

THE CAUSES AND PREVENTION OF TRENCH FOOT.

By BASIL HUGHES, M.B., F.R.C.S.,
CAPTAIN R.A.M.C.(T.F.).

THE pathologic condition which has been called "trench foot" has given rise to considerable discussion, and from time to time articles by different observers have been published in which various suggestions for its treatment have been made.

The importance of the discovery of the true cause of this condition can hardly be exaggerated, whether it be regarded from the point of view of the internal economy of the service, or that of the permanent disability that may result to the men so attacked.

Despite the conscientious following out of treatment recommended, numerous cases continue to occur, and, in consequence, much thought was given to the condition in the hope that the true cause might be found.

From October to the end of December, 1915, I was attached to a regiment which was holding a section of the line where the conditions were extremely bad. During August and September and July I had been attached to other regiments in the same salient, but the conditions during these three months were not comparable to those obtaining from the latter part of October to the end of December. During the earlier months the dug-out accommodation was good, and men could lie down during the day time; but during the later period many of the dug-outs had either fallen in or had been blown in, the parapet in other places had fallen in owing to the wet, and owing to difficulty in finding suitable soil it was not always possible to repair it. The men, therefore, during the day were unable to move about, and either had to stand or crouch until nightfall. At night they usually slept in a sitting position, when they slept at all.

The first case of trench foot I saw in October was that of a bomber who had been on duty through the night in a wet sap; and the next three or four cases were also of bombers who had been on duty in this sap, and the succeeding cases were sentries who had been in and about the entrance to this sap.

In all these cases the history was identical. The man had felt little inconvenience, except that the feet felt like "pins and needles," and had "gone to sleep." There was time and opportunity for one man at a time to sit down and get his feet up, but this particular sap was in such a bad condition that the one man who could sit could not get his legs up.

On coming off duty in the morning they were able to take their boots off, rub their feet, and turn in to a dug-out. In some of the dug-outs they could lie at full length, in others they were semi-recumbent. During their sleep, despite the fact that their puttees were off, their socks changed, and bootlaces slack, the feet swelled, became red and tender, and the circulation in them was sluggish. The oedema was soft and pitted on pressure. On putting their boots on again these men were unable to walk.

Another class of case I saw was in men who had been on sentry-go. They felt pain in and under the great toe; it spread rapidly to the heel and then along the outer border of the foot. This pain frequently came on during the resting period. Examination showed that the feet in the parts mentioned were red, tender, hot, and to some extent swollen; the condition resembled more the beginning of an acute inflammation than in the preceding cases.

Stage I.—The two above mentioned types of cases were seen in men who reported their condition early and may be called Stage I. It would seem that the exudation causing the oedema in the foot takes place first of all deep to the plantar fascia and extends to the dorsum of the foot, for the same reason that an inflammatory exudation deep to the plantar or palmar fascia usually manifests itself in oedema of the dorsal surfaces. The soles of the feet were very tender to deep pressure.

Stage II.—Men who did not report early, but persevered in treating themselves, and at the same time tried to do their share of duty in the trenches, presented a condition of the feet which differed materially from the stage already described. These men invariably reported twenty-four hours after the first stage had set in. Almost without

exception they told of the rapid onset of the initial swelling of their feet during the resting period, and that while on duty prior to their feet swelling they had noticed no inconvenience beyond some numbness and "pins and needles." The foot was swollen and cold, and the condition sometimes, though rarely, extended to the ankle and slightly above it. Pain was never a marked feature; loss of sensation seemed to take its place. The oedema was of quite a different kind, there was no pitting on pressure, and the feel imparted to the hand was that of a solid rubber ball. Circulation as tested peripherally was extremely sluggish, and in places about the toes it was questionable if it existed, but doubtless it did. This condition might be called Stage II.

Stage III.—The last and final stage is that in which gangrene supervenes. Fortunately, I met with no such cases in my own regiment, though I saw cases of this sort that had reached the hospitals in England late in 1914 and early in 1915.

After the occurrence of the first of my cases I went to the sap from which they had come. I examined the boots, socks, and feet of the men, the adjustment of their puttees, and was soon convinced that the rubbing of the feet was being most conscientiously seen to. The boots were letting in the thick soupy mud over the tops, and in some cases the fact that the tongue of the boot had not been stitched sufficiently high up made the letting in of this liquid mud the more easy. The socks were being frequently changed. In most cases two pairs were being worn, and the boots issued were a size larger than were normally required.

The only cause, or exciting cause, that could then be suggested was the soupy mud of the trenches, and its infective nature; it had come in contact with decomposing organic matter, which was present almost everywhere, and could neither be removed nor kept covered for any length of time owing to the enemy's artillery.

I then ascribed the condition to some infective agent, and set to work to examine cases more closely from this point of view. The socks of the men who came down with this condition had a faecal odour resembling that of wounds infected with the gas bacillus, but other men's socks, including my own, had the same odour, though there was no trace of trench foot. The smell was to be ascribed to the multiplication in the socks of organisms which got into the boots with the liquid mud.

Rubber kneec boots were then issued to the men, and attention was paid to the socks being clean and dry. Rubbing the feet was persevered with both with anti-frostbite grease and whale oil. In addition, whenever possible, the men were given exercise. Yet, though the men's feet were saved from coming in contact with this liquid mud, still the incidence of "trench foot" did not abate.

It was at about this time that an article was published in the BRITISH MEDICAL JOURNAL ascribing a microbic cause for "trench feet." Interesting as it was, it was apparent now to me that bacteria were not the cause of the condition, and it was evident that the cause must be looked for in some other direction.

As times were now hard in the trenches, I thought of fatigue and consequent collection of waste products of metabolism in the cellular tissues of the lower extremities. This was very possible under the then existing conditions. It seemed reasonable to suppose that fatigue with stagnation of products of katabolism in the lower extremities might act as a predisposing cause, and cold and wet as the exciting cause. The symptoms and onset seemed to fit with this view, and a scheme on new lines was instituted. Hot soup, made from the bones of the fresh meat issued together with meat-extract cubes and vegetables, was sent up to the men in the trenches each night. The fresh meat was cut off the bones at the transport lines, passed through a mincing machine, and was, with the service biscuit, made up into most appetizing rissoles. These were cooked in the transport lines and sent up to the trenches, where they were heated up by the men in their mess-tins. All suet fat was saved, and this, with flour and raisins bought from the profits of the dry canteen, was made up into plum-duff, which was exceptionally palatable and of high caloric value. On other days, where mutton had been an issue, Irish stew was made, and small suet dumplings included in it. It was served hot to the men in the trenches.

I will not go into the daily menu arranged by the commanding officer for the men, beyond saying that the rations were made most appetizing and were used to the last calorie; nothing was cast aside, the profits of the dry canteen being used to buy vegetables, flour, raisins, etc., by which means every particle of fat was turned to useful purpose. The soup made from the bones, etc., was excellent and was served most nights in the regimental head-quarters mess.

With this feeding the health of the men improved. There was less sickness; in fact, sick parades were for men in the trenches, under the conditions then existing, extraordinarily small, and incidentally the number of cases of trench foot began to fall. At this time an issue of long rubber boots had been made, and the men's feet were protected from trench mud, though not from wet, as socks got wet owing to condensation in the boot. The fact, however, remained that the number of cases of "trench foot," Stage II, fell.

This suggested that by an improvement in the general health of the men, by giving stimulating hot drinks at night with a rum issue at stand-to in the morning, and by the wearing of long rubber boots, we might hope to get rid of the condition entirely.

In this we were again disappointed, for though the number of Stage II cases fell almost to *nil*, yet a number of men paraded with painful swollen feet, that is Stage I, though their number was smaller than formerly. They were sent to hospital, and returned at the end of ten days, only frequently to relapse again. In the end those men who showed tendency to relapse were given employment further back, where they could turn in at nights, and under these conditions the trouble did not seem to recur.

We left that portion of the line at the end of the year, and went to another part where the trenches were in good condition, and were deep, so that men could move about during the day time. The weather, however, was bad, with much snow, frost, and wet.

I was doing my round of the trenches the first night we got in, and incidentally stopped to rest on the fire-step with my legs hanging down. I was surprised to find that at the end of three minutes my feet had "gone to sleep," there was the sensation of pins and needles, and the feet felt numb. Thinking this might be a coincidence, I tried it on two successive occasions, only to find the same thing happened each time. After the third time my feet in the morning were tender, and decidedly swollen, so that I could not get my boots on. I stayed in my dug-out the next day with my legs raised, and had my feet rubbed frequently. At the end of forty-eight hours all swelling and pain had gone. This experience caused me to go round at night and insist that when men were on duty in pairs the man whose turn it was to rest should lie with his feet up on the fire-step. Every man had a blanket; so that each man resting had two, his own and that of his acting partner. By this means every man resting did so with his feet up, and he had his great-coat and two blankets to cover him.

It was a pleasant change to see these men sleeping, and to find that they were warm and comparatively comfortable.

Though the weather we have experienced in the trenches has been most inclement, yet since taking this precaution we have had no cases of trench feet over a period of twelve days in the trenches. This is not a coincidence, I think; the unit which occupied the same trenches before us had several cases.

From the accompanying illustration it will be seen how congestion of the feet may readily be brought about by a man sitting on the fire-step and going to sleep. The sharp edge of the fire-step can exert considerable pressure over the popliteal space, and so impede the return of blood along the popliteal vein, without stopping the flow along the popliteal artery, and the soldier who is not on duty will invariably go to sleep sitting on this step, unless he is watched and warned to the contrary.

From the results and observations in the trenches, I have come to the conclusion that two factors are at work in producing trench foot:

1. A predisposing factor, namely, fatigue.
2. An exciting factor which is purely mechanical, namely, venous stagnation and consequent exudation of material into the tissues of the foot.

The condition may be classed in three stages, as follows:

Stage I, or the stage of congestion, brought about by resting, especially after any exertion or long standing, with the legs down. This is brought on more quickly if fatigue is in any way present, as after long standing while on sentry-go, when the lower extremity contains waste products of katabolism, so facilitating exudation from the capillaries into the connective tissue spaces. It will easily be seen how sitting on a fire-step, with the legs hanging down, would favour this, specially where there is some pressure exerted on the popliteal vein. The symptoms of Stage I have already been alluded to.

Stage II, or the stage of coagulation. Here the exuded material appears to have undergone coagulation. This, again, would be hastened and favoured by the presence of toxic katabolic products in the intercellular tissues. The feel of the foot in this condition, like to that of a solid india-rubber ball, coldness, and loss of sensation, marks some radical change between this stage and Stage I. Further, ordinary rubbing and massage seems to have but little influence on this condition, and electric vibratory massage combined with effleurage seem to be the only agents for removing the exuded material.

Stage III, or the state of gangrene, is brought about by the pressure of this exuded material on arteries and veins. There is thrombosis in the smaller venules, and such would be hastened by the presence of toxic katabolic substances present.

TREATMENT.

The whole plan of treatment aims at prevention. If once the condition has progressed to Stage II, then the case necessarily passes out of the hands of the regimental medical officer, and colleagues further down the line can better speak of the

treatment of the condition than I. The same applies to cases that have progressed to Stage III.

What concerns us who are working in the front line is prevention and the treatment of Stage I, which is the stage of congestion.

Prevention is attained by insisting, whenever possible, that the men while resting should do so with their legs elevated. This cannot too strongly be impressed on officers commanding battalions, the second in command, and especially company and platoon officers. In addition to this, a nightly tour of the trenches, to convince oneself that such recommendations are being carried out, is essential. A daily tour is not necessary from this point of view, as most of the men are sleeping in their dug-outs in the recumbent posture.

One blanket per man should be insisted on, so that the sentry resting at night on the fire-step has two blankets to roll himself in and lie with his feet up on the step.

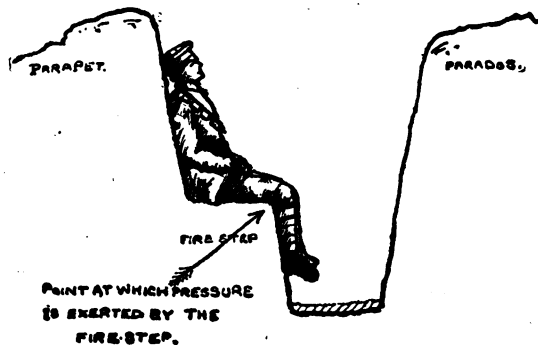
Hot soup and rum ration are, in my opinion, valuable assets for the general vitality in trench life; and other little alterations in the method of serving up the daily ration have already been referred to. Attention to this is all-important in warding off fatigue.

These points seem small and perhaps tending to "spoil the soldier," but, in my experience, they are thoroughly appreciated and call forth better spirit and better work, and have done much to ward off fatigue.

Rubbing of the feet does no harm and may do good, but the good, I think, comes from the fact that the men change their socks after doing it.

Let me here repeat that the main points in prevention are:

1. Keep the feet raised whenever possible so as to prevent stagnation, especially after a period of standing while on sentry-go or in a listening sap.



2. Keep the soldier fit by getting the full calorific equivalent out of his ration, thus keeping the blood pressure up and "warding off fatigue."

If congestion (Stage I) has occurred, I have always detained the men at the regimental aid post for twenty-four to thirty-six hours. If a regimental aid post has not existed in the part of the line to be held I have immediately made one, and have always been supplied with a fatigue by the commanding officer to erect it in minimum time. This dug-out will usually accommodate six to eight men, and timely massage with rest have rendered the men fit to go back to trenches in thirty-six hours. They report each day for three days for further massage, and at the end of this time, with instructions as to the keeping up of their legs whenever possible, I have had no further trouble.

By this means many men were kept in the firing line who would otherwise have been temporarily lost to the unit, and this is a point the importance of which need not be emphasized.

I have to thank my commanding officer for the kind help and co-operation he has shown in this endeavour against "trench foot," and I have every confidence that we shall be able to face another winter campaign with a minimum of men going down with this condition.

The remarks and suggestions made in this paper may not be new to many, but what I have written has been the result of careful and persistent investigation of my own cases, which at first were considerable in number, but which have, I am glad to say, been reduced to nil.

THE EXCYSTATION OF ENTAMOEBIA HISTOLYTICA (TETRAGENA) AS AN INDICATION OF THE VITALITY OF THE CYSTS.

BY

W. J. PENFOLD, M.B., H. M. WOODCOCK,
D.P.H., D.Sc.

(From the Bacteriological Laboratory, the King George
Hospital, Waterloo, S.E.).

AND

A. H. DREW,

BACTERIOLOGIST, ROYAL INSTITUTE OF PUBLIC HEALTH.

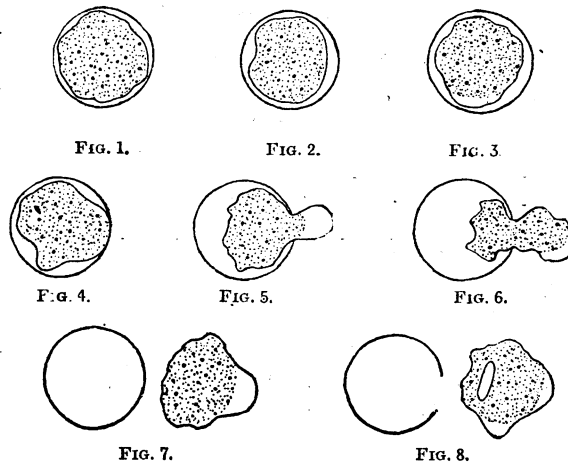
In the course of an experimental investigation undertaken to ascertain the value of emetine as a prophylactic for amoebic dysentery we have found kittens extremely refractory to the cysts of *E. histolytica (tetragena)*—that is, only a very small proportion (one out of twelve, after a three weeks' incubation period) of those fed with faeces containing large numbers of cysts become infected. We were thus led to endeavour to cultivate the Entamoeba from the cysts in order to obtain, if possible, stock cultures of active forms for rectal inoculation. Owing to the fact that we are going abroad very shortly, this work has now to be broken off for the time being. As we have found a method of causing the cysts present in the faeces to excyst and liberate the contained Entamoeba, we think it worth while to indicate briefly the results obtained, since this method furnishes the most reliable, and, indeed, the only conclusive, evidence of the vitality of the cysts. This is a point of the utmost practical importance as bearing upon the duration of life and the infective power of the cysts under varying environmental conditions.

A sample of faeces containing a good infection with cysts is well emulsified with saline (or water) and filtered through three or four layers of fine gauze, to remove the larger faecal particles. The filtrate is then centrifugalized and the deposit washed three or four times, the supernatant liquid, which contains large numbers of bacteria but no cysts, being pipetted off each time. By this means toxic products are removed and the cysts are concentrated in a mass of fine faecal debris. As excysting agents we have tried pepsin, in an acid medium, bile, and pancreatic extract, either alone, consecutively, or together, as appeared indicated, but the only success we have had has been with pancreatic extract used alone. The preparation used is Benger's *liquor pancreaticus*. A mixture is made

up in the following proportions: Nutrient broth 5 parts, liquor pancreaticus 2 (or 3), cyst-containing sediment 1 part. This mixture is then incubated for five to seven hours at 37°C. At the same time a drop of the mixture is placed on a slide, covered, and the cover-slip ringed to prevent evaporation; this is also incubated. This observation-preparation serves as a control to the tube and can be taken out and rapidly examined whenever desired, to ascertain how excystation is progressing; after five or six hours excystation is usually taking place.

Even of cysts in freshly passed faeces, the majority of which appear quite normal, only a small proportion excyst. The first indication of approaching excystation is that the protoplasm becomes very slightly retracted from the cyst-membrane and appears somewhat crinkled (Fig. 1). By careful watching it can be seen that the contour of the body is very slowly changing its shape, that is to say, the Entamoeba is becoming slightly amoeboid (Figs. 2, 3). The nuclei are not visible; it may be pointed out that when the nuclear rings are clearly visible in a fresh *tetragena* cyst, it is a sign that the cyst contents are dead; in this respect the *tetragena* cyst differs from the cyst of *E. coli*. Next, the periphery of the body becomes applied to the thin cyst membrane in the region where the wall is about to be dissolved (Fig. 4). Dissolution of the cyst-membrane takes place over a small area only. It is brought about, we consider, by the action of external influences; for example, the pancreatic juice, probably helped to some extent also by bacterial ferments present in the intestinal contents.

In the next stage (Fig. 5) the Entamoeba is beginning to emerge from the cyst. A small protuberance, often finger-like, is thrust out through the aperture; it may appear clearer than the bulk of the protoplasm, and be mainly ectoplasmic in character. The whole of the protoplasm now gradually flows out of the cyst (Fig. 6); the entire process of emergence may take only about ten minutes, though it may take longer. In every instance which we have observed, the entire protoplasm comes out as a single Entamoeba; there is no indication whatever of division while still inside the cyst. We are strongly of the opinion that this is the normal method of excystation. It may be mentioned that tyrosin was always present to saturation in the liquor pancreaticus which we used, the white deposit which is usually seen at the bottom of a bottle of this preparation (after keeping for a while) consisting of pure tyrosin needles and sheaves which have crystallized out. We are informed by Dr. Maclean that the amount of this amino-acid normally present in the duodenum is not likely to represent a greater concentration than we have



Excystation of *Entamoeba histolytica (tetragena)*; from sketches made at the time of observation. Figs. 1, 2, and 3. Slight amoeboid changes within the cyst. Fig. 3 shows a slight development of ectoplasm (this is unusual, and only seen if excystation is apparently delayed). Figs. 5 and 6. Emergence of the Entamoeba through an aperture in the cyst membrane. Figs. 7 and 8. Two liberated Entamoebae, with their empty cysts (seen in optical section); in the latter figure the aperture in the membrane is in focus, and this Entamoeba possesses a "chromidial block" (the endoplasm is dotted to indicate its finely granular character; the ectoplasm is left clear).