

I have said nothing to indicate that I do not put the highest value on this important function of science, which finds its noblest task in surrendering the richness of its achievements to the use of humanity. But I must ask you to reflect whether the achievement of wealth and power, to the exclusion of higher aims, can lead to more than a superficial prosperity which passes away, because it carries the virus of its own doom within it. Do we not find in the worship of material success the seed of the pernicious ambition which has maddened a nation and plunged Europe into war? Is this contempt for all idealistic purposes not responsible for the mischievous doctrine that the power to possess confers the right to possess, and that possession is desirable in itself without regard to the use which is made of it? I must therefore insist that if we delight in enlisting the wealth accumulated in the earth, and all the power stored in the orbs of heaven, or in the orbits of atomic structure, it should not be because we place material wealth above intellectual enjoyment, but rather because we experience a double pleasure if the efforts of the mind contribute to the welfare of the nation. When Joule taught us to utilise the powers at our disposal to the best advantage he did it not—and his whole life is a proof of it—to increase either his own wealth or that of the nation, but because, brought up in commercial life and deeply imbued with the deep insight and genius of science, he found his greatest delight in that very combination of æsthetic satisfaction and useful achievement which Poincaré has so well described. And again, when another of our fellow-citizens, Henry Wilde, showed how electrical power can be accumulated until it became an efficient instrument for the economic transmission of work, he found his inspiration in the intellectual gratification it gave him, rather than in the expectation of material gain. I am drawing no ring round a privileged class, but urge that the hunger for intellectual enjoyment is universal and everybody should be given the opportunity and leisure of appeasing it. The duty to work, the right to live, and the leisure to think are the three prime necessities of our existence, and when one of them fails we only live an incomplete life.

SCIENCE AND THE STATE.

I should have no difficulty in illustrating by examples, drawn from personal experience, the power which the revelations of science can exert over a community steeped in the petty conflicts of ordinary life; but I must bring these remarks to a conclusion, and content myself with the account of one incident.

An American friend, who possessed a powerful telescope, one night received the visit of an ardent politician. It was the time of a Presidential election, Bryan and Taft being the opposing candidates, and feeling ran high. After looking at clusters of stars and other celestial objects, and having received answers to his various questions the visitor turned to my friend:

"And all these stars I see," he asked, "what space in the heaven do they occupy?"

"About the area of the moon."

"And you tell me that every one of them is a sun like our own?"

"Yes."

"And that each of them may have a number of planets circulating round them like our sun?"

"Yes."

"And that there may be life on each of these planets?"

"We cannot tell that, but it is quite possible that there may be life on many of them."

And after pondering for some time the politician rose and said, "It does not matter after all whether Taft or Bryan gets in."

Happy were the times when it could be said with truth that the strife of politics counted as nothing before the silent display of the heavens. Mightier issues are at stake to-day; in the struggle which convulses the world, all intellectual pursuits are vitally affected, and Science gladly gives all the power she wields to the service of the State. Sorrowfully she covers her face because that power, accumulated through the peaceful efforts of the sons of all nations, was never meant for death and destruction; gladly she helps, because a war wantonly provoked threatens civilisation, and only through victory shall we achieve a peace in which once more Science can hold up her head, proud of her strength to preserve the intellectual freedom which is worth more than material prosperity, to defeat the spirit of evil that destroyed the sense of brotherhood among nations, and to spread the love of truth.

ON THE PATHOLOGY OF TRENCH FROST-BITE.

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THE following investigation was undertaken at the request of the Medical Research Committee (National Health Insurance).

During the winter 1914-15 a large number of soldiers fighting in the trenches in Flanders became disabled from the effects of cold on their feet. The condition is to be distinguished from true frost-bite in which very severe cold causes necrosis of the tissues. In cases of trench frost-bite necrosis may occur, but it is not frequent, and the characteristic symptoms are swelling, pain, and disturbance of sensation in the feet.

A considerable amount of investigation has been carried out on true frost-bite, but less attention has been paid to the effects of moderate cold on the feet of the soldiers in the trenches. Our inquiry consisted of two parts: (1) the observation of the clinical condition of a number of cases which were under treatment in the military hospitals in Edinburgh; and (2) a study of the effect on rabbits' feet of conditions similar to those to which the soldiers were subjected.

In the medical records of modern campaigns, accounts of trench frost-bite are frequently to be found. Larrey's (1812¹) description of the effects of cold in Napoleon's Russian campaign in 1812 shows that he was familiar with the condition. In the history of the Crimean War it is cited that cases occurred when the temperature was above

¹ Larrey: Mémoires de Chirurgie Militaire, 1812, tome iii., p. 60.

freezing point, especially when there was rain and a cold north-east wind with frost at night. Other factors which helped to bring about the condition were lack of opportunity for changing the clothes, tight boots, fatigue, defective nutrition, and diseases such as scurvy or fever. In the later stages of the Crimean campaign conditions were much improved and trench frost-bite became much less frequent and was then usually associated with exposure to extreme cold. Similar cases of frost-bite were described by Davys (1904²) and Powell Connor (1904³) among the members of the British Mission to Thibet in 1903, and again in the Balkans in 1913 by Weiting (1913⁴) and by Page (1914⁵).

In all these campaigns the condition was associated with prolonged exposure of the feet to a moderate degree of cold while at the same time they were immersed in water or mud. That the condition was the result of direct exposure to cold was shown from the fact that the severity of the lesion was determined by the extent to which it had penetrated from the surface. Yet it differed essentially from the frost-bite due to exposure to severe cold; as a rule the parts affected did not after a short time become dead beyond hope of recovery, and the face and hands usually escaped.

Clinical Observations.

We had the opportunity of examining clinically 51 cases of trench frost-bite. In all these cases there was a definite lesion in the feet, and we have had no opportunity of investigating the type of functional disease described by Fearnside and Culpin (1915⁶). In 23 cases the men had had weeks or months of turns in the trenches; in the others they had been exposed one to four times. The duration of the time of the turns varied; in a few cases it was 6 to 11 days, but in the majority it was 48 to 72 hours. The turn in the trenches was followed by a turn in support, and this alternation was usually repeated once, after which the men were sent back to billets for a period of rest. During the period they were in trenches or in support they had no opportunity of removing their boots, and they could attend to their feet only when they reached the billets.

The trenches from which the cases of frost-bite came were wet in all instances except two. To get to the trenches the soldiers had often to wade through water and mud which sometimes reached the waist. Their feet were thus often thoroughly wet before they reached the trenches, and often the weather was wet and cold. The water in the trenches not infrequently contained crystals of ice. In spite of the severity of these conditions the men found it possible to keep their bodies warm; in our series there was only one case of frost-bite of the hand. Fires in the dug-outs were not available for warming the feet. The general result was that the men had to keep standing, more or less stationary, in mud or water at a temperature near freezing point.

There was among the men who had been repeatedly in trenches in these conditions often a history of numbness in the feet in the period before the final disablement. The feet would also show slight swelling, but these symptoms disappeared before the next turn and they were able to go again into the trench. The final breakdown

was probably due to special severity of the conditions on the occasion, for in several cases a number of men from one company or regiment had to report sick on account of their feet at the same time.

Generally, the history of the final breakdown was that on the second day the feet began to feel numb and there was a sense of tightness due to commencing swelling. When the turn was over the men who were suffering had great difficulty in getting out of the trenches. The feet were paralysed and had lost sensation; occasionally, but less frequently, they were painful. In some cases the men could not walk at all, in others they crawled or hopped along till transport was available. The description frequently given by the men was that they felt as if walking on stilts. Swelling appeared in many instances only after the boots had been removed, and sometimes it was not present till the day following. The swelling and numbness were both confined to the feet as a rule. Pain was not a specially prominent symptom at first; it frequently increased in intensity as the swelling and numbness disappeared. Blistering and vesication were sometimes present from the beginning, usually they came on later, and they were absent in many cases. It is impossible to say exactly at what stage the redness and discolouration appeared; the feet were so stained with the mud that this point could not be determined. There was seldom pain above the feet, but in a few cases there were cramps. In one case only was there swelling of the inguinal glands, and in this case there was a septic excoriation of the foot. In two cases only was there serious gangrene of the toes, but in both several toes were lost; both these cases had been exposed to specially severe cold.

As a rule, a fortnight had elapsed before the men reached the hospitals in Edinburgh. During this time the treatment had consisted in rest and the application of dusting powder or of belladonna. The progress towards recovery was in any case slow, and we could form a picture of the earlier stages.

The swelling was present in the toes and extended usually to the metatarsal region, sometimes as far as the ankle but never above the joint. In slight cases there was either no discolouration or only a slight blush over the ends of the toes; the feet were usually warm to the touch. In more severe cases the discolouration was greater, there was more swelling, and the skin, especially on the plantar aspect of the feet, was hard. The increase in colour was due to hæmorrhagic infiltration and was observed specially under the nails. In several cases there was excoriation on the internal aspect of the smaller toes. In one or two cases the whole of the distal part of the foot was black and mummified, and the affected area was defined by a sharp margin. The swelling was in many cases resistant to pressure, more than that of simple œdema. In cases where the skin had become hard it was separating and leaving a layer of normal skin beneath. This separation occurred also in cases of general discolouration and was confined to the skin; sometimes even when a sharp limiting line had appeared the necrosis was still superficial.

During recovery there was sometimes a very troublesome and persistent pain which was described as the feeling associated with recovery from "sleep" in the feet; there was in other

² Davys: Indian Medical Gazette, 1904, vol. xxxix., p. 245.

³ Connor, P.: Ibid., p. 365.

⁴ Weiting: Centralblatt für Chirurgie, 1913, Jahrg. 40, S. 593.

⁵ Page: Brit. Med. Jour., 1914, vol. ii., p. 386.

⁶ Fearnside and Culpin: Brit. Med. Jour., 1915, vol. i., p. 84.

cases a burning pain usually worst at night and interfering with the patient's sleep. Occasionally alternating heat and cold feelings were experienced. The soldiers described their feet as "feeling like logs." There was marked anæsthesia in the area of the toes and extending to a fairly definite line across the mid-metatarsal region. Sometimes this area extended further back on the plantar aspect of the foot; sometimes it was limited to the great or little toes. The zone limiting the anæsthesia was usually paræsthetic, and here deep pressure caused pain in a few cases. Deep pain was also experienced when the man stood on his feet and this might pass up the legs. The plantar reflex was usually exaggerated. There was no evidence that these men had previously been liable to chilblains.

In reference to the possible influence of constriction of the feet, it is important to note that all these men except one had been wearing boots and puttees and that the lesions were entirely confined to the parts encased in boots. The exception was a private in a Highland regiment who wore shoes and gaiters. One of the patients was an artilleryman, and he volunteered the statement that few of the men in this branch of the service suffered from frost-bite; it is probable that not only the better conditions but also the freedom of movement in artillery work accounted for the immunity from frost-bite in the feet.

Experimental Observations.

The experiments were carried out in the cold chamber of the Laboratory of the Royal College of Physicians of Edinburgh, and the requisite degree of cold was obtained by keeping the temperature of the chamber about zero.

The observations were made on rabbits. One of the hind feet was shaved and the animal was then placed in a wide glass cylinder standing on a layer of earth which was kept dry or moist according to requirements. By this means it was found possible to reproduce in the rabbits' feet the œdematous swelling characteristic of trench frost-bite. In the first place, it was found that when the mud was both wet and cold the swelling became marked in from two to three days. On the other hand, when the mud was kept dry the cold had much less effect. Constriction of the limb by means of a band of sticking-plaster increased the tendency to œdema in the feet exposed to cold. This effect was not obtained by a single band, but when the band was taken twice round the limb the cold produced œdema more rapidly.

The effect of applying warm water (at 37°C.) to the foot after it had been exposed to the cold was to increase the œdema very markedly. The swelling was confined to the parts which were directly exposed to the cold; it was less marked in the hind foot which had not been shaved. The animal with a swollen foot could still walk with it, though there was a certain amount of limping. On the other hand, the evidence of anæsthesia in the foot was indefinite. When the rabbit was placed in its cage in the animal house after an experiment the swelling rapidly disappeared and it walked about normally after 24 hours.

The microscopic examination of the tissues showed that the chief effect of the cold was on the blood-vessels. The lumen was dilated and contained a certain amount of fibrin deposit; the endothelium of the intima was swollen; there was vacuolation in the muscle fibres of the media, and there was an

increase in the number of cells in the perivascular tissue. The lymphatic vessels were in some cases normal in appearance; in others they were dilated and filled with masses of fibrin, but as a rule the walls were unaltered. In the tissue spaces there was a copious deposit of fibrin in the form of threads and granules; the collagen bundles of the fibrous tissue were separated and swollen, and in areas where the exudate was abundant they were undergoing solution in it. In certain cases, and especially when the œdema had been present for a longer time, there was a diffuse infiltration of the swollen tissue with leucocytes. In cases where the foot had been subjected to warm water after exposure to cold there was a diffuse infiltration with red corpuscles which here and there amounted to hæmorrhage.

Generally, a few staphylococci were found in the tissues, and in one case streptococci were present. These bacteria had not, however, acted as foci of inflammation; they had come from the skin surface, especially in cases where there were slight abrasions.

The changes in the nerves consisted in œdematous swelling of the axis-cylinders, and this appeared to be merely a part of the general œdema of the feet. There was no sign of degeneration of the myelin in Marchi or Donaggio sections of the nerve or cord. The nerve cells in the cord were normal. The only degenerative change found in these experiments was a very slight blackening of the sheath in a Marchi section of a nerve twig taken from an area that had been frozen with carbonic acid snow. In other words, the severe cold of true frost-bite may cause changes in the nerves, but they are not found in cases of the milder type of trench frost-bite. The œdema noted in the latter condition taken along with the general infiltration would, however, account for the anæsthesia.

The voluntary muscle showed some slight changes; the staining was modified; there was a loss of striation. In cases of longer standing there was some leucocytic infiltration, œdema, and deposit of fibrin between the fibres. Very definite changes of the nature of disintegration and regeneration are seen in the muscle in cases of true frost-bite.

The regional lymph glands were enlarged from dilatation of their sinuses and from hypertrophy of the lymphoid follicles. The sinuses contained a deposit of fibrin threads and granules, and in the meshwork of fibrin were red corpuscles, polymorphs, and proliferated endothelial cells; the endothelial cells were actively phagocytic and contained red corpuscles and polymorphs. There was no evidence of the presence of micrococci. The follicles showed overgrowth of the cells in the germ centres and infiltration with polymorphs and endothelial phagocytes.

We have had no opportunity of examining tissues from the human subject after trench frost-bite, but there is no reason to doubt that the changes in the animal tissues are the same as those in man. The effect is inflammatory and is due to the direct action of the cold on the tissue. The injury to the blood-vessels is the most important element. The walls are so damaged that they are unable to perform their function; an excessive amount of fluid is poured out and accumulated in the tissue. From this fibrin is deposited, and the fibrous elements of the tissue are disintegrated more or less. When there is any congestion of the damaged vessels as may be caused by the application of warmth, the walls rupture and blood corpuscles are poured into

the tissue. Recovery from such a condition is naturally slow. Not only has the swelling to subside, but the damaged vessel wall has to be repaired so that it can bear the strain of normal circulation.

We carried out a few observations on the effect of actually freezing the tissues by the application of carbonic acid snow. Our observations confirm those of previous observers, and show that the slighter stages of injury in true frost-bite are essentially similar to trench frost-bite. In true frost-bite the predominant change is death of the affected part; in trench frost-bite there is little or no necrosis, but an exudative inflammation occurs in the parts directly exposed to the cold.

These experiments throw a considerable amount of light on the clinical phenomena of trench frost-bite. The degree of cold, the increase of effect due to wet earth as compared with dry, the time of exposure (48-72 hours), the localisation of the œdematous swelling in the feet and the effects of constriction are points in which the effects on the rabbits were very similar to the phenomena of trench frost-bite. On the other hand, the swelling in the feet of the rabbits subsided much more rapidly than that in the men's feet, and there was little evidence that the anæsthesia and pain characteristic of the condition in the men were experienced by the rabbits. Finally, the harmful effect of raising the temperature of the feet damaged by cold was clearly demonstrated. The animal's feet were placed in water which was at the beginning of the time at 37° C. and cooled down gradually till it was about 20° C. The result was a marked increase in the œdematous swelling and a considerable amount of hæmorrhagic infiltration. From this it becomes evident that during the period of recovery attention must be concentrated on preventing any strain on the damaged blood-vessels. Anything which causes congestion will have a tendency to increase the injury to the vessel walls already damaged by exposure to cold.

Practical Considerations for Prevention.

The following practical considerations are suggested by the foregoing investigation. The main efforts must be directed towards prevention. As the condition is one of damage to tissues, once it has been established recovery can only take place after a prolonged process of regeneration.

1. The soldiers should practise massage on their feet before going to the trenches. There is some evidence to show that persistent rubbing of the feet beforehand has enabled the men to escape to a considerable extent the effects of exposure to cold.

2. A study of the cases shows that the symptoms begin to be felt, as a rule, after 48 hours' exposure. It is clear, therefore, that to shorten the time in the trenches would be the most essential measure of prevention.

3. While men who have been exposed to the conditions causing frost-bite without having been affected are resting between their turns of trench duty, they should persistently practise massage of their feet twice daily.

4. Careful attention should be given to anything which may constrict the blood-vessels. Constriction by boots and puttees should be avoided. Loose moleskin leggings would probably be found more suitable than puttees, as they would provide warmth without constriction. The advantage of leggings is that they provide the protection of an ample cushion of air and they drain more readily than compact wrappings, the existence of a non-conducting air cushion being thus re-established.

The soldiers wear boots of a large size, but they have a practice of putting on two pairs of socks, and this probably tends to a certain amount of constriction. It was observed that the excoriations were situated on the outer and inner borders of the feet, and this fact suggests that some degree of constriction existed. It is significant that the parts most liable to trench frost-bite are the parts where under ordinary circumstances callosities and corns are most frequent. The question arises whether the upper leather of the boots could be made more pliable without diminishing the stability of the sole or of the boot generally. The soldiers very commonly cover their feet with oil and derive benefit from this. There may be several advantages in this. Among other effects it will act as a bad conductor of heat; it may minimise the effect of the wet; it may keep the leather of the boots more pliable and its application may be the occasion of a thorough massaging of the feet. In order to obtain the full effect the oil should be of high boiling-point and be used in considerable quantity; semi-solid oils such as vaseline would probably give the best results.

5. To maintain the circulation in the feet it would be helpful to increase the clothing of the legs. This might be done by using leggings reaching the thigh or by wearing two pairs of pants.

6. It is found that the onset of the symptoms was gradual as a rule. A soldier would at the end of a turn in the trench suffer from slight swelling. During the resting period he recovered, but on the next occasion the symptoms became so severe that he was disabled. Such cases should be investigated by the medical staff and tested before they are allowed to return to trench duty.

7. The period of commencing recovery. When the condition has become so severe as to disable the soldier he should not be allowed to walk or march more than is absolutely necessary when he leaves the trench. As soon as possible he should be conveyed to a resting-place. In many cases the records tell of disabled men having to walk back to billets some miles behind the line of the trenches. Wherever possible in such circumstances transport should be taken advantage of.

8. When the billets are reached measures should be directed to giving the feet as much rest as possible. The feet should not be warmed in any way that causes congestion, and the return of the normal circulation should be delayed rather than hastened.

We beg to express our thanks to the officers commanding and the members of the medical staff of the military hospitals in Edinburgh for the facilities afforded for the observations on the cases of frost-bite. We have also to thank the Medical Research Committee for meeting the expenses which have been incurred.

Dr. Levi Farndon, whose death occurred on August 27th, was born in June, 1846. He held, in addition to an American medical degree, the diplomas of L.S.A. Lond. and L.R.C.P. Irel., and in the earlier part of his medical career had an extensive practice in London. Later he removed to Maidenhead, where he carried on a general practice for 17 years with energy and generosity. Many of his humbler patients will long remember his kindness.

THE SITE OF ST. GEORGE'S HOSPITAL.—Dr. R. Salusbury Trevor, dean of St. George's Hospital Medical School, has now pointed out publicly that there is no change of site of the hospital in contemplation. There is now every reason to believe that the hospital will remain at Hyde Park Corner for many years to come, and the number of students will increase probably in consequence.