry Field Ambulances with a Cavalry division are 4 in number and each affords accommodation for 28 lying or 96 sitting-up patients.

† The old Clearing Hospital has now become the "Casualty Clearing Station." It is mobilized by the I.G.C.

For the force—in addition to the above.

Certain other units are provided apart from the divisional basis.

Convalescent depots—organized near General Hospitals, as needed.

Medical store depots—advanced and base depots.

Hospital ships—each to take 20 officers and 200 other patients.

(*b*) Medical Units with Special Sanitary Duties

These units and the general scheme of their distribution are indicated in the Frontispiece.

(1) *Sanitary section*

Sanitary sections are distributed similarly to S.S.O.'s (*vide* p. 163). The personnel consists of a nucleus of :

1 Specialist sanitary officer
2 Non-commissoned officers
23 Rank and file.

To this nucleus there may be added, at the discretion of the Director-General, an indefinite number of *sanitary squads*, with the following personnel :

1 Non-commissioned officer
5 Rank and file.

A sanitary squad is detachable to act as a small independent unit posted at an outlying position in a sanitary district, *e.g.* at a railway post, as indicated in the Frontispiece.

(2) *Divisional sanitary company*

This is a wholly new formation—a product of the war—and has been constituted tentatively thus :

1 Specialist sanitary officer, who is the commanding officer.
20 Men trained to act as sanitary inspectors and foremen
30 Labourers, who may be augmented in number by local labour, as occasion may require.

(3) *Regimental sanitary establishment*

Although this establishment is not precisely within the definition of a medical unit, it is under the orders of the regimental medical officer and may conveniently be considered at this point.

(i) *Water-duty men.* The R.A.M.C. personnel consists of one N.C.O. and four rank and file per infantry battalion—or proportionate numbers for other units.

They are specially trained in all duties relating to the provision of a pure water-supply.

Eight regimental men per infantry battalion personnel may be provided, on requisition by the medical officer, for the purpose of special work in connection with water-supplies. As this fact is not generally known and only one reference to these men is made in regulations, it is advisable to quote the reference. It is found in Field Service Regulations, Part i, paragraph 46, page 70.

(ii) *Sanitary detachment.* This consists of regimental personnel fully trained in duties relating to field conservancy and disinfection. One N.C.O. and eight men per battalion—or a proportional number for other units—are so employed under the orders of the regimental medical officer and should give their whole time to this work.

Full information regarding the personnel and duties of medical units is given in the Field Service Manual, A.M.S. (Expeditionary Force) and in R.A.M.C. Training, chaps. xiii to xvii.

3. Duties of Medical Personnel

Before proceeding to outline the duties of the medical personnel specially concerned with sanitation, it is well to consider the relative importance of certain spheres of energy.

It is impossible to over-emphasize the view, already discussed, that the essential aim of the medical service is maintenance of fighting efficiency. To this primary duty all other considerations must be wholly subordinated.

In this connection the enormous importance of sound sanitation on the lines of communication is obvious. However satisfactory the civil sanitary organization in the zone of active operations may have been prior to hostilities, it is inevitable that a certain amount of disorganization and inefficiency must result from the increased demands and stress of war. An advancing wave of units, fully officered, equipped and organized, should leave in its wake few insanitary conditions, but the matter is very different when small detachments subsequently use the lines of communication. These detachments lack equipment, trained personnel and organized medical supervision, and consequently the routes tend to become progressively more insanitary. The consequent potential danger becomes an actual menace when the routes still later are traversed by returning infective patients. The ultimate result is that the lines of communication, which should serve to maintain the fighting strength by a stream of healthy reinforcements, are apt rather to prove a source of weakness by passing into the firing-line men who have been infected *en route* to the front, where they become foci whence infection may be spread through the ranks. It is thus evident that there can be few more important duties in the field than those which deal with the maintenance of sound sanitation upon the whole lines of communication. As regards the measures to be adopted, those relating to conservancy and the protection of water-supplies will be dealt with in detail under their respective sections and only their general scope will be here indicated.

In peace it is the duty of the *War Office staff* to prepare for war at any time and in any country. General preparations in the widest sense are organized and the special conditions of possible campaigns are studied. All relevant information *re* climate, epidemiology, endemic diseases and transport is collected and digested. On the outbreak of war, these records should afford all the necessary data upon which special measures and calculations may be based. Upon the dispatch of a force to the scene of operations, the traditional policy of the service is that the combatant and administrative heads of the overseas force should be controlled as little as possible from home and that the War Office authorities should devote their energies to providing the striking force with whatever its commander thinks necessary for the successful prosecution of the war.

Director-General of Medical Services overseas and his Sanitary Staff

(1) *The Director-General overseas* controls the medical service of the force and advises the Commander-in-Chief on all matters concerning the health of the troops. His expert adviser upon all matters of hygiene and sanitation is his *A.D.M.S. (Sanitary)*, whose duty it is to keep in close touch with the needs of the troops, both by constant personal investigation and by careful analysis of all available statistical returns of sickness; to formulate practical measures for the maintenance of fighting efficiency—whether by improving the general health, lessening the risk of preventable disease, or by diminishing losses from sickness which must inevitably occur in spite of every sanitary pre-

caution ; to suggest, initiate and supervise such work and organization as may be required to achieve these objects.

The importance and onerous nature of these duties are so obvious that emphasis is unnecessary. It is safe to say that there is no individual officer overseas whose ability and energy should have more influence upon the maintenance of effective strength.

Two points are evident in relation to the duties of this appointment—the first is that in a big campaign it is impossible for a single officer to deal effectually with the whole area of operations ; the second is that the A.D.M.S. (Sanitary) should therefore himself undertake responsibility for the most important zone, *i.e.* that in advance of rail-heads, and leave the lines of communication, up to and including rail-heads, to the next most senior sanitary officer with the force, *i.e.* the D.A.D.M.S. (Sanitary) attached to the staff of the I.G.C. In a big war two D.A.D.'sM.S. are necessary.

Directors of Medical Services and their Sanitary Staff

(2) Next we come to the *Directors of Medical Services*, and the newness of these appointments makes it impossible to speak definitely regarding either their staff officers or their duties, as far as the D.M.S.'s of armies are concerned, seeing that no regulations have yet been formulated.

With regard to the D.M.S. of the L. of C., who fills the position formerly occupied by the Deputy Director of Medical Services, there is the guidance afforded by precedent. The D.D.M.S. was attached to the staff of the I.G.C. and was responsible for the medical service and sanitation of the lines of communication and for all arrangements concerning the conveyance of sick and wounded from refilling points (or their modern equivalent) to the home port.

On his staff was a D.A.D.M.S. (Sanitary) whose sphere of administrative (as distinct from executive) responsibility embraced the whole area controlled by the I.G.C. and thus included all not administered as regards sanitation by the A.D.M.S. (Sanitary), whom he should constantly consult and keep in touch with. These two officers thus divided the sanitary administration of the whole area of operations and had similar general functions. The details of the executive work which they supervised will be better dealt with when taking the duties of subordinate officers engaged in sanitary duties.

Specialist Sanitary Officers

(3) It is convenient next to deal with the *Specialist Sanitary Officers*, who are distributed as already indicated. Their functions are executive and may be summarized as those of a civilian M.O.H. plus certain essentially military duties such as the organization of sanitary policing, supervision of all arrangements for the comfort, conservancy, ablution and feeding of troops at railway stations, control of all matters concerning the health of military personnel employed on the railway lines of communication, the cleanliness of billets in billet-towns, etc.

It is thus indicated that among the most important duties of these officers are those relating to the railway stations in their districts. The first point to be noted is that one of the worst features of the arrangements on the lines of communication is that of the conditions under which the railway staff often live. This personnel forms no definite units with discipline well maintained, and organization for medical purposes supervised by special medical officers attached. The men are scattered along the line and make what arrangements they can, living in odd waiting-rooms or railway carriages shunted on to sidings. Lack of organized medical supervision and executive responsibility leads to these habitations being frequently in an insanitary condition. Hours are irregular and exacting, fatigues cannot be readily provided for, and these isolated detachments suffer from being "no man's child." They provide the first problem to be tackled by the keen S.S.O., and one of the most troublesome throughout.

The next point to be dealt with is that of the arrangements necessary for the troops passing through in troop trains. Water supplies and conservancy are discussed elsewhere, but here it is necessary to consider certain other needs. First there is that of the food supply, and the S.S.O. should ascertain that satisfactory arrangements are made for provision of refreshments at the stations where troop trains commonly halt. Simple common sense will indicate what such arrangements should be, but because they are so obvious they frequently escape notice and the result is that entrained troops suffer considerably from long sojourns in trains and often to an extent which is quite unnecessary. The trouble spent in making adequate arrangements for provision of hot tea or bovril is amply repaid by the appreciation of the men.

The same remark applies to ablution facilities. Trains halt for quite long periods at certain points, and at these points it is not difficult to provide for hot water being supplied in ablution enclosures close beside the line. The men can whip off their tunics and shirts and wash in two or three minutes, and this would add enormously to their comfort at a comparatively small cost. A kindly understanding with the local administrative service representative will often achieve in a few hours what it would take as many days to procure through the usual official channels: Railway Staff and R.E. officers are the best friends of the S.S.O.

In these sanitary districts, well behind the firing-line, civilian sanitary organization should have been re-established and work in connection with conservancy should be far less than in billet-towns beyond rail-heads. The S.S.O. has under his orders a Sanitary Section, and is given such sanitary squads in addition as may be considered necessary. One of his duties is that of distributing this personnel to the best advantage in the district.

Divisional Medical Staff

(4) We can now pass on from the area controlled by the I.G.C. to that in advance of the rail-heads, and we come at once to the divisional formations. Formerly the *A.D.M.S.* of each division was given one staff officer—the D.A.D.M.S.—who was supposed to assist in general staff duties, and to turn his attention to sanitation in his spare hours. As he had few spare hours, sanitation made a very bad second to other staff duties, and it is obviously beyond the power of any one officer to effectually carry out this double function. The institution of divisional sanitary companies has solved the difficulty, for the S.S.O. commanding the company can act as sanitary officer to the division, under the administrative supervision of the D.A.D.M.S.

In general it may be said that this S.S.O. has duties comparable with those of the district S.S.O.'s on the lines of communication, and those duties need not again be enumerated. It may, however, be noted that in this advanced zone civil sanitary control is largely disorganized, and in consequence the divisional S.S.O. must undertake far more conservancy work and deal with infective disease among the civil population to a greater extent than is necessary on the lines of communication. For this purpose the personnel of the divisional sanitary company is composed largely of men trained as sanitary inspectors. The idea at present is that the S.S.O. should be provided with a motor bicycle and sidecar. When he goes on his rounds to outlying villages in his area he takes a sanitary inspector with him and, upon finding matters urgently needing attention, he obtains the necessary labour, by fatigue or requisition on the civil population, and leaves the sanitary inspector to supervise the work.

One of the most important duties is the systematic inspection of billets, both as to their conservancy and as to the arrangements made for the cooking and service of food. Where, as is at present frequently the case in quite small towns, there are upwards of a hundred separate billets, many of which are occupied by detachments not forming a part of large units provided with medical officers of their own, this involves a very considerable amount of work. Overcrowding is often unavoidable, but it is at least as often irregular, and adequate inspection leads to salutary redistribution and adjustment.

It has been made evident that the sanitary company is of most use when the division is stationary. We must now turn to the duties of the D.A.D.M.S. when it is on the move.

Duties of Divisional D.A.D.M.S. on the March—

(i) *On the Line of March*

The D.A.D.M.S. must supervise arrangements for the replenishment of water-bottles from the water-carts, and choose the source whence the latter are to be subsequently refilled, so that sterilization of the contents may be immediately commenced. He must exercise supervision over conservancy at halting-places, and ensure that excreta deposited by the roadside are properly covered. He must ascertain that the troops get suitably cooked food at the proper interval on long marches.

He must most carefully observe the marching troops to see that they are maintaining their condition and not being depressed by any preventable conditions. In other words, on the march—as at all other times—he must be alert to detect any factors which interfere with the fitness, comfort, and well-being of the troops. In this he serves as the second line of observation, and supervises the work of regimental medical officers.

(ii) *On Approaching Camp*

He rides on ahead with a staff officer and a R.E. officer to select the camp site and make certain advance preparations.

The general duties in this connection are laid down in Chapter XIII of the R.A.M.C. Training, and need not be repeated here. One or two notes may be added.

He is responsible for the quality and purification of the water; the R.E. officer is responsible for its quantity and conveyance to suitable delivery points; the staff officer arranges for the picquetting and flagging of the various water sources. The ideal camp is divided into living and sanitary areas. As the end in view would be defeated if adjacent units fronted in opposite directions, the D.A.D.M.S. should decide, in conjunction with the staff officer, as to which aspect the sanitary areas of all units should be located on, and the staff officer will indicate this to the unit representatives to whom he points out their camp site.

He should select the site for camp abattoirs.

He must not only investigate the existence of infective diseases in adjacent houses, but must arrange for the picquetting of the infected houses, farms or villages to prevent their being visited. It may also be necessary for him to arrange for isolation and disinfection, either in conjunction with the civil authorities or on his own initiative.

(iii) *On Occupying a Billet-town*

The sanitation methods must be arranged with the civil authority (*vide infra*).

Infectious cases must be located and the houses picquetted to prevent the troops occupying or entering them.

The number of men per billet must be decided upon in conjunction with the staff and medical officers of units. The following means of rapid calculation will obviate much mental arithmetic: For rooms of from 15 to 25 ft. in width, allow 1½ ft. of length per man along each side wall. For rooms over 25 ft. wide, allow 1 ft. of length per man similarly. For good agricultural districts allow for ten men being billeted per one inhabitant. For towns and industrial districts allow for five men per inhabitant.

Any building which provides roof covering will serve as a billet.

For hospitals the following data are useful :

Per patient

Desiderata	12½′ × 8′ × 12′ high ..	1200 c. ft.
Minima	6′ × 7½′ × 9′ high ..	400 c. ft.

The term minima does not indicate that in no circumstances may patients be accommodated in buildings giving smaller space, but that, in the event of less space being provided, the measure should be regarded as a temporary expedient and be remedied at the earliest possible moment. Apart from the objection to crowding cases which may be infective or become septic, access to patients is difficult if less than 40 sq. ft. of floor area be provided per man.

(iv) *General Duties*

Whether the division be on the march or stationary, there is one important duty which demands the immediate personal care of the D.A.D.M.S., and it is that of maintaining the closest touch with acute infective disease incidence and its control.

Another staff function is that of putting up drafts of sanitary standing orders for consideration by the A.D.M.S. This introduces the difficulty that is experienced by recently commissioned officers in understanding the classification of orders on active service—a difficulty which can be disposed of in a few words.

Operation orders deal with matters relating to the actual tactical and strategical operations of war.

Routine orders deal with matters not concerned with operations, and which are unaffected by war.

Standing orders are those which adapt existing regulations to war conditions, or which obviate frequent repetition of operation and routine orders. Standing orders have the advantage from the sanitary standpoint that it is the duty of every person to make himself acquainted with them as soon as possible after joining the force. Ignorance of their nature hence cannot be pleaded as an excuse for non-compliance. Once a standing order is published, it remains in force until explicitly cancelled by a further standing order.

Regimental Medical Officers

(5) The final link in the chain is the *Regimental Medical Officer* in charge of an individual unit, whose duties are not only concerned with maintenance of health and prevention of sickness, but also involve the keeping of a watchful eye upon every factor which affects the comfort and well-being of his men.

The allocation of responsibility as between the commanding officer and the medical officer of an unit is succinctly stated in Field Service Regulations, Part ii, paragraph 4. The final responsibility lies wholly with the commanding officer; the medical officer is under his orders; the sanitary personnel is under the medical officer's orders.

Infective Disease

The need for early diagnosis and certain aspects of the disposal of infective cases have already been dealt with. The prompt detection and control of infectious disease depends most largely upon the regimental medical officer, who is the first line of defence against epidemic disease. The efficiency with which measures of precaution are carried out in the unit depends upon the whole-hearted and intelligent co-operation of every member of that unit. This in turn must depend upon the power of the medical officer to make the whole personnel of the unit understand the reason and importance of the measures required, and to exert a personal influence which will ensure their being thoroughly carried out. The ideal regimental medical officer must thus possess versatile abilities of no mean order, and the most powerful ally that he has is the men's knowledge that he shares their dangers and devotes a large part of his energies to securing their comfort.

On the March

Until nearing the end of the day's march, the medical officer will gain the most useful information regarding the fitness of the unit, and be of most service, among the stragglers at the tail of the regiment. Being mounted, he can rapidly push on if an engagement should occur.

When camp is approached he should always be among the first to arrive, and should bring his sanitary men along with the advance party, so that all sanitary arrangements will be well advanced by the time the main body arrives. The positions of latrines, urinals, kitchens and sullage pits should be marked as soon as possible.

Water and conservancy duties are discussed later, and matters relating to food and cooking have been already dealt with.

In Billets

Adequate space, warmth, good cooking and service of food, general cleanliness and suitable conservancy arrangements should be provided for in the first instance and subsequently maintained by unremitting care. One of the needs which receives the least adequate attention in proportion to its importance is that of suitable means of relaxation and healthy mental occupation.

In the Trenches

Here there is much to be done. Sanitation, dryness, prevention of frostbite, the supply of warm meals and hot tea—all tax the ingenuity of the medical officer to suggest suitable means of securing. When the men return from their spell of trench duty, hot food and drink should be available promptly, their wet clothing should be dried, and anti-frostbite precautions should be enforced. Not the least important result will be the assurance thus conveyed to the men that thoughtful consideration and practical energy has been devoted to measures for securing their comfort. Such an assurance will go far towards promoting that good feeling which is the foundation of satisfactory morâl in the unit.

List of Regulations and Books

So many questions have been asked as to the regulations with which medical officers should be familiar that a list of those dealing with active service conditions may prove acceptable.

R.A.M.C. Training.

Field Service Manual—A.M.S., Expeditionary Force.

Manual of Elementary Military Hygiene.

Regulations for Mobilization.

Field Service Pocket-book.

Field Service Regulations, Parts i and ii.

War Establishments, Part i—Expeditionary Force.

Certain information embodied in the Regulations for Army Medical Services and Standing Orders for the R.A.M.C. will repay a rapid perusal of those works.

Many matters extracted from various sources are very conveniently summarized in Banning's

"Organization, Administration and Equipment Made Easy," which is a popular work among officers preparing for promotion examinations.

CIVIL SANITARY ADMINISTRATION

This section may be fittingly concluded by a few brief notes on the civil sanitary administration in the zone of present and prospective operations.

(*a*) FRANCE

Departments. France is divided into eighty-six departments, each controlled by a prefect. This officer is appointed by the Minister of the Interior, and is a civil service representative of the Government.

He is advised, but not controlled by, a local prefectorial council.

He controls the communal mayors and the police in his department.

Communes. The departments are divided into communes, each with a mayor, who controls conservancy measures—with the exception of street cleaning—and also acts as the military agent of government in his commune.

He and his deputies are elected by the municipal council. He appoints all communal officials, and exercises all control over civil administration.

The medical officer of health (*directeur*) is usually a general practitioner in small communes, but a whole-time officer in the more important.

The sanitary inspector (*agent technique*) supervises the staff, which deals with water-supplies, sewage disposal, abattoirs and housing problems.

A laboratory and disinfecting station must be provided.

An isolation hospital may be provided.

Notification of infectious disease is optional, and is made to the mayor, who notifies the police and sanitary inspector who take joint action.

Police. The police are controlled by the Prefect of the Department, and deal with street cleaning and the investigation of such cases of infectious disease as may be reported.

It is thus evident that in billet towns the mayor is the official who should be consulted first, and action should be taken in conjunction with him on sanitary matters.

(*b*) Germany

(1) The German system is highly complicated and tis head is the Chancellor, who is advised by a Central Health Department which investigates; records; issues regulations; and prepares legislative measures.

(2) The separate States are controlled by their Ministers of Education.

(3) Within the States are Provinces ruled by Governors, who are assisted in medical matters by Provincial Medical Colleges.

(4) Next come Districts, each under a President who has an inspecting Medical Officer of Health on his staff.

(5) The Districts are divided into Circles, each administered by a Landrat, who is appointed by Government and assisted by:

An Assembly—with deliberative functions.
A Committee—with executive functions.
A M.O.H.—for executive control of all medical measures, this officer being a state official.

There is in each circle:

A laboratory.
A disinfecting station.
An isolation hospital.

(6) Finally there is the Municipality.

Each municipality is under the control of a Burgomaster, who is a salaried but elected official. He exercises disciplinary control over all personnel, whom he may fine or imprison, but cannot engage or dismiss.

The Magistrat—under the presidency of the Burgomaster—is a body which exercises all actual executive functions, and deals with water, sewage disposal, street cleaning, housing, abattoirs and isolation hospitals.

Infectious cases are compulsorily notifiable.

Police. The police deal with all measures for the prevention of infective disease, save that the civil authority provides and administers the isolation hospitals.

LECTURE VII

CONSERVANCY IN THE FIELD

GENTLEMEN,—Our topic to-day is the most important one of field conservancy—the disposal of waste products.

The first feature which arrests attention is that of the ignorance of conservancy matters and the helplessness to deal with them which are engendered in the individual by the perfection of our municipal sanitary organization.

The acquaintance of an ordinary household with conservancy methods consists in the daily pulling of a handle and a weekly listening to the opinion of the dustman regarding the dryness of his job. Consequently, when the householder is faced by the problem of disposing of his own excreta his bewilderment is only equalled by his inertia.

This attitude is not peculiar to the layman: it is sometimes assumed by the medical officer who has never been under canvas in his life, and never had need to consider the solution of the problem on practical lines.

Occasionally one finds that even the D.P.H.—accustomed to the refinements of municipal methods—is stricken by similar helplessness in face of the problems of camp and field.

One can illustrate many points by a simple enumeration of the defects noted in an inspection of a latrine in a fixed camp on British soil.

The latrine was constructed with so great a space between the seat and the receptacle that no person of normal anatomy could possibly succeed in getting all his excreta—solid and fluid—into the bucket ; the interspace between every pair of buckets was heaped with fæces, owing to the vain endeavour to locate the positions of the buckets at night when no light was provided; there was no paper, no earth, no disinfectant, no orderly, and no orders. If anything were needed to call attention to this condition of affairs, the admission of a case of suspected enteric from this fly-infested camp on the day prior to inspection supplied the need, but no remedial action had been formulated—much less taken.

The main problem presents for consideration the universal hygienic law that all life is arrested by accumulation of its products—from the lowly micro-organism to the highest product of biological evolution—man.

When faced by the necessity of disposing of our own waste products, we must either revert to the method taught by the dog to Adam some 500,000 years ago or we must adopt one of the alternatives which Indian experience has taught to generations of medical officers. It is probable that it is on this subject—next, perhaps, to that of organization—that the civilian, approaching these problems for the first time, is likely to be most appreciative of some practical hints from his military colleague who has perforce had to turn his attention in this direction with considerable thoroughness.

It is convenient to consider the various matters of which we must dispose, and to take in detail the methods of disposal appropriate for each.

DISPOSAL OF SOLIDS

1. Surface disposal

To our simian ancestor there was no conservancy problem: no injunctions from the nether levels as to nuisance reached the well-disconnected, swaying bough.

Descent to terra firma brought for awhile no difficulties, but, as our rude forefather later surveyed his rapidly growing family in its first hutments, vague fears of a coming problem disturbed his malodorous peace.

As the community increased, and fixity of tenure became established, the difficulties grew apace until the advent of the hyperosmic landed-proprietor, whose strong views as to the rights of property brought the problem to an acute stage and ended the era of surface disposal.

2. Burial

The result was the introduction of the excellent method of burial, which obviated many objections to surface disposal which are so familiar to the wanderer among native villages. This method takes us back to the pentateuch, but, since Mosaic instructions dealt with the individualistic needs of a nomadic population, there are certain modifications necessary for communities which, in view of uncertainty as to duration of halts, must substitute deep trenching for shallow covering.

(*a*) Fæcal Trenches

Type. Originally the single, long, deep trench was used, but this had the objection that one side was heavily fouled by fæces right up to the ground level, while an area in front of the trench was saturated by urine. Infective material was thus liable to be brought back into the living area on the men's feet, or by flies.

The modern narrow trench obviates this by enabling the user to stand with one foot on either side. Its dimensions are 3 ft. by 1 ft. area and 1 ft. is the regulation depth for each day's use, although it would be better if the minimal depth were increased to 2 ft.

Calculations. One such trench accommodates one person at a time and provides for 33 per cent. of the strength of the unit for one day's stay, or 20 per cent. for a longer halt. The methods of laying out and calculating the space required for the short-trench latrine are given in paragraph 60 of the Elementary Military Hygiene Manual, but the formula there suggested for space calculation is not readily remembered. The frontage in feet should be one-fifth of the total strength of the force, and the width of the latrine area is 4 ft. for every two days' stay.

Another useful datum is that the average man in average soil should excavate 30 cubic ft. in the first hour and 80 cubic ft. in four hours' continuous work.

Site. The latrines should be sited where no contamination of the water supply is possible, and not less than 100 yards from, and to leeward of, the kitchens. The standard pattern of fixed camps, *vide* Fig. 20, should be adhered to as far as possible in camps and bivouacs.

Care. Paper should be provided and "camp butterflies" should not be allowed to blow about the camp.

The footholds should be boarded in fixed camps, if possible. The excreta should be covered with

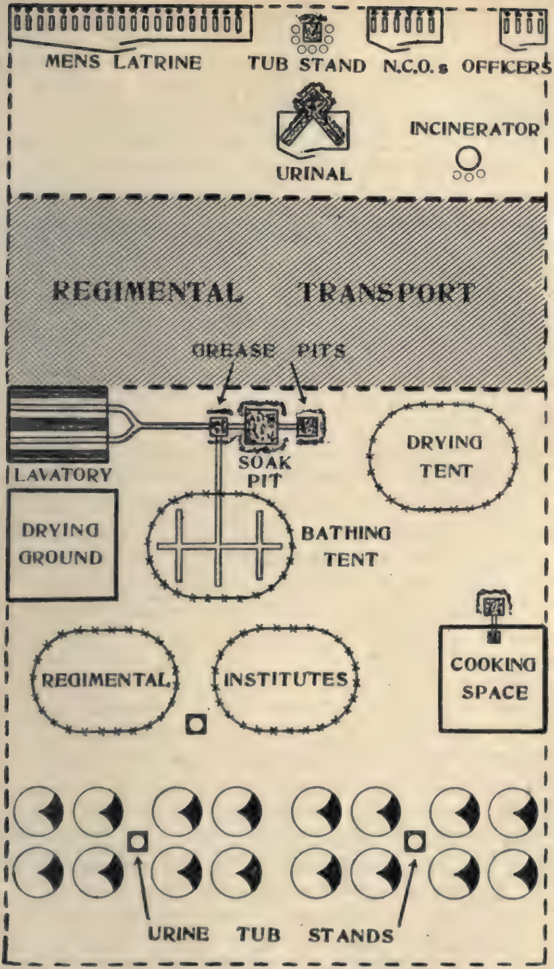


FIG. 20. Standard plan of fixed camp showing living, transport, and sanitary areas

earth by each man using the latrine, and as soon as possible. The method of kicking earth in is unsatisfactory, and tins should be provided.

Flies should be kept off by sprinkling the trench contents and surroundings at frequent intervals with antiseptic solution, kerosene or dry lime.

These measures should be laid down in standing orders, and an orderly should be posted to see that the orders are obeyed, failure being made a disciplinary matter and severely dealt with, for individual carelessness endangers the health of the whole unit.

The occurrence of an undue amount of diarrhœa should be carefully watched for and reported to the medical officer.

It is very useful to know that sub-paragraph 12 of paragraph 60 of the Manual of Military Hygiene lays down that the orderly officer should inspect the latrines at least once daily, for there is a tendency among junior combatant officers to relegate all such duties to the medical service.

It is the duty of the officer in command of the rearguard, before moving off the ground, to see that all latrines of the unit are filled in and banked over so as to indicate their site to subsequent occupants of the camp. Special care is needed to ensure that this duty is carried out, for open latrines involve a danger which is indicated by the following extract from a report on the South African War: "On visiting deserted camps there would frequently be found half a dozen open latrines containing a fœtid mass of excreta and maggots, while swarms of flies rose with a hum when disturbed." The importance of all measures for keeping flies away from human excreta has been fully dealt with in a previous lecture.

(*b*) Pits for Organic Refuse

In addition to human fæces there are other organic refuse matters which may be buried. They are usually disposed of in pits, for which a 3 ft. cube is a convenient size.

The desirability of periodical disposal of stable litter has been fully discussed, but a few words may be said about offal. This affords considerable trouble in camp for it is too wet to be burnt and large amounts must be dealt with. The abattoirs should be placed well away from living areas, and offal and blood should be disposed of in large pits, the contents of which should be treated by the same antimuscid measures as are adopted for latrines, otherwise large numbers of hatched imagines will struggle to the surface through the loose earth covering.

3. Incineration

The alternative to burial is incineration, and this method is of such enormous importance that it demands most thorough consideration.

(*a*) General Principles

There is much to be said for the peace-time view that burning of organic refuse involves a constant and unnecessary drain of nitrogen from the soil. That view finds expression in the Boer tradition that a guest should never leave his host's domain without first having given practical expression to his gratitude by paying a visit to the vegetable garden. On active service, however, incineration obviates so many dangers and difficulties that economic ethics cannot be considered, and this method should be adopted whenever possible.

(1) *The desiderata* are: the most rapid destruction of infective material; the least exposure to disease-disseminating agencies; economy in fuel, labour and transport.

(2) *Evaporation capacity.* This provides the chief preliminary study, for the materials needing to be burnt are all moist, and upon their capacity to supply sufficient heat to evaporate their fluids depends the possibility of combustion without the additional fuel which so greatly increases both the difficulty and the cost.

Each person passes the following daily averages:

Fæces, 4½ oz., of which 3 oz. consists of water, and

"Defæcation urine," *i.e.* urine passed with, and not conveniently separable from fæces, 5 oz.

The total fluid in the latrine buckets, therefore, amounts to 8 oz. per head, per diem.

The first question to be asked is: can this liquid be satisfactorily disposed of by evaporation from bulk surfaces? From the army standpoint, and as far as research has taken us, the answer is an unhesitating "No!" Even if a body of liquid be maintained at 80° C. for twenty-four hours, it will only lose 6 gallons per sq. ft. of surface in that time. In India an incinerator was made which dealt with the excreta of some 750 persons daily, and was provided with an urine evaporating tray giving 20 sq. ft. of surface and only 6 in. of depth. Even with this ratio of surface to bulk, only 1½ gallons per sq. ft. per twenty-four hours was evaporated when the incinerator furnace was worked at its own rate of economical combustion.

In devising evaporators for fluid, the usual mistake is made of providing a cylinder instead of a tray and, further, the point is lost sight of that the surface tension of urine is so high that the liquid froths over if the receptacle be filled more than about one-third full. These defects in design are illustrated by a device in which a tank was fitted with a central pipe, stopping just short of the clamped-down lid. The idea was that the fumes would pass down the central pipe and be destroyed in the fire beneath the tank. The practical result was that, if the receptacle were filled more than one-third full, the contents when boiling drove enough froth down the pipe to put out the fire, while if the boiling point were not reached the amount of fluid evaporated was negligible. These practical points are commended to the notice of the prospective designers of evaporators, for such devices are constantly being suggested, with demands for trial and claims that they will deal easily with the 300 gallons of urine provided by an unit daily. Moreover, the boiling of such tanks involves a great waste of fuel by the escape of heat up the flue, thus making the expense prohibitive.

An experiment was tried in India by which an attempt was made to evaporate urine from the double surface of cotton textile, which fed itself by capillarity from the tank from which it was suspended. Although the total evaporating surface was 360 sq. ft. the evaporation rate was so reduced by the consequent absorption of heat that only 10 gallons an hour were evaporated in an atmospheric temperature of 30° C.

The next question is: Can better results be obtained by soaking urine up in absorbent material, which must thus get rid of its charge of liquid before it can itself burn? Experiment proved that evaporation from a bulk surface is increased by 37 per cent. if charcoal be floated on the fluid.

Theoretically such a "matrix" will evaporate 95 per cent. of the total fluid which its caloric value is capable of evaporating, if combustion is slow enough to be just maintained by the remaining 5 per cent. of the total caloric value of the matrix.

Practically it has been found that under field conditions, fluid is evaporated by 66 per cent. of its weight of combustible matrix, such as sawdust or dry stable litter. Under more favourable conditions this ratio of efficiency is doubled.

(*b*) Practical Application of the foregoing Data

A battalion of standard strength of 1000 men provides 600 lb. of filth a day in the latrine buckets—500 lb. of this being liquid and 100 lb. solid. Normally this is collected in ten buckets of 60 lb. each.

The fluid in one such bucket is absorbed by 10 lb. of sawdust, and the regiment thus needs 100 lb. per diem of absorbent matrix, of the equivalent value of sawdust, to take up the liquid.

The total fuel of that value which is required to completely incinerate the 500 lb. of liquid is (on the datum of 66 per cent. by weight) 330 lb. As the total combustible refuse from the standard unit averages 1500 lb. per diem, the unit should be self-supporting in its incineration, and practically this has been found to be the case. At most, all that is needed is some 50 or 60 lb. of sawdust extra a day, if the ordinary refuse be found insufficiently absorbent.

Certain data regarding other fuels may be useful :

In the field each horse gives an average of 8 lb. of droppings per diem when in camp, and this suffices to burn the fæces of four men in rough camp incinerators of the closed type.

In the light of these essentially practical data, it is evident that the contents of filth buckets in fixed camps can be economically burnt if a suitable incinerator be used, but that some other means must be found for dealing with the remaining urine. It is also evident that stable litter, which contains far less fluid, can be incinerated without any difficulty save that consequent upon its bulk : in fact, apart from saturation by rain, litter has to spare, for the combustion of the contents of filth buckets, a certain amount of caloric value beyond that required to evaporate its own moisture.

Fuel	Cost per ton	Caloric value	Absorbs its weight of fluid	Amount needed to incinerate 60 lb. of bucket filth
Sawdust	18/–	·5	× 5·00	20 lb.
Breeze	3/–	1·0	× ·85	10 lb.
Slack	3/–	1·0	× ·50	10 lb.

4. Incinerators

We have now to discuss the types and working details of various forms of incinerator, but before proceeding to detail it is interesting to comment upon the range and genuine nature of the objections which are raised to this method of conservancy.

The odour of burning organic matter is much the same, whatever the nature of the matter, so long as it is fresh and undried, but it throws an interesting light upon the relation between the special and æsthetic senses to note the abrupt change in public opinion when the nature of the burning matter becomes known. The "odour of burning peat, so delightfully reminiscent of the cotter's hearth" becomes "the intolerable effluvium of burning matter of an indescribably objectionable nature" when it is discovered that excreta are being burnt. The latter quotation is from a letter of complaint written by a lady in India immediately a preliminary trial with wood fuel was commenced to test the combustion efficiency of a new destructor designed to deal with filth. This intelligent anticipation proved most useful in discounting subsequent objections when the genuine processes were commenced! It also indicates that many of the long series of objections are merely obstructionist, and their ingenuity is illustrated by the mental effort of one anxious inquirer as to the effects which would follow if an iron incinerator were struck by lightning. These objections must, however, be faced, whatever one's views of their nature.

Types

(*a*) *Open types.* There are two main types—the open and the closed. The former type varieties give rise to complaints that they are:

Slow to make and start.
Wasteful of fuel.
Productive of offence.
Liable to be put out by rain.
Certain to have their contents blown all over the camp.

These objections are all well-founded, and open types should never be used if closed patterns are available. On the other hand they can be improvised from materials always at hand, while the portable varieties—consisting merely of a grid and its supports—are cheap and light. Having no effective draught, the contents simply smoulder, and genuine offence is due to the resultant products of partial oxidation.

Portable Incinerators—Closed Type

Various patterns are described in paragraph 68 of the Manual of Elementary Military Hygiene.

The closed types are numerous, and the portable and fixed forms call for separate consideration.

(*b*) CLOSED TYPES. (i) *Portable.* The simplest form is that provided by two rolls of corrugated iron, one of which forms the wall and the other the roof. The former is perforated by a series of holes which support the ends of bars thrust through them from side to side to form a grid near the base.

The next advance was the invention of a box formed by sheets of flat iron, of 23 S.W.G., hinged to a grid, upon which they fold for packing and to which they are fixed by angle-iron uprights extended to form short legs. To the roof is hinged a chimney, which also folds up for transport and fits into the roof concavity. The whole weighs ½ cwt., costs £1, and gives a 2 ft. cube of space. It is thus extremely light, cheap, and convenient for transport, and will stand the wear and tear of several months' work in the field. Its life, however, depends upon the fierceness of combustion, for the thin side-plates will soon burn through if a roaring fire be maintained. If such material as damp manure be burnt, the apparatus will last for a considerable time—three or four months at least. These incinerators have served well in India, and several dozen have been sent to the Field Force during the present war. They need little attention and will burn all night if well damped down.

The most recent pattern for field use is described as portable rather as a matter of courtesy than of fact, for they weigh 32 cwt., but this objection is largely discounted by their capacity for destruction of large amounts of refuse. The design of an example of this type is given in Fig. 21, which shows that the most important feature is a baffle plate separating the furnace from the bottom of the flue. As each charge of moist material falls in the furnace it gradually dries, and the discharged gases are aspirated down through the red-hot heart of the fire, where they are fully oxidized to inodorous products before they reach the base of the flue. If the apparatus be well worked there is little offence from either smoke or gas escaping from the flue-top. Owing to there being a half-inch air space between the iron walls and their firebrick lining, the heat reached is well over 500° F., which is the minimum effective flue temperature.

The necessary accessories are—a shed in which to dry the fuel, a roof to prevent rain cracking the plates, and a perforated iron cone to rest on the grid and prevent wet fæces from falling right through the furnace unburnt if the stoking be defective.

The working is simple. It is important, *re* the prevention of offence, that filth should not be burnt until there is a full depth of fire, white-hot at its core. To half a bucket of latrine filth there should be added a like amount of absorbent fuel and the whole thoroughly mixed before being thrown on to the fire. This amount of filth should be added every half-hour and the other combustible refuse should be added at intervals so as to maintain a fierce fire throughout. The whole 600 lb. of filth and the total combustible refuse from an unit 1000 strong should be destroyed in ten hours by one destructor of this type and size (16 cubic ft. furnace capacity). If well damped down at night, the fire burns until morning without further attention; the stoker should force the combustion rate in the early morning so that the furnace is

FIG. 21

working at full blast by the time the morning filth arrives at the installation.

The buckets are brought to the destructor on low lorries fitted with hoops and swivel hooks from which the buckets are suspended by their handles. This device prevents the contents being slopped as the lorry traverses rough ground. The whole load is readily pushed by two men if there be a slight downward incline from the latrines to the incinerator. These details have been given at length, as of considerable value to the medical officer who is called upon to supervise the working of a novel method concerning which he can find no literature. For single units there is no doubt that this type of destructor affords a simple, effective and economical method for the disposal of latrine filth and all organic refuse in fixed camps.

(ii) *Fixed.* Progressive improvements in the art of incineration have led to the evolution of the destructor cell, which plays so important a part in the municipal conservancy of to-day but is unsuited for camp use. Military needs have led to renewed attempts to deal with urine and these attempts call for review. The endeavour has been made to evaporate from bulk, with the familiar errors and the familiar results already noted.

The most interesting product of inventive ingenuity has been an installation which aims at destroying organic matter by a process of fractional distillation, the final product of which resembles coke. The gases are aspirated off by means of a fan and are condensed, with the recovery of a valuable ammoniacal disinfectant and sufficient oil to work the oil-engine. The non-condensible gas is highly combustible and is led into a hopper where it is used to burn off the coke-like product of the distillation process. The oil-engine supplies all the power required to make the installation wholly self-supporting when once the cycle has been fully established. Urine is dealt with by evaporation in the interior of the furnace. The whole excreta are thus disposed of without the discharge of any product into the air save carbonic oxide.

For large concentrations of troops an economy is effected, both in initial cost and in the maintenance expense of labour, by the erection of a single large destructor instead of separate incinerators for each unit. A suitable type is shown in Fig. 22. The filth undergoes preliminary drying on a solid slab and is then raked on to the grid. Forced draught is maintained by steam blowers discharging into the furnace, the heat escaping through the chimney being utilized to generate steam in a boiler placed at this point. Much of the heat going to waste might be used to provide hot water for baths.

A final note may be added *re* a simple method of preventing offence from any type of incinerator which is so constructed as to maintain an aspiration draught up the chimney. The flue is splayed out at the base to form a small chamber, which is divided into two parts by a horizontal grid. Both halfs of the chamber are loosely plugged with any matrix, such as hay, tow or litter. First water condenses on the fibres of the matrix ; then carbon particles in the retarded air current adhere to the moist fibres of the matrix ; finally the carbon particles absorb the greater part of the offensive gases. As the matrix gradually gets occluded by tarry material, it must be renewed and this is effected by alternately replacing the loose plugs on either side of the grid so that at no time does unfiltered smoke escape. The saturated " filter " can be burnt and the method thus involves no

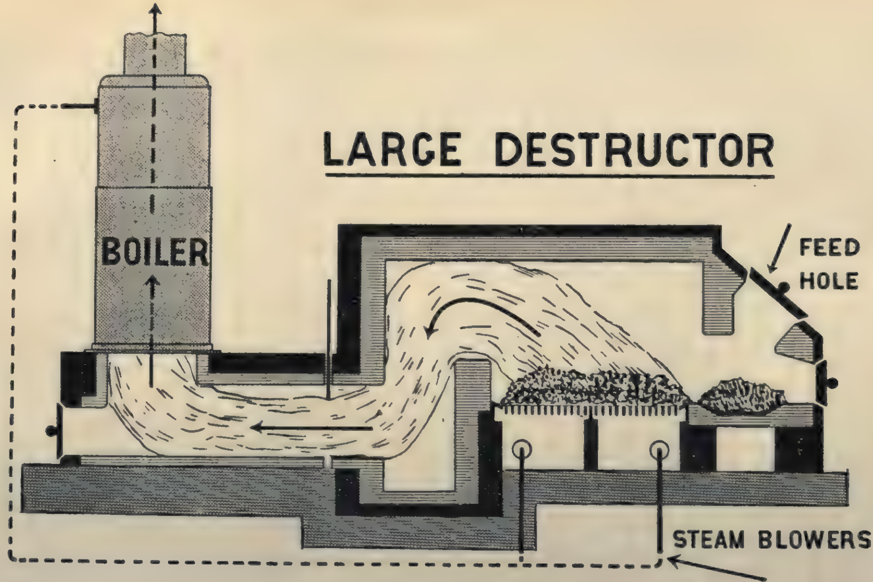


FIG. 22. For fixed camps

waste of fuel, while the only extra cost is that of making the chamber and lengthening the chimney to ensure that there is sufficient aspirating force to carry the smoke through the matrix.

5. Kitchen Refuse, Carcases and Corpses

Before leaving the subject of incineration there is a word to be said with regard to kitchen refuse and carcases.

Kitchen refuse burns well and it is necessary that it should be disposed of, owing to its attraction for flies. With regard to the larger masses of waste matter there is no difficulty, save that of getting cooks to collect them in a receptacle, but the smaller greasy particles interfere with disposal of kitchen sullage in soakage pits. Removal of grease will be dealt with later when considering ablution sullage. The waste kitchen solids may be readily removed by passing the sullage through a box perforated at the bottom, and filled with a filtering matrix. The matrix and entangled solids may be burnt twice daily. Meanwhile flies can be kept at bay by sprinkling the filter with kerosene or lime or liquor cresoli.

All those who have had to dispose of the *carcases of animals*—or have suffered from their not being disposed of—will agree that this is a difficult problem. The labour involved in burial of the carcase of a horse is far more than appears at first sight. One most convenient method is a combination of burial and burning. A hole is dug beside the body, which is then disembowelled, and the viscera are buried and well covered. The carcase is dragged over the buried viscera and blood-saturated soil. Into the cœlom and over the surface there is distributed 30 or 40 lb. of dry grass, or litter, which is soaked well with a quart of kerosene and set fire to. The method aims at sterilization of the surface, which is charred, and not at incineration. If the work is done before the saprophytic organisms have had time to penetrate any but the very superficial tissues, the result is that the whole exposed surface is sterilized and so charred that it affords no attraction for flies. Further, the method also achieves the purpose of sterilizing the surface of the soil which has been fouled by blood, possibly highly infective. This is of the utmost importance where the animal has died of infective disease due to sporing organisms, such as anthrax or tetanus. In dry climates—such as that of South Africa—it will be found that the carcase so treated shrivels and undergoes what was formerly known as eremacausis which causes no offence.

Some foreign armies have incinerated the *corpses* of their dead on huge stone cairns upon which there were piled alternate layers of corpses and wood, the whole mass being saturated with tar and kerosene and set fire to. It is claimed that this method proved practically satisfactory in Manchuria, but it is probable that public sentiment in this country would not permit of its adoption, illogical as this attitude appears when thoughtfully considered.

A final note is necessary on the importance of having a tin placed outside each tent, for the collection of *food fragments* and other combustible refuse which should be incinerated. If this be not done, the habitual carelessness of the men leads to the throwing on the ground of waste which attracts and feeds flies. Having got the tins provided it needs much persistence to get them used.

DISPOSAL OF LIQUIDS

Coming now to the means of disposing of liquids, we have to deal with dangerously infective urine and grease-laden sullage, which require separate consideration. It may first be remarked that, to the uninitiated, the amounts to be dealt with in camps are surprisingly great. The standard unit of 1000 men daily produces 300 gallons of urine, and is given from 3000 to 5000 gallons of water, the whole of which must somehow be got rid of without the aid of drains. It may at the outset be said that this constitutes the most difficult problem of camp sanitation.

(a) Urine

The potentialities of the bacilluric carrier for adding to urine vast numbers of infective organisms have been fully indicated in a previous section, and need only be referred to here, but it may be noted that it is difficult to get the men to realize that urine is possibly more dangerous than fæces, and hence difficult to obtain their necessary co-operation in precautionary measures. The means of disposing of defæcation urine have been discussed, and we must now consider the methods of disposal of the balance. Evaporation having been dismissed as impracticable, there remain open trenches and closed soakage-pits to discuss.

Trenches. The form of trench is figured on page 66 of the Manual of Elementary Military Hygiene. This has the objectionable feature that the men stand on one side of the trench instead of straddling across it. The result is that one edge of the trench gets sodden with urine, and the consequent tendency of successive users to stand further from the trench leads to the fouling of an increasingly wide surface of adjoining ground. Flies are provided with free access to large quantities of infective urine, and dangerous matter is carried back on the men's feet into the living area of the camp. As the urine finally flows into a pit and soaks thence into the subsoil levels, it would involve far less danger if it were taken direct into the pit, thus avoiding use of the wholly unnecessary and dangerous open trench. This can be done without additional labour by means of the modern soakage-pit.

Soakage-pits. The small additional equipment required consists of two dozen funnels per unit. As these are nested for transport, they may be made of light metal. They should be 4 ft. long and tapered from a diameter of 6 in. at one end to 2 in. at the other.

The pit—a 3 ft. cube—is excavated, and the soil at the bottom is thoroughly loosened; the pit is then filled to near the top with graded stones, and when a suitable height is reached the funnels are inserted one in each corner; when nearly full a layer of brushwood or grass is laid on top and earth is then spread over it until level with the surrounding surface. If necessary to provide more accommodation, four other funnels may be used—one at the centre of each of the pit sides—and the whole of the eight funnels should then be sloped outwards at their tops so that sufficient space is available for all being used at one time.

The tops of the funnels being at a convenient height, there should be little fouling of the ground. If kerosene or lime be sprinkled twice daily over the area and on grass lightly plugged just within the mouths of the funnels, the whole urine can be disposed of by this method without flies gaining access to it. In India two such soakage pits were sited outside the canteen of an unit 1100 strong, and they disposed of the large volume of urine from that source for fifteen months without causing any offence or receiving any attention. When they were finally opened only the bottom six inches were found to contain urine, lying among stones covered with blackish slime. There are always two stock questions which are asked about this method. The first—as to what happens in wet weather when the ground is saturated—leads to the reply that, as the urine must in any case be run into the soil, the soakage-pit is no worse than the trench. The next—as to the danger of infecting the subsoil water—raises a point of great practical importance, which also is common to all methods of urine disposal in the field.

If bacilluric urine may contain one hundred million motile enteric organisms per cubic centimetre, there apparently must be a grave risk in running this highly infective liquid into the subsoil water levels whence drinking water is drawn. Every care must, therefore, be taken to site the soakage-pits so that the subsoil flow is directed from the wells towards the pit.

It has been mentioned that the best technique does not enable us to recover *B. Typhosus* from bacilluric urine after the third or fourth day, and this fact—although it does not prove that enteric organisms are absent—proves that they have been reduced in number at a rate which justifies the belief that few, if any, could survive several days' contact with soil teeming with more vigorous saprophytes which are known to outgrow and destroy them. It is satisfactory to know that, if every care be exercised, the only method available for urine disposal in the field is certainly reasonably safe. If these premises be admitted, it follows that the soakage-pits may be sited close to the living area. This does away with the necessity for having urine tubs for night use placed at the end of each row of tents—a former necessity when the urinals had to be placed at a distance, and one which led to fouling of the living area by slopping of the contents as the tubs were carried every morning to their stand by day in the conservancy area. *Vide* Fig. 20.

(b) Sullage water

The minimal amount of water required daily per man for drinking and cooking is 1 gal. In camps 5 gallons per man per diem are supplied if laundry work be done, and 3 gallons, otherwise. There is never need for more than 5 gallons: a larger supply only leads to waste and greatly increases the difficulty of disposal of sullage.

The first practical point to note is that laundry work should always be done at a distance from camp, where natural conditions enable the waste to be disposed of without difficulty. The ablution benches must be nearer the tents, but it is better that the men should walk a few yards further than that their camp should be waterlogged.

Grease Removal

The large bulk of sullage must be disposed of on or in the soil, and the first essential is that it should be freed as far as possible from the finely emulsified fat which clogs absorbent surfaces and is so unsightly and offensive when undergoing decomposition. As regards the former point one has seen camp sullage, wholly untreated, run into huge pits where the rapid fluctuations of level have resulted in successive deposits of grease collecting on the pit sides until they have been rendered as impervious to water as if lined by puddled clay. This has led to the first pit rapidly filling and another pit being dug, until finally there has been a series of huge pits amounting to half a dozen, each full of water covered by an offensive scum, and it has been reported that the soil is unabsorbent and the site unsuitable for a camp. It is remarkable that the myth that grease can be effectively removed from sullage by gorse or bracken should have survived so long: a moment's consideration shows the idea to be impracticable. One has seen camps in which this method was adopted with a faith so simple that it was unshaken by the sight of long channels winding into the distance, lined by black and decomposing grease, and ever prolonged a few more yards, as each successive section became grease-saturated, or else finally discharging into a foul-smelling pond.

It is probable that there is only one universally available material for filtration of finely divided grease from sullage, *i.e.* sand. A box, or a pit lined by puddled clay, should have a few inches of sand placed in it and be then divided by a transverse vertical partition which dips into the sand for a couple of inches at its bottom end. Sullage discharges into one compartment, and its head of pressure forces the contents through the sand underneath the partition, until a clean effluent flows away from the top of the distal chamber. The tax on the sand is lessened if there be a plug of absorbent material floating in the proximal chamber: this plug entangles the floating grease, and the whole mass can be removed and burnt. As the sand gets clogged with grease the surface layers must be periodically renewed, and this may be effected by either having a bung in the side of the box so that the water can be run out, or by having the sand placed in a removable tin perforated at the base. Having removed the grease, disposal of the effluent is usually not difficult. In geological formations in this country where clay exists it is usually in "pockets" with intervening porous material, and the porous interspaces can be found by trial pits. If there be a continuous clay layer, sullage cannot be absorbed and the site is so damp and cold that it is not suitable for camping on.

Given a good effluent and absorbent soil, the sullage may be disposed of either by soakage-pits or broad irrigation. The former are similar to those just described for urine. The latter method is applicable to sloping surfaces, which may either allow the liquid to soak into the soil or drain down the surface into a discharge runnel. If the former, parallel runnels should be dug along the contours and the fluid allowed to fill them by successive overflows. The ground should be divided into areas which should be used for a day and then allowed to dry for a day or more, when the soil lining the runnels should be turned and loosened preparatory to being again used. The general arrangement is figured on page 75 of the R.A.M.C. Training Manual.

CONSERVANCY IN THE ZONE OF OPERATIONS

The general measures of field conservancy having been described, we are in a position to consider certain points of special application to various areas in the zone of operations.

(*a*) *On the lines of communication.* Stress has already been laid on the importance of sound sanitation on the lines of communication. No special methods are required at the bases, where the usual arrangements can be organized on a permanent basis. The troop trains must be provided with conveniences and in many cases this has been done by fitting one compartment up as a latrine, with a receptacle slid under the seat. Arrangements must be made for emptying the bucket and disposing of its contents at fixed points on the line. It is also desirable that at places where long halts are made, latrines and urinals should be provided so that they afford ample accommodation close beside the rails. It must be remembered that most station premises are permanently occupied by railway defence troops and personnel of the railway transport staff.

At detraining points permanent camps must be established and a permanent staff and organization provided. Special care is required here to deal with detachments of inexperienced soldiers in charge of young officers. Similar arrangements are required at halting camps along the roads beyond rail-heads, for it is here that the streams of on-going reinforcements and returning sick come into closest contact, thus establishing channels of possible infection which require most careful watching.

(*b*) *Camps.* With regard to camps there is little calling for special note, but the general arrangement and division into living, transport and conservancy areas—*vide* Fig. 20—should be adopted in all fixed camps. These fixed camps represent the furthest points to which heavy types of incinerator can be taken and such should be used wherever it is possible. Beyond the area of fixed camps the small portable incinerators will do much to solve the difficulties of disposing of the mass of fly-breeding material which it is one of the principal duties of sanitary officers to cope with. It is the transport units which need the most attention, for their duties, small numbers and lack of trained sanitary men make it difficult for the officers to detail a sufficient strength to deal with the enormous quantity of manure which is apt to accumulate near their lines. The use of mechanical transport should greatly lessen these difficulties. All commanding officers are made responsible, by regulations, that camps are left in a sanitary condition.

(*c*) *In billet towns.* It is in billet towns that the disadvantages of campaigning in a friendly country are most acutely felt, and sanitary officers need their utmost tact. The methods to which we are accustomed are not always those which commend themselves most to the officials upon whose co-operation depends the extent to which the billeted force can secure the methods of sanitation which we think desirable. The divergence between British and Continental practice in conservancy matters is best indicated by a brief sketch of the municipal sanitation of a typical town now occupied by our troops.

Some 90 per cent. of the houses are provided with cess-pits. The closet in these houses contains a funnel, level with the ground at the top and opening at the untrapped apex directly into a cess-pit below. There is no water flush: when the funnel is full the contents are pushed down by a stick and a little water is poured in from a can. Gas from the cess-pit escapes freely through the open funnel.

The cess-pit (fosse) is fitted with only a loose cover; it is usually not imperviously steined, so that its contents leak freely into the surrounding soil, in which shallow wells are situated. The freedom of leakage is indicated by the fact that many houses containing half a dozen persons have not had the contents of the pits removed for four or six years. When the pit is full, the municipal staff remove the contents by means of a suction apparatus—as this is done at the householder's expense, the operation is not carried out until absolutely necessary, and there is no incentive to provide the fosses with impermeable linings.

The urinals leave little to the imagination of the opposite sex. Some are provided with fosses and some discharge into the gutters.

Refuse is deposited daily by householders in the gutter in front of their premises and is simply dumped on the ground. As much of the heaps as is left by wind, rain and dogs is collected daily by municipal carts which, however, make no rounds on Sundays.

There is thus a large amount of organic refuse carried into the storm-water drains and, as these are untrapped and communicate with the gutters by large holes, there are many and powerful odours in the streets in hot weather. It is probable that considerable amounts of cess-pit contents leak into the storm-water drains and so pass untreated into the rivers.

Every allowance must be made for disorganization consequent upon the war, and no comment is added to this plain account of the conditions met. It is not an easy task to hit upon precisely the most tactful method of approaching local authorities with suggestions for bringing municipal conservancy into conformity with our own ideals.

It is in billet towns that the divisional sanitary companies find their most useful spheres of action and they must frequently co-operate with the municipal staff in carrying out the suggested measures. Maintenance of individual billets in a cleanly condition involves the issue of standing orders; cordial co-operation on the part of regimental officers; constant inspection; and detailed supervision. The more the unit is broken up into small numbers of men in separate billets, the more regimental discipline tends to be relaxed. Concentration of the force necessitates billets being occupied alternately by troops which relieve each other in the trenches: there is thus continuous occupation which affords little opportunity for thorough cleansing of the dormitories and premises. The infestation of practically all billets with vermin provides a problem which taxes the ingenuity of sanitary officers to the utmost and has yet to be fully solved.

(*d*) *In the trenches.* Here the conditions as regards conservancy are practically those of a siege. Disposal of excreta has been attempted by various means which may be briefly indicated.

The trench within a trench was first tried—fæces being buried in short off-shoots from the communication trenches. The probable length of occupation and onset of rains soon led to this method being abandoned.

Then ordinary filth trenches were made, where possible, behind contours which afforded cover from rifle-fire and were approached by traverses. At first an excess of bloodthirstiness and ammunition led to so severe shelling by the enemy that every ruined house and barn was razed to the ground, but it is practically impossible to destroy all cover against rifle-fire, and now many well-constructed latrines have been sited behind such ruins and are approached by communication trenches.

Finally it has been found most satisfactory in the majority of cases to place buckets in bomb-proof dug-outs in the trenches. The buckets are removed by the relieved troops, who bury the contents and bring the buckets back with them on their return.

There is another method—an unofficial one—which represents a reversion to the Chinese method of fighting by stink-pots. It consists in placing excreta in empty tins and lobbing them into enemy trenches which happen to be near enough. Reprisals were found so unpleasant that apparently this method has been abandoned by mutual consent.

Much must be done to secure such comfort for the men as is possible under the exacting conditions of trench warfare. Increase of available strength has resulted in the occupants of the trenches being on guard and at rest alternately. Dug-outs have been made and protected from water in the main trench by low clay partitions. In these dens the off-duty men warm and dry themselves before coal braziers and here they can warm their food and make themselves hot drinks. In many cases provision has been made for ablution by a short length of trench containing a small boiler heated by a coal brazier. Water, obtained by hand-pumping from a short tube-well, is thus warmed and the men are able to get an occasional wash, the sullage being flung from the basin on to the ground as far as possible from the trench.

The most important result of trench warfare in winter has been the occurrence of frostbite in men who have stood for many hours immersed continuously up to their knees, or above, in icy water. Every effort has been made by the Royal Engineers to reduce the water in the trenches to the lowest possible level, but in many cases the subsoil saturation has brought water levels almost up to the surface.

* * * * *

Before concluding this section it is interesting to record the effect produced on the mind of the sanitary officer by personal inspection of municipal sanitation in the zone of operations. The first impression made was one of misgiving as to justification for many recommendations made for conservancy improvements which have involved considerable expenditure: if the conditions described be found to give good results as regards the health of the population, then British conservancy stands convicted of much waste of money on unnecessary refinements. This led to a comparison of the enteric statistics of the capitals of various belligerent countries, for the last year in which all are available. The comparison is shown in Fig. 23.

It is seen that the amount of enteric in France is approximately three times that in England, and this disparity would be considerably more marked if compulsory notification were enforced there as it is with us. Further, there is a very large amount of sickness among children in the French towns, and the liability to infection of water-supplies by the leakage into them of cess-pit contents justifies the view that many of these cases of sickness in the child population may be due to enteric, which is known to occur in children in a mild form difficult of diagnosis. If this be so, there logically follows the conclusion that these juvenile cases of enteric supply a proportion of the adult population which is immune to enteric itself but which increases the ratio of carriers to an extent which makes the area the more dangerous to our troops, while reducing the apparent rate of enteric incidence on the civil population. The final conclusion is

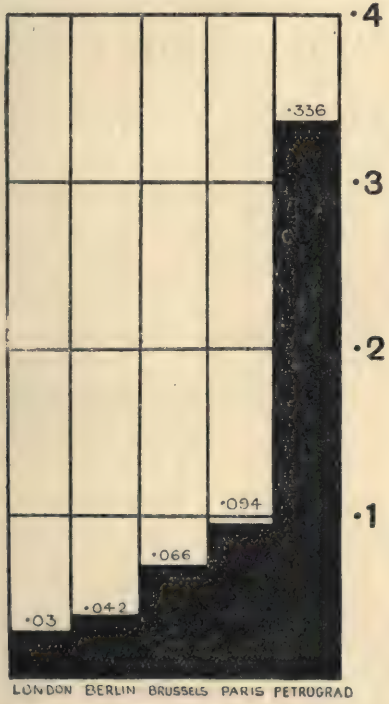


FIG. 23

therefore that not only is there thus afforded a full vindication of the expenditure recommended for improvements in our conservancy methods, but also support for the opinion that that expenditure represents the soundest economic policy.

LECTURES VIII AND IX

WATER AND WATER-SUPPLIES

GENTLEMEN,—There is one subject which has loomed larger in the public mind than any other in relation to preservation of the public health—it is that of water-supply. This prominence is probably due to the fact that, among the three primary needs of man—air, water and food—municipal responsibility has been concerned with water only.

The product of communal responsibility in this matter has been a series of water experts, first the engineers and then the bacteriologists, who are concerned respectively with the quantity and the quality of water supplied. The present excellence of our municipal supplies is due to the work of generations of such experts, comparing results and perfecting their methods by every means which wealthy communities have placed at their disposal. The quality of water, thus safeguarded by all devices which science and accumulated experience can suggest, is kept under constant observation by means of the bacteriological technique of elaborately equipped laboratories. And, finally, the laboratory findings are again controlled by careful study of statistical returns of sickness for fixed populations, by which means high incidence of water-borne diseases leads to immediate investigation and prompt remedial action if required.

The contrast which faces the force which passes from the security of this organization into war conditions at the front might be laboured point by point, but is perhaps more forcibly emphasised by illustration.

There rises from memory the picture of a small Boer farm lying at the bottom of a huge basin which stretches to the horizon unbroken by another building, tree, or sign of animal life. The only water sources in this expanse are the shallow well and the pond which supply the farm. A division of our army has just passed on, leaving the well dry and the little remaining water in the pond so fouled by the watering of a huge herd of transport animals that it clogs the filter candles before a pint has passed through them. Every fragment of wood that could be torn from post and fitting and roof has been carried off. The field hospital remains behind with its 120 wounded men, who must be fed, and whose wounds must be dressed.

Or again—on the verge of the Great Sahara Desert there is a surface pool which affords the only source of supply on an otherwise waterless march of thirty-eight miles. The water in the pool is covered by a green scum, which is so offensive that even the horses, thirsty as they are, turn away from it in disgust. By some means this water must be rendered potable, and the means must be provided by such apparatus as the party can carry with them on their long journey.

In the face of problems such as these it is unnecessary to labour minutiæ of detailed comparison, and we may pass on to consider the means whereby this apparently impossible task may be accomplished—which affords us our topic for to-day.

Before discussing in detail the various methods at our disposal, it is advisable to note a few points regarding the amounts of water required in the field and the examination of water sources *re* their yield and liability of contamination. As these are matters the full consideration of which is beyond the scope of these lectures, all that can be attempted is to include some odd notes of special use or interest.

1. The water requirements of a military force

(*a*) Each man requires daily the following amounts:

In barracks	20 gallons
In standing camps, when clothing is washed	5 ,,
In camps, when no clothing is washed	3 ,,
In bivouacs, for drinking and cooking only	1 gallon
For drinking only, as a minimum.	3 pints

(*b*) The daily requirements for animals are:

Horse or camel	10 gallons
Ox	8 ,,
Mule	6 ,,
Donkey	5 ,,
Sheep or pig	2 ,,

2. Methods of estimating the yield of water

(*a*) *From wells.* By pumping, the water-level should be rapidly lowered by a measured depth. The time occupied by the well in refilling to the original level should be noted. The area of the well is obtained by taking ¾ (or more precisely .785) of the square of the diameter, which multiplied by the depth refilled gives the cubic capacity of the space refilled. The number of cubic feet multiplied by 6¼ (or more precisely 6.23) gives the number of gallons yielded in the noted time of refilling.

(*b*) *From streams.* The mean velocity of the stream is arrived at by taking four-fifths of the surface velocity as measured by the time a floating stick takes to traverse a measured length. The sectional area is obtained by taking the average depth, as determined by several measurements on a given section.

The number of cubic feet of water passing this sectional area in a given time is thus obtained and converted by the above factor into terms of gallons.

3. The best sites for sinking trial borings for water

In hilly districts the most promising site is the base of the steeper side of a deep valley, just below a point at which the valley bifurcates.

The most likely situations in a plain are :

The lowest depression.

The points where vegetation is greenest ; the morning mist hangs longest ; the midges are most numerous.

4. Examination of water sources

(*a*) *Wells.* The old division of wells into shallow and deep, in relation to some arbitrary standard of depth, which was supposed to afford an indication of the probable purity of the water, has been abandoned. The essential point is whether or not a well pierces an impermeable stratum, and this should always be inquired into. Next the well itself is examined as to whether it is fully protected, by being :

(1) Wet-steined, *i.e.* lined by stone, or brick, set in cement.

(2) Covered by a dust-and-water-proof cover.

(3) Provided with a coping, to prevent surface washings flowing into the interior without filtration.

(4) Fitted with a pump, which obviates the dangers of filth being carried into the contents by rope and bucket, unless they be worked by a Persian wheel.

(5) Of sufficient depth to ensure efficient filtration of the water, which in this case can only enter it from below.

The next step is to ascertain if there be any source of probable contamination within the danger zone, the extent of which is estimated by certain arbitrary standards. Sometimes the area is regarded as that lying within a circle whose centre is the well-mouth, and whose radius is an absolute minimum of thirty feet. Or the radius may be taken as four times the depth of the well. As the subsoil water-level becomes parabolic when the level of water in the well is much depressed, a more reliable datum for the radius is that of 150 times the depression of the well contents produced in an hour by vigorous pumping. All these figures must obviously be taken in conjunction with the ground slope, the direction of flow of subsoil water, and the porosity of the soil.

(*b*) *Springs*. The important distinction between springs is that of whether they are land or main springs. The former are derived from water percolating through superficial pervious strata and reaching the ground surface by flowing above the highest impermeable stratum. They are almost always intermittent, and the water is to be regarded with suspicion qualified by the extent of the zone around them which is free from contamination. The latter are derived from underground reservoirs in water-bearing strata lying between two impermeable strata. The water reaches this interspace at a distance, and thus is usually efficiently filtered by the time it escapes from a hillside. Owing to the large bulk of water in these underground reservoirs, main springs usually give a continuous flow. It is important to note that if the water-bearing stratum be of chalk or limestone it is liable to be fissured, and thus the length of percolation affords an unreliable criterion as to the probable purity of the water yielded.

(c) *Streams.* Streams must be regarded as not only liable to contamination in ways common to all other surface waters, but also by deliberate use of them as means of sewage disposal from habitations on their banks. This sewage is disposed of by sedimentation and oxidation, but no authority can be found to state a distance of flow within which these agencies will render polluted water potable, seeing how variable are the important factors of the ratio of sewage to flow and the degree of effective oxidation. No stream can therefore be regarded as a safe source of supply unless it has been examined throughout its whole length. An Indian experience illustrates this point. One remembers standing on a Himalayan slope from which a clear mountain stream could apparently be followed by the eye in its whole course from the hill crest down a kloof in which no sign of human life was apparent. The next turn in the road showed it emerging from the dhobie-ghat in which was washed the foul linen from a large hill station notorious for its enteric prevalence.

5. Examination of waters

(a) Inspection

The appearance and taste of waters afford no warning of contamination: in fact, up to a certain high degree of organic pollution, the more contaminated the water the more attractive are its physical qualities. This is so important a point, and one which it is so difficult to get the men to realize, that illustrations are most useful to medical officers whose duty it is to instruct all water-duty personnel.

One illustration drawn from experience of rural conditions is that of a gaffer, lauding his well as giving "Powerful good water; the best in four parishes"; pointing with pride to the health of the villagers; holding up a tumbler of the water to demonstrate its exceptional qualities. Inquiry, however, elicited the fact that in rainy weather this "powerful good water" gave "a bit of a niff" when boiled. The unsteined, shallow well stood beside a high wall, on the other side of which, and not six feet from the well, was a cess-pit so leaky that it had not been emptied for certainly two years. This experience illustrates many interesting points which cannot now be discussed.

The classical illustration of the lack of relation between the physical properties of water and its dangerous pollution is that afforded by the incident of the Broad Street pump. This pump had so great a reputation as to its water that a lady who removed from its neighbourhood to Hampstead, sent daily to get a supply from the old source. A sailor in a house near by was attacked by cholera, and his infective dejecta leaked from a cess-pit into the well. There was an epidemic of cholera in the neighbourhood, the outbreak being confined to the users of the well. The only house elsewhere which contributed cholera cases to the epidemic was that of the lady in Hampstead: she and her daughter died, and the maid who fetched the pump water only recovered after a severe attack.

Mere inspection of water being thus obviously of no value, we must turn to other methods of examination.

(b) Bacterial Examination

(1) *Motor laboratories.* It is obvious that it is difficult in the field to undertake a full bacterial examination with the object of isolating pure *B. Coli* (Escherich). That difficulty has been met to a certain extent by the provision, during the present war, of motor laboratories fully equipped for carrying out the usual chemical and bacterial technique. These mobile laboratories are interesting if only for their novelty and the successful negotiation of the practical difficulty of getting so large an amount of apparatus and material into one vehicle. They can, however, only deal with a fraction of the needs of a large force, and the question arises as to whether, in the absence of means to conduct complete examinations on a very large scale, valuable information may not be obtained by a modified investigation which can be carried out with much smaller apparatus.

(2) *Portable boxes for bacterial examination of water.* A box has been devised which enables the total organisms and the minimum amount containing lactose-fractors to be estimated for sixteen waters sampled at the well-mouth in a day's round. Eight test-tubes are provided for each water—one of agar for the total count, and seven of McConkey's taurocholate-lactose-litmus broth for the lactose-

fractor estimation on amounts ranging from $\frac{1}{2}$ to 20 c.c. and totalling 50 c.c. The sampling cabinet is complete for work at the well-mouth, to which it can be carried by hand, and is enclosed in a double casing of tins which provide the necessary incubator and sterilizer. All accessories and materials for examination of some 500 samples are carried in another box. The total weight is little over 1 cwt. Examination of sixteen waters a day may be carried out continuously. The details of working need not be described here, but it is instructive to consider the value of the indications which may be thus obtained and form a conclusion as to whether that value justifies the additional equipment required.

The following Table embodies the results obtained by using this apparatus for the examination of 290 waters, from which upwards of 2500 tubes of media were seeded. The various water sources were classified according to the conclusion formed on simple inspection, and for this purpose the wells were divided into three groups :

First class. Those fully protected.

Second class. Those imperfectly protected but having no source of pollution within the danger zone.

Third class. Those which were imperfectly protected and had a source of pollution within the danger zone.

The bacterial findings of waters from sources in these different classes were averaged, and the following Table gives those averages in round figures, which are in no case different from the actuals by more than 4 per cent.

This investigation was conducted with two objects—to estimate the total bacterial impurity by means of the total count, and, by means of the lactose-fractor datum, to enable an opinion to be formed as to the probability of that total impurity being due in part to organisms derived from a potentially dangerous source. Although the presence of lactose fractors has not the full significance of the presence of true *B. Coli*, it must

BACTERIOLOGICAL EXAMINATION OF WELL WATERS IN RURAL DISTRICTS

CLASS		TOTAL ORGANISMS	LEAST AMOUNT CONTAINING LACTOSE FRACTORS
SPRINGS	1	50 PER C.C.	39 C.C.
	2	100 " "	9 "
WELLS	1	25 " "	50 "
	2	70 " "	5 "
	3	140 " "	2·5 "

FIG. 24

have a very distinct value—if only the negative one that is afforded by the fact that if there be no lactose fractor present there can be no *B. Coli*. As, however, the tendency of recent research is to reduce the tests for excretal *B. Coli* to the reactions of fermentation of lactose in the presence of bile-salt and the production of indol, the most recent improvements in tests for the latter enable that control to be simply carried out with this method. The important points which are indicated by this Table are:

(1) There is a general agreement between the

indications afforded by these findings, and the opinion formed by inspection as to the relative safeties of these water sources.

(2) The well data not only show a striking difference between the safe and the unsafe sources, but a very marked difference between the doubtful and the dangerous sources, as classified on inspection.

Of fifty-three "doubtful" wells, 40 per cent. would be classed as dangerous on the lactose-fractor figure, and in 40 per cent. of these that opinion is confirmed by the total count.

It appears therefore that this method of examination has a very distinct value as soon as average figures for these various classes of supply can be determined. At the least it would enable a definite conclusion to be drawn within twenty-four hours as to which were the worst and the best of various alternative sources of supply. Further, when once the findings from a given source have been recorded, subsequent examinations should indicate whether the bacterial purity were being maintained, and so afford timely warning of any deterioration in the efficiency of protective measures. Such examinations are obviously impracticable in the zone of actual fighting, but they might prove most useful on the lines of communication, in billet towns, and in sanitary districts.

WATER PURIFICATION

Having dealt with the sources and examination of water in the field, we have now to consider the methods of purification which may be adopted in war.

In dealing with various branches of this important subject there are advantages in an initial survey of means which have been discarded in the course of evolution. Much time is wasted—of their own and of other people's—by enthusiastic amateurs who, with much declamation, rediscover methods discarded as useless long since; means not now generally practised may prove of great value to medical officers who may have to improvise under circumstances which place the latest improvements out of reach.

It is regrettable, from the standpoint of a desire for completeness, that it is undesirable at present to publish precise information regarding the practical outcome of experimental work done just before and since the outbreak of this war. Officers who go to the front will find full information at their disposal.

(a) Heat

Sterilization by heat is the earliest, and still one of the most effective, methods of water sterilization.

(1) *Boiling*. The simplest means is that of boiling water in the Flanders kettles supplied to units for cooking purposes. The contents of the kettles at one boiling suffice to fill the water-bottles. The procedure adopted is that overnight the water is heated to boiling-point and then poured through funnels into the water-bottles, which are thus sterilized. When the bottles have been filled, a second boiling provides enough to fill the water-carts. In the morning the unit is ready to move off with all bottles full and the carts containing a refill for the bottles, the whole water being cool and sterile. If preferred, the water may be made into weak tea, which is a better thirst-quencher. Other points have been dealt with under the heading of the needs of the march.

An advance on this primitive method, and one specially applicable to semi-permanent camps, is that of providing fixed apparatus, consisting of both boiling and cooling tanks. These should be connected by pipes, and the cooler should be covered, so that the sterilized water is not exposed to risk of contamination by conveyance in buckets or by the settling of dust on the surface. One has seen a camp provided with such an installation, but, the coolers having been left uncovered while the transport mules passed, the history of the regiment could have been written on the dust covering the surface of water which had just been so carefully sterilized.

The practical difficulty is that of obtaining sufficient fuel, and when one has seen men carry railway sleepers on their shoulders during the whole length of a twelve-mile march, in order to ensure getting a fire at night, the extent of this difficulty is realized. This method, like that of chemical purification, leaves unaffected the particles of sand and mica which are so potent factors in causing irritative diarrhœa in the field.

(2) *Heat-exchange.* The most economical means of sterilization by heat is some form of "heat-exchange" apparatus in which the outgoing hot water is made to impart its heat to the incoming stream. Sterile water is thus rapidly obtained at a temperature only 10° or 12° above that of the source, while the greater part of the heat given off in cooling is taken up by the current of supply, thus economizing both time and fuel.

The general construction of such apparatus is shown in Fig. 25, in which the degree of heat of the circulating water is indicated by the depth of shading, and the direction of flow by arrows. An oil lamp is used to heat the sterilizing chamber, in which the temperature of the contained water rises to between 80° and 90° C. The exit from this chamber is guarded by a valve so constructed that it only opens when the desired temperature has been reached, and an automatic control is thus established which prevents the passage of

HEAT EXCHANGE

WATER STERILIZER

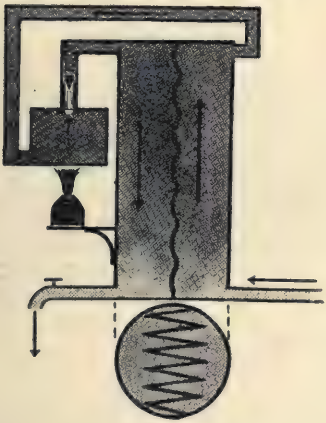


FIG. 25

unsterilized water. This valve action is usually secured by the expansion of a capsule containing some highly expansible fluid. The heat exchange is effected in a cylinder divided by a vertical partition, of thin plicated copper, separating the outgoing hot water from the incoming cold stream. Although excellent in theory, this apparatus presents several defects in practice. The copper diaphragm is most difficult to secure to the sides of the cylinder, and dangerous short-circuiting occurs, which may result in unsterilized water being delivered without this being detectable by other means than bacterial examination. The joint is so extensive and the copper so thin that jolting on rough roads is apt to cause detachment of the diaphragm. The valve is apt to get out of order. The weight, bulk and cost of oil are very considerable. The apparatus is heavy.

(b) Filtration

(1) *Sand.* On turning next to filtration, the first filtering material to be considered is sand. Unfortified sand will allow such organisms as enteric to pass through a depth of 15 ft., and effective filtration is only secured by obtaining a gelatinous layer on the surface, so that the gelatinous material becomes the actual filtering stratum and the sand merely a supporting matrix. Such a layer is provided by either zooglœa, which forms naturally after a due interval for ripening of the filter, or by aluminium-hydroxide thrown down by chemical action. In either case the sand must be purified by washing in sterile water or by heating. Waiting for the zooglœa layer to form involves delay; removal becomes necessary when it gets too thick; and disturbance of its integrity allows organisms to pass freely. Alum is more manageable in that it can be made effective rapidly, but it is more liable to be disturbed by agitation.

For these reasons sand is not used alone and has a very limited applicability. The existing zooglœa on the surface of river beds may be utilized by digging a trench parallel to, and a short distance from, the bank, when well-filtered water percolates from the stream into the trench. One simple method is that of placing a cylinder in a barrel, partly filling both with sand, and precipitating aluminium oxyhydrate upon the surface of sand in the cylinder. If water be carefully siphoned into the cylinder, so that the gelatinous

METHOD OF TAKING WATER
FOR ALUM & SAND FILTRATION

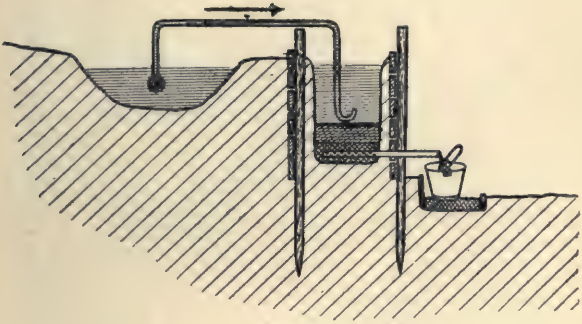


FIG. 26

layer be not disturbed, the water filters until it finds its own level in the barrel, whence it can be drawn off.

A more elaborate system on similar lines is shown in Fig. 26. A revetment is built parallel to a hill-side contour, so that a deep water-trench is made. This is lined by puddled clay, through which and the retaining wall delivery pipes are thrust into the bottom of the trench. Stones are placed over the ends of the pipes in the trench, then successive layers of smaller stones, gravel and sand are added, and finally a layer of gelatinous aluminium hydroxide is thrown down on to the surface of the sand. It is necessary that water from an adjoining stream should be run in by siphonage—lest the filtering layer be disturbed—and this must be effected by making the trench at a suitable level. The siphon is shown with an up-turned end. Given a sufficient head of pressure, such an installation will yield a free supply of pure water from the pipes, and feeds itself automatically from the stream.

Recently a most ingenious attempt has been made to provide a portable sand and alum filter of a continuous-action, self-cleansing type, which is shown in diagrammatic form in Fig. 27. Water which contains sand and alum enters the top of the filtering chamber and the precipitate falls on to a funnel until a cone is formed. The natural slope causes the surface layer, as it forms on the cone, to slide down into an outer, concentric funnel. From the apex of this outer funnel the surface layer and its entangled impurities fall into a washing chamber fed from the inlet pipe by a small jet of water and provided with an overflow escape. The constant current in this chamber washes the sand, which then falls through the jet—to re-enter the inlet pipe and complete its cycle—while the impurities are carried away and escape through the overflow. Meanwhile water, which has filtered through the stable cone of sand into the inner funnel, passes through a discharge pipe into the storage tank. The points in favour of this apparatus are: It is self-cleansing and continuous in action; practically no sand is lost in the process; the water delivered has been well filtered by passing through the gelatinous layer on the stable cone—sufficient alum being delivered to the incoming water by automatic feed from a mixing chamber on the inlet pipe. Flow is maintained by a pump feed which keeps up pressure in the clamp-lidded

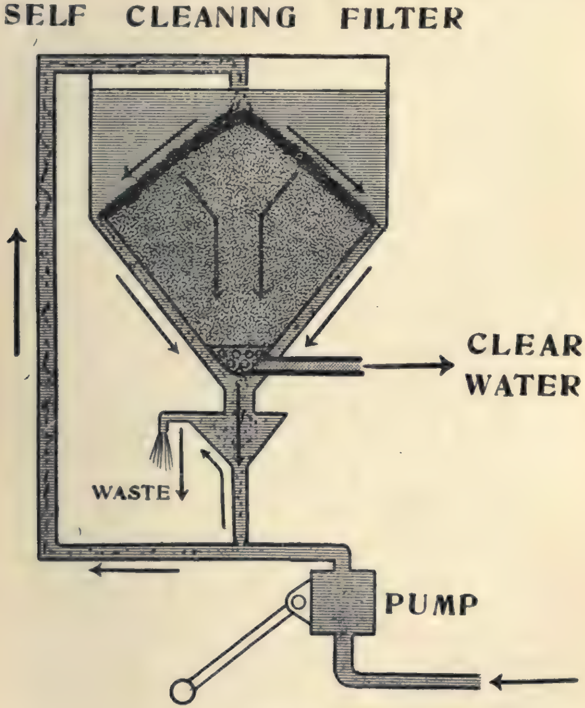


FIG. 27

filtering chamber. It would appear that installations of this type, while not being portable in the usual sense, might be most useful if rapidly pushed up in the wake of an advancing army and worked to supply the returning population in districts where a retreating enemy had destroyed all the existing permanent municipal filtering installations. Its efficiency must depend upon the relation between the amount of added alum ; the thickness of the resulting gelatinous layer ; the pumping pressure ; the rate of delivery. As these factors are mutually interdependent, back to the amount of alum added to the incoming water, a scale could be experimentally established for the alum required for given delivery rates.

(2) *Filter-candles of porous material.* The next filtering material to be considered is infusorial clay moulded into cylinders closed at one end and fixed at the other end to metal delivery nozzles. Each candle is placed in a metal case, through one end of which the nozzle is screwed from the interior, while the other end of the metal case is closed by a screw cap. Into the space between the case and the candle, water is pumped and can only escape by passing through the thickness of the candle to its interior and on through the delivery nozzle. The efficiency of filtration depends upon certain essentials : The candle must be of finely porous material without cracks or flaws ; it must be securely fixed to the metal nozzle—and the great difficulty lies in making at this point a joint which will prevent unfiltered water passing into the delivery nozzle ; the nozzle must screw tightly enough into the end of the metal case to prevent water escaping at this point and running down the outside of the delivery nozzle.

Even when these difficulties have been overcome, others arise. Fine sand or clay will block the filtering pores so rapidly that water can only be forced through in driblets. The candle must therefore be frequently taken out and brushed, which involves risk of its being cracked and so rendered dangerous in proportion as the crack is small enough to escape notice. Organisms which are held up during a short test, gradually grow through the candle interstices. The following average numbers of organisms per c.c. in the filtered water were obtained by leaving a culture in the space between the metal case and the candle, and pumping water through for fifteen minutes on each of four successive mornings, samples being taken at the end of the pumping period each day.

Day	*Organisms per c.c. of filtered water*
1	4
2	25
3	130
4	705

As this practically represents what might happen with a candle not cleaned for four days, it is obvious that the water delivered on the fourth day would be unsafe, and it has been found that if enteric organisms be placed in the interspace they appear in the filtered water after that interval. This makes it necessary that the candles should be sterilized by boiling on every third day—the objections to which, from the practical standpoint, are obvious.

These candles have been fitted to water-carts and used for filtration of water which has undergone preliminary clarification by passage through sponge and asbestos strainers. During the rapid retreat from Mons, over rough cobbled roads, many of the candles were broken or detached, and the units to which they belonged were thus abruptly deprived of all means of water sterilization. The carts were fitted with eight large candles, in two batteries, and gave a delivery of 200 gallons an hour. It is important to note that the two halves of the cart were separated and could be used independently of each other.

Another point worth mentioning is that the water-carts have been found to rattle so much that they drew the enemy's fire and so could not be used to bring water near the trenches at night. This has necessitated the introduction of alternative arrangements in which the sanitary officer is directly interested.

(3) *Norton's tube-well.* This account of filtration methods would be incomplete without reference to Norton's tube-well, which appeals so strongly to the new-comer, and is shown in Fig. 28. It consists of lengths of iron piping, the first having a pointed end which is driven into the ground vertically. Other lengths are then successively screwed on as preceding sections are driven in by a "monkey" arrangement. As soon as water is reached, a pump is screwed on and pure water should be obtained if the depth be sufficient to ensure adequate filtration.

The practical objections are, however, numerous and strong. The depth from which water can be pumped is reduced from the theoretical 30 ft. to some 25 ft. The weight of the whole apparatus is 1400 lb. The normal rate of penetration is only 10 ft. an hour, and moderately hard rock checks it entirely. On the other hand sand is equally objectionable, for it has to be pumped out with the water until a large cavity has been cleared around the end of the tube. The water has thus to be settled for long periods before it can be drunk at all, and even then it contains much fine suspended inorganic matter. In India it was sometimes found necessary to send a strong fatigue out overnight in order to get the apparatus working satisfactorily for the supply of troops on the following day.

(c) Ultra-violet rays

It has been suggested that ultra-violet rays should be used for sterilization of water in the field.

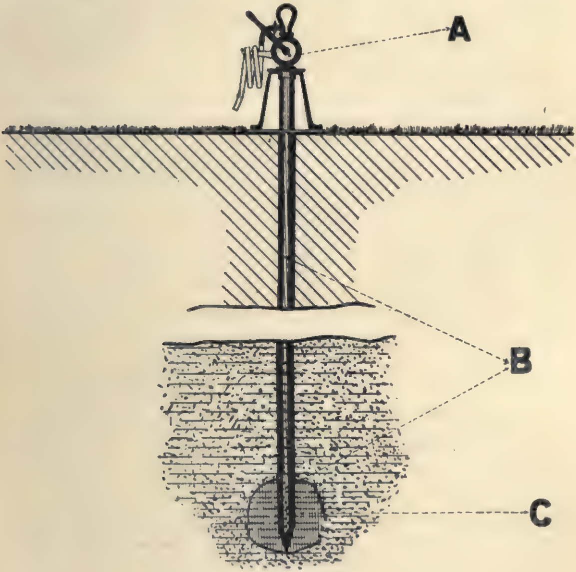


FIG. 28

These rays, passing at the rate of 757 billion per second, have a powerful lethal action on bacteria. They are generated in vacuo by electrolysed mercury vapour at incandescent heat, these conditions being produced by an electric pressure of 200 volts. It is evident that the apparatus is heavy, fragile, and so intricate that it can only be worked by experts. Further, it is found that the bacteria are protected by suspended inorganic particles, and hence good results are only obtainable with quite clear waters. The plant is thus useless for the very classes of water which most need treatment. The suggestion that this apparatus should be supplied for use in the field, and worked by plant similar to that used for skiagraphy, has now been abandoned.

(d) Chemical methods

As these various means of water purification have one by one been tried and found difficult of application or unsatisfactory in results, attention has been more and more directed towards the hope that some chemical method might afford a solution of the problem. The use of chemicals has been directed towards either simple clarification or sterilization.

(1) *Clarification by precipitation.*

Alum is the substance used for the former purpose and clarifies water by forming a gelatinous precipitate of aluminium hydroxide which entangles, and carries down, suspended matter—inorganic and organic, silicates and bacteria.

The most convenient form is potash alum, which —in view of its extensive use—calls for some description. It consists of a mixture of sulphates of aluminium and potassium, with the approximate formula and molecular weights of :

$$Al_2(SO_4)_3,\ K_2SO_4,\ 24H_2O$$
$$343 \quad , \quad 174 \quad , \quad 432 \quad = 949$$

The potassium sulphate and water of crystallization being inert as far as the essential reaction is concerned, the remaining aluminium sulphate forms only 37 per cent. of the total weight.

The aluminium hydroxide which forms has the formula of $Al(OH)_3$ and forms a flocculent, gelatinous precipitate which slowly settles to the bottom of the receptacle. It is soluble in acid solutions and in excess of fixed alkali, both of which facts are of great practical importance. Aluminium salts having an acid reaction—probably due to ionic dissociation—their solutions in neutral water do not allow the hydroxide to form. The addition of alkali is thus required, and various considerations compel us to supply for this purpose a fixed alkali, in excess of which the hydroxide is again dissolved. It is therefore necessary to calculate the relative weights of alum and sodium carbonate which ensure a good precipitate. The reaction and weights are :

$$\underset{343}{Al_2(SO_4)_3} + \underset{318}{3Na_2CO_3} + 3H_2O = 2Al(OH)_3 + 3Na_2SO_4 + 3CO_2$$

It was shown above that it required 949 parts of potash alum to give 343 parts of aluminium sulphate : it therefore follows that sodium carbonate should not be added to potash alum in a much greater proportion than 318 to 949 parts by weight, or roughly one-third. These essentially practical points are demonstrated by adding alum to distilled water, when there is no precipitate ; by then producing a copious precipitate by the further addition of sodium carbonate, and finally redissolving the precipitate by the addition of an excess of sodium carbonate. These chemical facts serve to explain many failures and afford a simple calculation by use of which they may be avoided.

Five grains of potash alum and 1½ grains of sodium carbonate are the amounts needed for a gallon of water—or a heaped tablespoonful of alum per 100 gals.—and the resultant precipitate is allowed to settle without being disturbed by movement. In an hour or two the muddiest water has been clarified and the precipitate and suspended solids have settled to the bottom of the bucket. As very slight agitation reverses the process, the clear supernatant water should be drawn off by siphonage. The use of alum in conjunction with sand has been referred to, but it may also be used with any matrix—such as canvas or cloth—which will support the hydroxide as a continuous layer. By these means the organisms may be reduced by 95 per cent., but this is insufficient when one is dealing with highly polluted waters, and hence this method is regarded as merely a preliminary clarification preparatory to true sterilization.

JAPANESE ISHIJI CLARIFIER

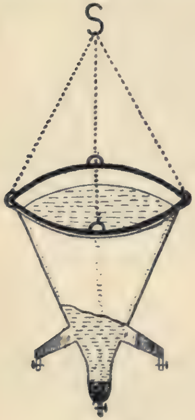


FIG. 29

One simple and effective application of this method is that of the Japanese "Ishiji" filter. which is shown in Fig. 29. The heavier impurities settle to the apex of the cone, whence they are discharged through a scour pipe. A short distance from the apex are hollow radial arms in which are boxes containing a mixture of alum, charcoal, silicon and potassium permanganate. The water is charged with certain of these substances as it percolates through the boxes, and it then deposits hydroxide on sponges through which it subsequently passes to discharge from the ends of the radial arms. The canvas cone is suspended from a wooden tripod and the parts fold together for transport, while the cone can be detached and boiled.

(2) *Chemical Sterilization*

(1) *Permanganate of potash.* Permanganate of potash sterilizes water slowly and feebly by means of the nascent oxygen liberated, to the extent of 15 per cent. of its weight, when the salt is exposed to the action of acid. The reactions and proportionate weights are indicated by the following equation :

$$\underset{632}{4KMnO_4} + \underset{588}{6H_2SO_4} = 2K_2SO_4 + 4MnSO_4 + 6H_2O + 5O_2$$

In order to ensure a sufficiency of acid it should therefore be added in a weight at least equal to that of the permanganate.

The treatment of wells is effected by adding to each gallon of water 60 grains of permanganate ; leaving for twenty-four hours ; pumping until the water is colourless ; removing dead aquatic fauna.

The objections to this method are the cost, colour, taste, and weak lethal action of permanganate on organisms other than cholera vibriones.

The vibrio of cholera is particularly susceptible to the action of oxygen—as is evidenced by the fact that growth of this organism in an atmosphere of oxygen provided the attenuated culture which was formerly used for prophylactic injections—and it is in sterilization of water during cholera epidemics that permanganate has been mostly used.

(2) *Calcium permanganate.* This reagent is interesting from the fact that it has recently been advocated in Germany, .06 gramme per litre of water being used. A tablet of the salt is dissolved in enough water to fill a water-bottle; the solution is thoroughly mixed and allowed to stand for ten minutes; manganous sulphate is then added and the water is filtered free of the resultant precipitate by means of a filter-paper cap placed over the mouth of the bottle. Insoluble calcium sulphate and manganese dioxide are thus formed:

$$Ca(MnO_4)_2 + MnSO_4 = CaSO_4 + 3MnO_2 + O_2$$

The objections to the method are the liability to confusion of the tablets and the need for filter caps which fit the mouths of the water-bottles.

(3) *Sodium bisulphate.* This salt provides a most useful means of sterilizing water by the use of a single tablet. The following reaction shows that, on being dissolved in water, it liberates 40 per cent. of its weight of sulphuric acid:

$$\underset{240}{2NaHSO_4} = Na_2SO_4 + \underset{98}{H_2SO_4}$$

Addition of 2 grammes of the salt to the contents of a water-bottle gives .07 per cent. of free acid, which is sufficient to destroy vegetative organisms in half an hour. The product is rendered palatable by making the tablets up with oil of lemon and saccharin so that the solution resembles lemonade.

Although it is possible that long-continued ingestion of small quantities of free sulphuric acid may be undesirable, on account of the formation of insoluble sulphate of lime in the alimentary tract, this method affords a most valuable means of sterilizing water for troops—such as cavalry—which occasionally find themselves detached from their water-carts, or for units working in detachments too small in number to permit of a bulk-sterilizing apparatus being supplied to them. Each cavalryman should carry a bottle of tablets, and when refilling his water-bottle he should add a couple of tablets to the contents and abstain from drinking until a half-hour has elapsed.

The objection to this method is the liability to formation of soluble sulphates of certain toxic metals from the water-bottles. If aluminium bottles be used, the slight amount of aluminium sulphate formed is of no consequence as it is non-toxic. If iron be used, there is formed a thick brown ferrous sulphate which would prevent the water being drunk. Attempts were made to take advantage of the insolubility of silver and nickel in so dilute an acid by coating the interior of water-bottles with these metals, but it was found that the lining layer was microscopically porous and permitted solution of the underlying stratum. Marked action occurs on alloys known as "nickel silver," "German silver," "white metal," and "Britannia metal," containing copper in an amount (up to 60 per cent.) which leads to as much as 1½ grains being dissolved in twenty-four hours in a single bottle. Although copper is only slightly toxic, it is cumulative, and officers in medical charge of cavalry units should see that aluminium bottles are supplied to their men who use these tablets. The simplest test for copper is that of the bronze colour produced in cupric solutions by addition of potassium ferrocyanide, which will detect minute quantities of the metal.

(4) *Bromine*. There remain for consideration

only the halogens, which provide the most important chemical reagents at our disposal.

Bromine was first used by Schomberg, being supplied in glass capsules containing 2 c.c. Gramme ·06 sterilizes a litre of water, and the bromine was converted into sodium bromide by subsequent addition of thiosulphate. The practical objections to this method are obvious.

(5) *Iodine.* Attention was directed later to iodine, which was liberated by the action of tartaric acid on a mixture of iodide and iodate. The free iodine was removed by thiosulphate, after an interval to permit of sterilization being effected. The reagents were made up in three tablets, and the fact that the tablet bottles were distinguished by different colours led to this device being known as the " red, white, and blue " method. As simpler means of chemical sterilization of water are now available, it is unnecessary to reproduce the somewhat complicated equations showing the exact chemical reactions involved, but it is interesting to record an illustration, afforded during a practical trial of this method, of the undesirability of trusting to individuals the purification of water by any but the simplest means. During the practical trial referred to, the following conversation was overheard : " Now then, Bill, which of these here pills goes in fust." " Lord knows—shove the whole blooming lot in together and have done with it " !

(6) *Chlorine.* The use of chlorine led to various suggestions which have been aptly described as " fantastic." One was the use of metal cylinders of the compressed gas ; another was the liberation of chlorine by free sulphuric acid. Such proposals need but be mentioned to be dismissed as impracticable in the field.

Bleaching-powder

In bleaching-powder, however, Nature has placed at our disposal a simple and invaluable means of sterilizing water on active service. The bulk and weight to be carried are very small in proportion to the amount of water which can be sterilized, and the use of a solid reagent has obvious advantages. It is advisable to discuss in detail the composition and chemical reactions of bleaching-powder, and its practical application to the problem of water-sterilization in the field. A full account cannot now be given of certain developments which have been worked out during the present war: there are imperative reasons for reticence regarding them.

(*a*) *Chemical Composition*

The precise chemical composition of bleaching-powder still remains uncertain, in spite of searching investigations, but it is now generally accepted that the essential ingredient is calcium chloro-hypochlorite, which has the rational formula of CaClO, Cl. The commercial article contains considerable impurities, such as hydroxide, carbonate and chloride of lime, and the amount of those impurities is explained by the process of manufacture. This consists, in brief, in leading chlorine gas into a large leaden chamber provided with an inspection window. On the floor of the chamber slaked lime has been previously raked into furrows so as to expose a large surface to the action of the gas. At the end of twenty-four hours the atmosphere of the chamber loses its greenish colour, showing that nearly all the chlorine has been absorbed. To remove the last trace of free chlorine, before he enters the chamber, the operator discharges from a mechanical distributor a shower of finely powdered lime. This lime absorbs the residual gas and makes entry safe, but the operator—in his own interests—makes sure that it is added in excess. The substance collected on the floor of the chamber constitutes commercial bleaching-powder.

(*b*) *Liberation of Chlorine*

The original conception was that the whole chlorine in bleaching-powder was liberated in a free state by the action of even the weakest acids —such as carbonic acid—thus :

Equation (*a*)

$$CaClO, Cl + H_2CO_3 = CaCO_3 + H_2O + Cl_2$$

(weights) 127 71

It is probable that this view is correct when the powder is exposed to the action of humid air containing carbon dioxide, but a different reaction occurs in solutions, in which chloride and hypochlorite of lime are formed.

$$2CaClO, Cl = CaCl_2 + Ca(ClO)_2 \text{ (hypochlorite).}$$

The hypochlorite is a powerful oxidizing agent, being converted into calcium chloride by the loss of all its oxygen.

$$Ca(ClO)_2 = CaCl_2 + O_2$$

It is thus seen that the actions in air and water are wholly different : in the former the total chlorine and in the latter the total oxygen is given off.

In appears that, in water, the sterilizing power is partly due to toxic action of the hypochlorite and partly to oxidation.

(*c*) *Estimation of the chlorine content.*

As bleaching-powder is originally impure and is, further, liable to lose its chlorine if exposed to air, samples should be examined from time to time to ascertain that they remain effective for the purpose of water-sterilization. The result of chemical examination is expressed in terms of the percentage of chlorine in the powder, although both the analytical methods about to be described actually work out the oxygen content and calculate from it the amount of chlorine present.

The combining weights in equation (*a*) *supra* show that there should be 71 parts of chlorine in 127 parts of pure bleaching-powder—*i.e.* 56 per cent. In the commercial powder, owing to the impurities present, this figure is reduced to between 30 and 35 per cent., but it should not fall below 30 per cent. It is necessary to consider how this proportion can be determined in the field, for which purpose two methods are available.

Penot's method

(1) *Rationale.* Bleaching-powder when dissolved in water breaks up into chloride and hypochlorite of lime.

$$2CaClO, Cl = CaCl_2 + Ca(ClO)_2$$

The hypochlorite yields its oxygen to arsenious anhydride in an alkaline solution, thereby converting the anhydride into arsenic pentoxide.

$$Ca(ClO)_2 + As_2O_3 = CaCl_2 + As_2O_5$$

One molecule of As_2O_3 thus requires for its oxidation the oxygen contained in two molecules of CaClO, Cl, and these two molecules contain four atoms of chlorine.

The process consists in the addition of a solution of a known strength of As_2O_3 to a known weight of bleaching-powder until the whole of the oxygen has been removed from the latter. From the ascertained weight of As_2O_3 required, the chlorine in the known weight of bleaching-powder can be estimated on the above basis of one molecule of As_2O_3 being equivalent to four atoms of chlorine. The weight ratio of chlorine to bleaching-powder is then expressed as a percentage.

(2) *Requirements.*

(i) Standard alkaline arsenite solution.

4·95 grammes of As_2O_3 (arsenious acid or arsenious anhydride) are dissolved in a litre of water, to which 25 grammes of pure sodium carbonate are added. Solution should be effected on a water-bath or by immersing the flask in boiling water.

(A litre = 1·76 pints. A gramme = 15·43 grains.)

(ii) Bleaching-powder solution.

10 grammes of bleaching-powder, from a well-mixed sample, should be mixed with water to make a thin cream and washed into a flask by successive additions of water up to one litre.

(iii) Starch and potassium-iodide papers, kept in a well-stoppered bottle.

If an oxidizing agent be brought into contact with these papers, there follows a liberation of free iodine which forms blue iodide of starch.

$$O_2 + 4KI + 2H_2O = 4KOH + 2I_2$$

(3) *Technique.* Place 10 c.c. of the bleaching-powder solution in a flask and from a burette run in the standard arsenic solution by successive

additions until the mixture fails to strike blue when a drop is placed by a glass rod on a starch and potassium-iodide paper. This shows that all the oxygen has been used up. It is safe to run in 6 or 7 c.c. of the arsenic solution to commence with, but after that the additions should be made a quarter of a cubic centimetre at a time, testing after each addition. If great precision be needed a second estimation should be made, and when the end-point is neared the additions can be made a drop at a time. The amount of arsenical solution used is read off from the burette and, if the above directions have been followed, each cubic centimetre used represents 3·55 per cent. of chlorine in the bleaching-powder examined.

The molecule of As_2O_3 has a combining weight of 198 and is equivalent in this reaction to four atoms of chlorine; therefore one-quarter of this weight is equivalent to one atom of chlorine.

As_2O_3		*Chlorine*
49·5 grammes per litre	=	35·5 grammes
4·95 ,, ,,	=	3·55 ,,
1 c.c.	=	3·55 milligrammes

Ten grammes of bleaching-powder were originally taken and one-hundredth of the total solution was used; therefore there is ·1 gramme in the titration flask or 100 milligrammes.

3·55 milligrammes of chlorine in 100 milligrammes of the bleaching-powder gives the percentage, and about 9 c.c. of arsenical solution should be required to complete the titration.

Thiosulphate method

Although this method is not so exact as Penot's, a comparison of the results obtained by these alternative processes of estimation shows less than

1 per cent. difference, and the method is thus sufficiently exact for our purpose.

The various stages are:

(1) Ten grammes of the bleaching-powder are made into a thin paste and made up to one litre with distilled water. The solution is mixed thoroughly.

(2) One gramme of potassium iodide and some freshly prepared and boiled starch solution are then added. A blue colour develops.

(3) Ten c.c. of the product are added to 10 c.c. of dilute hydrochloric acid.

(4) A solution of 24.8 grammes of sodium thiosulphate in a litre of water is then run in from a burette until the blue colour disappears.

Each cubic centimetre of the thiosulphate solution is equivalent to 3.55 milligrammes of chlorine, and represents 3.55 per cent. of chlorine in the sample.

The rationale of the process is as follows:

The element actually estimated (as in Pinot's method) is the oxygen of the chloro-hypochlorite molecule, and the chlorine in that molecule is calculated from the amount of oxygen.

(*a*) The available oxygen takes hydrogen from the hydrochloric acid to form water, thus liberating free chlorine.

$$CaClO, Cl + 2HCl = CaCl_2 + Cl_2 + H_2O$$

(*b*) The free chlorine liberates free iodine from the potassium iodide.

$$Cl_2 + 2KI = 2KCl + I_2$$

Free iodine forms blue starch iodide with the starch present.

(*c*) The thiosulphate yields part of its sodium to combine with free iodine and form sodium iodide, while the remainder of the sodium is left as tetra-thionate. When all free iodine has been thus taken up, the starch iodide is attacked and removal of all the iodine from this combination finally discharges the blue colour.

$$I_2 + 2Na_2S_2O_3 = 2NaI + Na_2S_4O_6 \text{ (tetra-thionate)}$$

(*d*) *Practical uses*

To ensure sterilization, it is necessary that one part of available chlorine be introduced into water, by adding the requisite amount of bleaching-powder, and that the chlorine be allowed to act for at least half an hour on the contained organisms. By available chlorine is meant chlorine in excess of the amount which is absorbed by various impurities present in the water. An improved test cabinet has been devised by means of which the amount of bleaching-powder used up by the impurities present in any water sample can be rapidly estimated.

It will prove useful to indicate a simple method of calculation by which the amount of bleaching-powder required to give one part per million of chlorine in a given bulk of water may be determined. For this purpose the contents of an ordinary water-cart, holding 110 gallons, may be taken as an example.

	Powder grammes	2 in 110 gallons
=	Powder grains	30 in 7,700,000 grains
=	Chlorine grains	10 in 7,700,000 grains
=	Chlorine grain	1 in 770,000 grains
=	Chlorine grains	1.3 in 1,000,000 grains
=	parts	1.3 per million.

Factors — One gramme = 15.43 grains
— One gallon = 70,000 grains

The addition of two grammes of bleaching-powder thus give one and a third part of chlorine per million parts of water in a water-cart, but in practical working this is called one part per million so that deterioration of the quality of the powder is provided against.

The means of calculating the amount of water in a well is given in a previous section, and it may be stated here that one pound of bleaching-powder is sufficient to give one part per million of chlorine in 33,000 gallons of water.

No more than this may be said at present regarding our methods of water purification in the field.

GEOLOGICAL FORMATIONS IN RELATION TO THE WATER-SUPPLIES OF NORTH-EAST FRANCE AND BELGIUM

It is advisable to include in this lecture a short account of the geological formations in the zone of operations and to consider their bearing upon the question of water-supplies.

The most striking geological feature is provided by the position of the great chalk belt. From Paris to Compiègne the chalk lies at so great a depth below the surface that it is only reached by the deepest valleys; between Compiègne and Douai it forms the main mass of large ranges of hills, either reaching the surface or being thinly covered by tertiary deposits; in Belgium it again recedes from the surface and gradually falls to below sea-level. The position of the chalk therefore makes it necessary to describe separately three distinct areas, while to the east yet another different formation calls for special attention. The boundaries of these different areas are indicated in

Fig. 30 and lettered A, B, C and D, while the general arrangement of the geological strata in the first three of these areas is diagrammatically shown

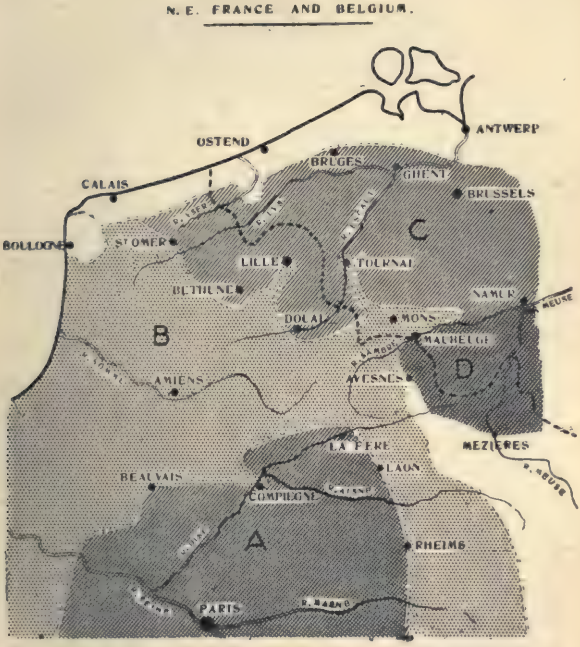


FIG. 30

in Fig. 31. It is therefore only necessary to add here certain notes on the yield and quality of water obtainable from various sources.

Area A. The limestone is fissured, and in some instances the fissures have been so enlarged by the solvent action of percolating water that they allow large quantities to pass without filtration. What, therefore, appears to be a main spring emerging from a hill-side may be merely foul water escaping freely through the fissures from a heavily contaminated area at a higher level.

Wells sunk in the sand-layers give a free and often a pure supply, but the water is apt to be objectionable on account of fossilized remains and iron, which impart an odour and colour to it.

Area B. The gravel and sands on the hill-crests often contain considerable amounts of water, held up by cups in the underlying clay. Wells may be sunk in areas free from any contaminating source. They should be placed at the centre of the underlying clay cup, as determined by probing or trial bore-holes, but care should be taken not to penetrate the clay and so make a way for the water to drain off through the chalk beneath.

The chalk yields generally a pure but hard water. The softer the chalk the less the yield. The yield further depends upon whether the well is above or below the level of the nearest river and upon the parabolic curve of the water-level.

The chalk is extensively fissured, and allows water to percolate so freely through it that most of the high valleys are waterless. It is thus useless to bore for water on the sides of the higher chalk hills. If, however, a valley be found with a spring emerging from its side, it is probable that a free supply is there obtainable.

Lower on the slopes of the hills are gravel terraces. These are usually covered by light soil, farmed and heavily manured. Owing to their great porosity, wells sunk in these terraces drain very large areas, and the practice of manuring indicates an obvious danger.

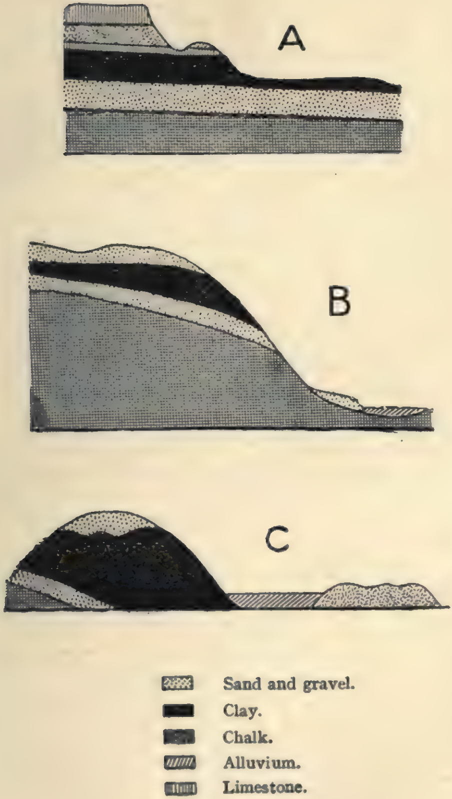


FIG. 31

The valleys in the lower levels contain alluvial flats, which will be dealt with in the next section.

Area C. The superficial layer consists mostly of sand. On the few and low hills there occurs a certain amount of sandstone, which generally affords a free and pure supply of water.

Towards the north the country becomes quite flat and the surface consists of alluvium formed by deposition of sand, gravel, clay, silt, and peat in alternating layers. These alluvial flats are below flood-level but slightly above the level of water in the rivers, dykes, and canals. The subsoil water is not far below the surface, and the absolutely flat nature of the country enables the direction of the subsoil flow to be accurately determined from the various water-levels. The water is not only apt to be heavily polluted by sewage but may be offensive as a result of decay of vegetable matter in the alluvium. Although a very free supply can be obtained at the level of the dyke water, it is unsafe for drinking without treatment.

Towards the coast the surface is formed of sand-dunes, which may rise to a height of 100 ft. or more. Fresh water is often to be obtained in the hollows of this blown sand. If wells be sunk, their yield may be increased by constructing radial feeding trenches leading to the well and filled with stones before being covered in.

Area D. This is a mountainous area in the Ardennes, bounded on the north by Maubeuge, Namur and Liège, and reaching to Mezières on the south. Here the geological formation consists of highly inclined strata of limestone and chalk which yield a very free supply of pure water. When hostilities commenced, a large scheme was in process of execution whereby large districts in the south and west of Belgium, including Brussels, Ghent, Bruges and Ostend, were to be provided with water from extensive intakes in this area. The main aqueduct was partially completed, and the various large towns which expected to be supplied had naturally spent no money for a considerable time in improving existing supplies which were so soon to be superseded. The aqueduct will be destroyed by the retreating enemy and the out-of-date and unsatisfactory existing conditions will have to be faced when Belgium is reoccupied by the Allies.

Notes on existing supplies in North-East France and Belgium

(*a*) *North-East France.* The municipal supplies are mostly obtained from deep borings in the chalk or by shallower wells tapping the overlying gravel and sand. The water is thus generally of good quality, although hard, and the amounts supplied daily per head vary between 20 and 32 gallons. In some instances the less wealthy communities derive their supply from river-water, so as to avoid the cost of pumping. The river-water is highly polluted and purification is necessary.

Many of the smaller towns have no public supply and depend upon private wells. The danger of this source has been dealt with in the description of municipal conservancy in a previous section. The wells are unsteined and closely adjoin leaking cess-pits. These conditions afford sanitary officers constant anxiety in the small billet towns.

(*b*) *Belgium.* Pending completion of the scheme already mentioned, many of the large towns are supplied from foul wells or sewaged rivers, while the reservoir capacity is quite inadequate.

In few towns does the daily supply exceed

20 gallons per head. At Antwerp, for example, the intake is from the tidal waters of the Scheldt, which receives large amounts of sewage from towns along its course. In order to avoid the water being brackish, the intake is limited to half an hour at dead low tide when the pollution is at its worst. The water is settled and chlorinated, but the reservoir accommodation is inconsiderable.

At Bruges and Ghent there is an accessory supply from rivers and the water is purified by chlorination.

It is evident that the advance of our forces into Belgium will bring us face to face with a water problem of the utmost difficulty, and one which will tax to the utmost the ingenuity and resource of our sanitary officers.

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