if in any way the food was in fault. My experiment had to be given up in less than three months, as more than half of the twenty cases had by then developed symptoms of the disease. The opinion I then came to was that beri-beri was a place disease, that the soil and buildings were infected, and that people dwelling there were liable to absorb the poison, whatever it was, that this poison absorbed in sufficient quantities was the cause of beri-beri, and this opinion I have never seen reason to change. From that date disinfection has lately been relied on to combat the disease, and I can only regret that the more thorough manner in which we now try to carry it out was not adopted earlier.

An instructive instance of a small epidemic of beri-beri on shipboard came under my notice in 1900, entirely, I think, putting Siam rice out of the question as a cause of beri-beri. A well-found steamer carrying 28 Malay and 51 Chinese hands, sailed from Singapore for New Zealand and Australian ports. All were fed on Siam rice cooked in the same manner and in one galley. When in cold weather near New Zealand, beri-beri broke out in the starboard forecastle inhabited by 14 of the Malays, and in all there were 8 cases and 5 deaths. This forecastle had the galley situated immediately aft with but a thin wooden partition between. The heat from the galley caused the cabin to be always sweating and steamy, as it was somewhat wet from the bad weather experienced at the time; in fact converted it into a perfect incubation chamber. Such a condition has been noted many times as favourable to the spread of the disease. No food was taken to or consumed in the forecastle.

I was consulted by wire as to any precautionary steps that could be taken, and recommended the erection of shelters on deck to accommodate the hands occupying the forecastle, the thorough disinfection of the ship, paying special attention to the starboard forecastle, which should not be used for habitation during the remainder of the voyage, and some ordinary medicinal treatment. On the ship's arrival at Melbourne the 3 sick were sent to hospital, where they recovered; 5 had died, and no further case had occurred, nor did one. Had the rice been in fault it is difficult to understand why the 8 cases occurring should have all been among 14 men occupying one cabin, and that the remaining 65 hands should have entirely escaped.

THE PHYSICAL FACTORS IN PHOTOTHERAPY.

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These investigations have been made with a view to ascertain to what agencies we may attribute any therapeutic effects that the light treatment may produce. To obtain exact experimental data on this subject would place the light treatment in a more satisfactory position, for despite the results recorded the methods may be said to be somewhat empirical.

One of the first questions that arise in considering the effect of the light treatment on any specific disease, such as lupus, is whether the result produced is due to bactericidal power of the light, or to the reaction which it excites in the tissues themselves. In other words, are the tubercle bacilli in lupus destroyed, or at any rate prevented from multiplying, by the direct action of the light, or does the tissue reaction caused by the light set up a condition inimical to the growth of the bacilli?

We have as yet no certain answer to this question. That light, without heat, destroys micro-organisms outside the body is well known, as the results of numerous experiments by many observers, and their results we have verified in the most conclusive way, as will be subsequently shown. But that bacteria lying inside the tissues of the body can be destroyed by the action of light is a matter of considerable doubt. Light is, in the first place, powerless to destroy bacteria in those cases where its rays are made to pass through any organic substance before impinging on the bacteria, even the thinnest film of agar, for instance, serving as a protection. Much less can the bactericidal rays in light penetrate living or dead tissue under the ordinary conditions of experiment. This statement has been proved in the following way:

The light from an automatic arc lamp, that is a lamp in which the carbon electrodes were kept at a suitable distance by means of a clockwork arrangement, was allowed to pass through metal cylinder, through which water continually circulated in order to eliminate heat, and which was closed at each end with a disc of quartz. An agar plate thickly inoculated in the usual way with an active culture of bacillus coli communis was exposed to the light directly after inoculation, and then incubated for twenty-four hours or longer at 37° C. The light was only allowed to fall on a portion of the plate, so that on the other portion, unacted on by the light, the organisms should grow normally and serve as a control. A current was used of 7 ampères at a distance of 10 cm. from the arc. It was found that when exposed for as short a time as eleven seconds, the comparative number of surface colonies was greatly reduced, but that those in the depth were unaffected. The deep colonies were unaffected even after two hours' exposure to the light under the same conditions.

Again a portion of human skin, in one instance the cortical layer, in another the subcutaneous cellular tissue, was placed on the quartz disc of the apparatus before mentioned, covering it entirely. An agar plate on which had been spread, with a sterilized brush, an active culture of bacillus coli communis, was so placed that the light from an arc fell on it after passing through the water-circulating apparatus and the human skin. After two hours' exposure, and whatever the current used, no effect was produced on the bacilli, as on incubating the plate at 37° C. for twenty-four hours, the resulting growth was found to be equally vigorous over the entire surface of the plate. The same experiment was conducted with a living and a dead frog's foot, interposed in the same way as the human skin, and with equally negative results.

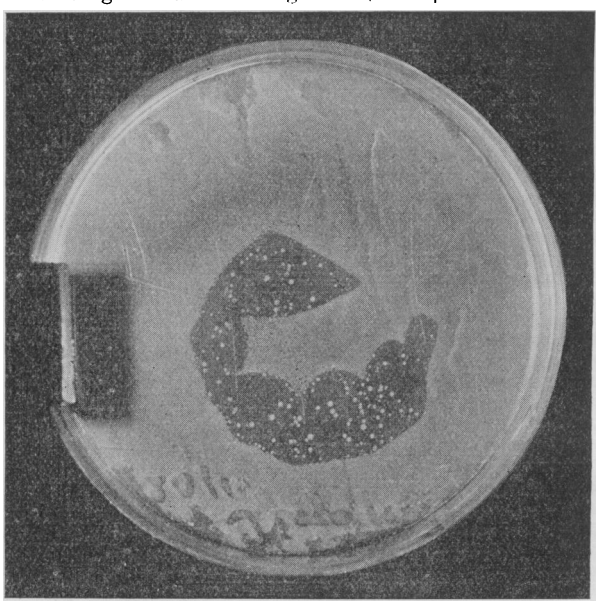

Fig. 1.—Experiment with dead frog's foot.

The light passing at the side of the frog's foot produced the effect reproduced in the figure, namely, a destruction of almost all the surface bacilli, while those protected by the semi-transparent webbing of the foot grew normally. The reason why all the colonies on the surface of the agar are not destroyed even where the unobstructed light falls on them is still undetermined. It is perhaps possible that some few of the organisms, during the process of inoculation, have been introduced under the surface, and not being strictly superficial, are protected by an overlying absorbent film of agar. From these experiments we are therefore led to conclue that, the bactericidal rays being non-penetrative, the therapeutic effects of light may possibly be due to the reaction produced in the tissues by the light rather than to the direct bactericidal action of the rays themselves. Our next object was to differentiate, if possible, between the rays which are bactericidal and the rays which excite a reaction in living tissues.

In this we have up to the present been only partially successful. Whilst we have been able to find in the spectrum the exact position of the bactericidal rays, those causing the reactionary effect on tissue are still unlocalized, at least with any certainty. With the object of determining the most actively bactericidal rays among those produced by a continuous current arc, some superficially inoculated plates were exposed to the spectrum as transmitted by a spectroscope with

quartz lenses and prism. The light was obtained from a hand-fed arc lamp, a lamp in which the distance of the electrodes was adjusted by hand, not by clockwork, and ordinary carbons used. The image of the arc was projected on to the slit of the spectroscope by means of a subsidiary quartz lens of 18 in. focus, thus obtaining the arc spectrum of carbon. The spectroscope was adjusted as for photography, but the spectrum was projected on to a superficially inoculated bacterial plate instead of on to a photographic one.

It was found that the bactericidal effect was entirely confined to the ultra-violet portion, as will be seen from Fig. 2. The line shown at V is where the ultimate edge of the visible violet in the spectrum fell, the red in the spectrum falling at the extreme edge of the plate. The bactericidal lines are seen to begin 2.5 cm. from the edge of the visible violet, and to extend from that point for 1.8 cm. into the ultra-violet. The limit of the ultra-violet, as seen in a photograph, was about 1.5 cm. beyond this. With exposures as long as two hours no effect whatever was obtained in any other portion of the spectrum, even when the slit of the spectroscope was opened to an extent that in photography would have been regarded as inadmissible. The active radiations we have been able to determine, and we find that they lie in that portion of the spectrum between wave-length 3,287 and 2,265. In other words, in about the middle-third of the ultra-violet, as seen in a photograph of the spectrum of carbon. It therefore appears that relatively the action of other portions of the spectrum is negligible compared with the activity of this portion, although it is probable that when using white light there is a slight action which extends over the whole spectrum. Neither the extreme ultra-violet rays nor those nearest to the visible violet appear to be active. The affected portion of the bacterial plates corresponded with a photograph taken of this portion of the spectrum, and it was possible to identify the nearly sterile lines on the plates with those known to exist in the ultra-violet spectrum of carbon.

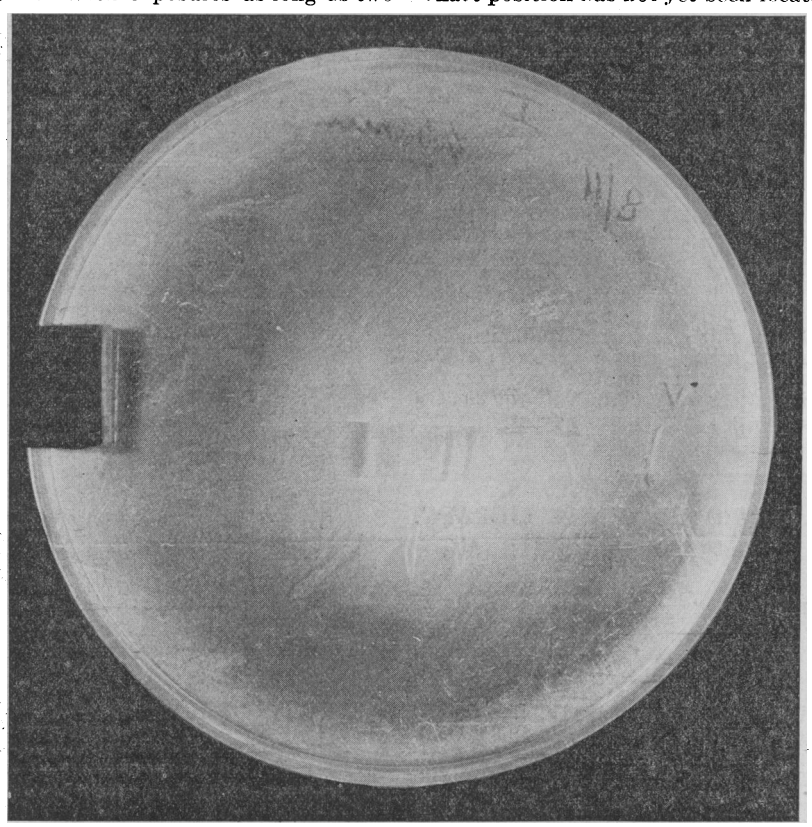

Fig. 2.—Plate showing effect of ultra-violet rays upon growth of bacteria. V, ultimate edge of visible violet rays, to the right of which is the visible spectrum, and to the left the ultra-violet.

Having therefore determined which rays were actively bactericidal, our next object was to discover which rays excite the reaction on the part of the tissues. So far we have not been successful. Making use of the same spectroscopic arrangement as before, we subjected the shaved skin of a rabbit to the spectrum, putting the animal under an anaesthetic to ensure absolute stillness, and placing the shaved skin in the same position as we had formerly placed the bacterial plates. In the same way we made experiments with guinea-pigs, white rats, frogs, and even with the human arm. No effect was produced even after an exposure of two hours and three-quarters, using a current of 25 ampères.

The following experiment seems to show, however, that the rays we are in search of exist somewhere in the ultra-violet region. A rabbit was shaved on both sides of its body, and one side was placed in contact with the quartz disc of the water-circulating apparatus, the light passing through it from an arc lamp to the exposed skin. After five minutes' exposure, using a current of 25 ampères, the other side of the rabbit was exposed, but with the insertion of a sheet of glass between the skin and the water-circulating apparatus. This second exposure lasted an hour, using the same current of 25 ampères. It was found on the following morning (the effects not usually being perceptible until after the lapse of some hours) that on the skin of the rabbit which had been exposed to the light for a whole hour, with the glass interposed, absolutely no effect had been produced, while on the skin subjected for only five minutes to the light without the intervention of glass there was a well-marked redness.

It is a well-known fact that all the rays of the spectrum, with the exception of the greater part of the ultra-violet, readily penetrate glass. The failure, therefore, to affect the skin in the first experiment was due to the fact that the ultra-violet rays had been stopped by the glass, and this appears to point conclusively to the ultra-violet rays as the cause of the reaction that occurs in the tissues. It is thus clearly indicated that these rays, like the bactericidal ones, exist in the ultra-violet region, though, unlike them, their exact position has not yet been located by us.

In view of the results obtained from the experiments with the spectroscope on bacterial culture plates, we were led to experiment with the arc spectra of various metals, such as iron, cadmium, silver, and aluminium. Our results have entirely agreed with those obtained with carbon spectra, except that the action is greater in proportion to the number and intensity of the lines in what we may call the bactericidal origin. It therefore appeared that an electrode composed entirely or partly of iron should be more actively bactericidal than a carbon one, and this we found to be the case. The form of electrode that we found most convenient was that in which, in the case of the positive electrode, the soft carbon core was removed, and in its place was substituted a mixture consisting of the particular metal it was desired to use, with sufficient carbon, in the form of sugar, to prevent the core from dropping out when in use. The negative electrode we left unchanged. The respective electrodes were then fitted into the arc lamp, and the bactericidal power tested on a hanging-drop specimen of bacillus coli communis. The slide on which the hanging drop cover-slip was placed was composed of quartz, so that the ultra-violet rays might be intercepted as little as possible. The hanging drop thus mounted was placed on the water-circulating apparatus, the light from the arc being projected from below upwards on to the hanging drop. It was found that the time required to destroy the bacilli when using these various electrodes in the arc lamp, with in each case a current of 11 ampères, at a distance of 10 cm. from the arc, varied as follows:

Ordinary carbons	30 minutes
Carbons charged with silver	30 ,,
Carbons charged with iron	15 ,,
Carbons charged with cadmium	15 ,,
Carbons charged with aluminium	25 ,,

The method employed to ascertain whether the bacilli were killed or not was to examine the hanging drop from time to time under the microscope, and, on finding that all motility had ceased, to drop the cover-slip, with the hanging-drop on it, into a tube of peptone beef broth. This tube was then incubated at 37° C. for some days to see if any growth

resulted. It will be seen that carbon electrodes charged with iron or cadmium have twice the bactericidal effect of ordinary carbons, and the cadmium electrodes appear to be preferable to the iron ones, as they burn more steadily in the arc lamp. It has been hitherto supposed that the violet and blue rays are of almost equal bactericidal power to the ultra-violet rays, but this does not appear to be the case, as is shown both by the spectroscopic experiments and by the following experiment made on a hanging-drop specimen of bacillus coli communis.

An ordinary glass slide was used, through which the light from the arc was passed after having been cooled by transmission through a water-circulating apparatus. The electrodes used were charged with cadmium. It was found that although the motility of the bacilli was stopped after an exposure of forty-five minutes, they were not killed even after an exposure of one hour and twenty minutes, that is, a period five times longer than was necessary to kill the organisms when a quartz slide was used. The violet and blue rays, therefore, which pass readily through glass, are not bactericidal under these conditions, or only slightly so. The ultra-violet rays, on the other hand, having been to a great extent intercepted by the glass, were unable to exert their bactericidal action.

On comparing the results obtained with hanging-drop specimens, as just described, with those obtained by exposing superficially inoculated agar plates under the same conditions, we found that although it requires half an hour to kill the bacillus coli communis, when exposed to the light in the hanging drop, the same result can be obtained on an agar-plate culture in five minutes. In other words, it takes six times as long to destroy the bacilli when they are suspended in a fluid medium. This fact turned our attention to the following question: What proportion of the bactericidal rays are absorbed by the thickness of the water they have to traverse in the water-circulating apparatus employed?

To determine the influence of this factor, the following experiment was made: The water-circulating apparatus, as already described, consisted of a short brass tube with an inlet and outlet for water, the ends being closed with a quartz disc. The distance between the quartz discs was 2.5 cm., and represented the depth of water to be traversed by the light. An extended image of the arc was projected on to an agar plate, which had been superficially inoculated with the colon bacillus. The arc image was obtained by means of a pinhole in a metal plate interposed between the light source and the agar film. A projected image of the positive and negative poles and of the image of the arc resulted. We found, however, that under these conditions the loss of light was so considerable that a very long exposure became necessary. We therefore substituted for the pinhole a metal plate with a slit in it. The slit was less in width than the length of the arc itself, and was placed about 3 cm. from the arc, with the direction of the slit at right angles to the axis of the carbons.

We thus obtained an image which was in reality made up of a number of superimposed images similar to those obtained with the pinhole arrangement. On the agar plate the image was seen as a central broad violet band, above which was the narrow white band of light projected from the negative carbon and below the brighter white band projected from the positive electrode.

As heat might be a posible disturbing factor, the images from the electrodes were eliminated from the experiments, only the effects of the broad violet band from the arc itself being considered.

Although, therefore, we had no absorbing medium other than air between the arc and the agar plate, the light was almost free from heat rays, any possible rise of temperature being quite negligible. Inoculated plates were then exposed in the first instance without any heat-absorbing apparatus, and subsequently with a water-circulating apparatus interposed between the slit and the inoculated agar film.

It was found that an exposure of five minutes without the water-circulating apparatus had a greater bactericidal effect at the point of incidence of the light than a twenty-five minutes' exposure with it. In other words, that the light on passing through 2.5 cm. of water lost four-fifths of its bactericidal power. This result we had hardly anticipated in view of the researches of Hartley and others, in which water was shown to be but slightly absorbent either to visible or ultra-violet radiations.

The loss of bactericidal power may, however, be attributed to general rather than to selective absorption. The quartz may be regarded as negligible, as its transparency is well known, and we subsequently found that it transmits the bactericidal radiations practically without any loss by absorption. It would therefore appear that in phototherapeutics the generally used water-cooling appliance might well be dispensed with if the heat could be eliminated by other means, and assuming that the directly bactericidal rays are the only essential ones, which at present is by no means certain.

The next experiment was to determine whether, when using the electric arc, the effect is in any way a function of any particular current. It is well known that the efficiency of an arc as a source of light increases as the current is increased. The ratio of light production is approximately as follows, the standard in this case being an efficient type of oil lamp:

7 ampères	39	15 ampères	117
10 ,, ...	75	20 ,, ...	160

On exposing bacterial plates in the above inverse ratios we found that the action was exactly proportionate to the light produced, a current of 10 ampères having approximately double the bactericidal effect of a current of 7 ampères and so on. This was tested carefully up to 25 ampères with unvarying results, showing that the action is exactly proportionate to the light efficiency.

To conclude, when reviewing the experiments made with light by ourselves and others, we are bound to confess that at present the scientific treatment of disease by means of light is still in its infancy. Though undoubtedly a promising remedy in certain affections, phototherapy is still an empirical method of treatment, inasmuch as we do not know which rays of light cause the therapeutic effect, nor how this therapeutic effect is brought about. The bactericidal rays we think we have located with exactitude. It remains to locate those rays which excite the reaction in tissue with equal exactitude, in order that a method of producing the required rays in greater intensity may be devised.

The experiments have been carried out principally with the bacillus coli communis, but the following organisms have been also employed with similar results: Bacillus prodigiosus, bacillus subtilis, micrococcus tetragenus, staphylococcus aureus, and bacillus tuberculosis.

We have to thank Dr. Allan Macfadyen for the suggestion that the research should be undertaken, and for much help and advice during the progress of the work.

A CASE OF DOUBLE GANGRENE OF LEGS FOLLOWING A MILD ATTACK OF ENTERIC FEVER.

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The following notes on a case of the above comparatively rare complication of enteric fever may prove of some interest:

Early History.—The patient, A. D., was a Scotchman, aged 22 years, and an engineer on one of the mines here. He was first seen at the mine on May 10th, and was admitted to the Primrose Hospital two days later suffering from enteric fever. He went through a typical mild attack, his temperature never going above 101°.

After-Progress.—On the evening of May 22nd he, for the first time, complained of pain in the right calf, his temperature then being 97.6°. Next morning the calf felt hard to the touch, but was not inflamed, and there was no evidence of phlebitis. There was an area of anaesthesia on the outer surface of the leg. Belladonna was applied locally to relieve the pain. On the same morning the nurse in charge noticed some twitching of the left side of the face and eye, drawing down of the angle of the mouth, and a slight thickness of speech. This passed off in two hours time. On May 24th the dorsum of the right foot commenced to show discoloration, extending as far up as the ankle, and the patient complained of great pain in the right calf. There was now total anaesthesia of foot. At the same time the patient began to complain of a similar pain in left leg, and, coincident with the pain, an area of anaesthesia developed on outer side of the left leg. On May 25th discoloration began to show in the left leg as well. The discoloration in the right leg now extended up to within 1½ in. of the knee-joint, being more marked on the outer than the inner side. With the appearance of the gangrene the application of glycerine of belladonna was stopped and the treatment changed to swathing the affected parts with cotton wool, keeping them warm with hot-water bottles, and administering morphine hypodermically. On the 26th the discoloration of the right leg appeared to have diminished slightly, and there was some return of sensation on the dorsum of the right foot, which did not, however, extend to the toes, and these now began to shrivel. The discoloration of the left leg was now getting more distinct. This dis-