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COMMUNICATIONS

ULTRA-VIOLET LIGHT IN THE TREATMENT OF
OPHTHALMIC DISEASE

I.—GENERAL PHOTOTHERAPY

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EARLY in 1922, in an endeavour to co-ordinate on a scientific basis experimental and clinical studies which were beginning to attract considerable attention, the Medical Research Council instituted a Committee on the "Biological Action of Light" under the chairmanship of the late Sir Wm. M. Bayliss. In the autumn of 1925, under the aegis of this Committee, at the instigation of Sir John H. Parsons, an ultra-violet clinic for the treatment of diseases of the eye was instituted at the Royal London Ophthalmic Hospital. Since its institution a large number of patients, representing many various conditions, has been treated, some with success, some with failure; but on the whole with such results as have led to the establishment of the clinic as a recognized part of the hospital practice. Preliminary papers (1926, *a* and *b*) have already been published dealing in a tentative manner with the earlier results which were obtained with this method of therapy in the first seventy cases which were treated; but inasmuch as the technique has now become standardized, and as it is possible to deal with the matter with the added authority of considerably extended

experience, it may be of interest to review the matter in the light of the following series of four hundred and twenty-five cases. These are classed into the two divisions in which treatment by ultra-violet radiation may be considered: general phototherapy, in which the patient is subjected to artificial sun-baths, and local phototherapy, in which the eye itself is directly radiated. To each of these a short paper will be devoted.

Throughout—for reasons closely akin to ignorance—theoretical matters will be avoided as much as possible; the purpose of these papers is entirely clinical. It is no secret that the practice of ultra-violet phototherapy is still to a large extent empirical, although in many directions it is controlled and guided by experiment; but in extenuation it may be urged that the same may be said of most of the advances in therapeutics. And in any case, whatever the theoretical considerations involved, the method, when employed within limits, has justified itself in practice. It is to be hoped that some of the present enthusiasm which exists in some quarters for its well-nigh universal use will be damped in the future; but at the same time it is reasonably sure that in certain directions this enthusiasm will be strengthened and augmented.

The biological effects of ultra-violet radiation

Ultra-violet light appears to exert a complex effect upon the subject radiated, the response being partly photo-chemical and partly photo-electrical. The chemical effect embraces photo-reactions involving the proteins and sterols in or near the surface layers of the skin; the products of the first of these probably increase the non-specific immunity of the body, those of the second seem to have a pronounced effect on vitamine activity.* The intimate nature of these reactions is very imperfectly known, and there are almost certainly others as yet wholly uninvestigated. Recent work is showing that the photo-electric effect which accompanies the radiation of living tissues is much greater than had been anticipated; so great, indeed, that it cannot fail to produce a considerable effect upon the organism, an effect which is probably to a large extent responsible for the undoubted stimulating influence of suitable doses of light.

Clinically the most obvious effect of radiation is the production of an erythema in the skin. It appears after a latent period, the duration of which varies inversely as the intensity of the radiation employed, but which averages four to eight hours, and its maximum

* Xerophthalmia, which is produced in rats by feeding on a diet deficient in vitamine A, is rapidly cured by ultra-violet radiation (McCollum and Davis, 1914; Ellis and Macleod, 1922). The similar effect of radiation in rickets is well known (Hume, 1922; Hess and Unger, 1923; Eckstein, 1924; and many others).

intensity is usually reached in about thirty hours. For clinical purposes it may be divided into four degrees :

First degree : an extremely slight reddening of the skin, not followed by any exfoliation, and involving transient subjective symptoms.

Second degree : a faint but definite reddening, followed by a fine granular desquamation, and involving a varying degree of itching and mild irritation.

Third degree : a marked erythema, followed by coarse, flaky desquamation and pigmentation, accompanied by considerable itching and smarting.

Fourth degree : a deep and intense erythema, with oedema and the formation of blisters, accompanied by considerable pain.

The reaction in the skin is characterized by swelling in the deeper layers of the epidermis and marked capillary dilatation, the lumen of these vessels being increased two, four, or six times. This vascular reaction leads to stasis and diapedesis, with the formation of a varying amount of oedematous fluid which may collect in droplets or vesicles to form blisters. Subsequently, owing to coagulation of the proteins in the epidermal cells, necrosis occurs, and these desquamate. Meantime, especially with rays slightly longer than 2,900 A.U., deposits of melanin tend to accumulate round the nuclei of the basal epidermal cells, and a greater or less degree of pigmentation appears, a phenomenon which is largely absent if the shorter wave-lengths are employed.

A second and extremely important effect of radiation is the production of an increase in the bactericidal power of the blood (Colebrook, Eidinow, and Hill, 1924). This is a very definite result. It appears that the erythema dose of light applied to an area of the skin increases the bactericidal properties of the blood flowing through the site of radiation, and in this way the blood in the general circulation develops greater bactericidal activities (Eidinow, 1927); thus blood from a suitably radiated subject when inoculated *in vitro* with staphylococci remains sterile while that from unirradiated controls grows colonies profusely. Moreover, by testing its effects on typhoid agglutinins a rise in the antigenic properties of blood after radiation may be demonstrated (Sonne, 1920). There are further histological and serological changes in the blood. A mild degree of radiation has little or no effect on the cellular composition (Jaulmes, 1925), but more intense doses result in a slight erythrocytosis (Russell, 1927), an increase in haemoglobin, an increase in platelets (Kramer and Drew, 1923), a decrease in polymorphonuclear cells, an increase in lymphocytes (Koopman, 1924), and a marked increase in eosinophiles. The

calcium, phosphorous and iron in blood are increased (Orr, Holt, etc., 1922; Lesné, de Gennes, and Guillaumin, 1923; Kramer, Casparis, and Howland, 1922; etc.), the sugar is increased except in those cases where it is pathologically high (Frenkel-Tissot, 1920), the proteins are refractometrically changed (Kroetz, 1924), and the pH is raised (Balderrey and Barkus, 1924). The parathyroid glands are increased in size (Grant and Gates, 1924), the iodine content of the thyroid is increased, and the general metabolism is accelerated, the carbon dioxide tension of the alveolar air being raised (Ederer, 1922) and the nitrogenous excretion augmented (Pincussen, 1924).

Dosage

From time to time it has been suggested that ultra-violet dosage should be standardized by some "actinometer" corresponding in principle to the "pastille dose" in the application of X-rays. Various devices have been suggested, none of which is entirely satisfactory; they depend on some photo-chemical reaction brought about quantitatively by ultra-violet light, in the course or at the end of which, some definite and easily determinable change, such as a colour change, takes place.

Webster, Hill, and Eidinow (1924) recorded a number of such suggested reactions and concluded that the most satisfactory was the bleaching of a solution of methylene blue in aqueous acetone. The photo-chemical decomposition of oxalic acid sensitized by uranyl salts, first investigated by Mathews and Dewey (1913), has been standardized for actinometry by Anderson and Robinson (1925), and with a different technique by Moss and Knapp (1925-27). MacKenzie and King (1926) described a method based on the photo-decomposition of carbon tetrachloride, the liberated chlorine being estimated quantitatively in the presence of potassium iodide by the determination of the equivalent amount of liberated iodine. The photo-chemical decomposition of hydrogen peroxide has also been carefully investigated (Henri, 1911; Henri and Wurmser, 1913; Mathews and Curtis, 1914; Anderson and Taylor, 1923); and similarly a buffered solution of potassium nitrate has been used (Gillam and Morton, 1927), the liberated nitrite being determined colorimetrically. The majority of these photo-chemical reactions, however, are complex, and direct evidence of the attainment of a definite stage is difficult to accept. Moreover, every source of ultra-violet radiation has its own spectral energy distribution, and every reacting substance its own individual absorption spectrum, and every photo-chemical change its own spectral distribution of efficiency; the energy measured quantitatively is therefore frequently limited to a small spectral range,

and may bear little true relation to the total abiotic radiation which may be emitted at the time.

Apart altogether from their intrinsic defects, it is doubtful if any such reaction as these will be of service clinically, since the reaction to light is very individualistic, and varies considerably from patient to patient; moreover, in the same patient during a course of treatment a certain immunity gradually develops, and each dose has to be varied on the basis of the reaction of the last. Generally, fair people respond to radiation more rapidly than dark, the reddish most readily of all, the young more than old, females than males, and a thin, dry, pale skin than an adipose, moist, pigmented skin. The reaction varies also with the part of the body treated; the face and hands are less susceptible than those parts habitually covered with clothes, the back and the posterior aspect of the limbs are more responsive than the chest, abdomen, and the anterior surface of the limbs. Further, there is a definite individual variation which it is impossible to assess accurately until each patient is tested and observed separately. It is true that the great majority respond within a reasonably narrow margin, but these considerations render a routine dosage based on a standard test inexpedient and in some cases unsafe.

The only systemic effect of which we have accurate knowledge and which lends itself to exact quantitative estimation is the increased bactericidal power of the blood which follows radiation; up to a certain intensity of radiation this gradually increases, beyond this limit a negative phase is induced and the haemo-bactericidal power falls, an effect which can be correlated with the mental and physical depression which too intensive doses of light invariably produce. It would seem reasonable to attempt to attain the dosage which will give the maximum height in this curve. The most readily observed effect of radiation is the production of the erythema on the skin, and fortunately this has been correlated with the changes in the haemo-bactericidal power (Eidinow, 1926). It appears that the optimum effect is obtained with radiation of such intensity as produces a mild erythema (of the second degree) which is followed by a fine desquamation over an area of about one-quarter of the body surface. The initial dose is therefore estimated by exposing four small areas on the arm or the back to the lamp for periods of two, four, six, and eight minutes respectively; the following day these areas are observed and the dosage is commenced whose duration is judged from the standard thus obtained. Thereafter the body is divided into three areas, the chest and front of the abdomen, the back, the front and the back of the legs, and each of these is irradiated on alternate sittings, the dose on each occasion being gradually increased by an amount based on the reaction obtained at the previous sitting.

The dose, of course, varies directly with the intensity of the ultra-violet output of the lamp, inversely as the square of the distance at which the patient is away, directly as the time of exposure, and also with the direction in which the patient is sitting with regard to the rays. The amount of reaction varies with the quantity of ultra-violet energy actually received, and it does not make any difference in practice whether the dose is varied by altering the time of exposure or the distance of the patient (Angus, 1927). With a mercury vapour lamp (K.B.B. atmospheric) running on 220 volts 2 to 3 ampères, with the patient sitting normally to the incident rays at three feet distance, the average duration of a commencing dose is three minutes.

Technique

The general scheme of treatment recommended is as follows, and it may be taken as a standard, subject to individual variations with the requirements of each particular case. After the initial dose has been obtained, the patient attends the clinic three times a week, when one of the three areas specified above is exposed, the greater part of the body being thus radiated once a week. At the end of this time the slight reaction has died down and the fine desquamation has passed off leaving fresh and light-sensitive skin available each time the alternating areas come up for re-exposure. By this routine an optimum effect is produced over an optimum area, a maximal increase in the haemo-bactericidal power is obtained three times a week, and as far as we can judge, an optimal effect is obtained from the course of treatment, while the patient is kept almost continually under the influence of the light.

Treatment is begun with the mercury vapour lamp,* the dose being gradually raised from the initial three, to nine or twelve minutes as the patient develops a certain degree of tolerance. After the first few weeks, usually somewhere between the ninth and fifteenth treatment, depending on the rapidity of the development of this immunity, the carbon arc is employed. The spectrum of the mercury vapour lamp is rich in the shorter ultra-violet rays while the carbon arc gives a more intense output in the longer and more deeply penetrating ones, and these seem to be the most useful at this stage. Moreover, in the practice of a large clinic the latter is the more easily worked; for while two patients can be treated simultaneously with the mercury lamp, six to ten can be accommodated with the carbon arc. Further, the dosage required is considerably longer, and having thus a greater margin of safety, has to be less carefully regulated. With simple carbon poles the output of ultra-violet is relatively small, but this can be increased by coring the carbons with various metals. Of the

*The apparatus used is obtainable at Theodore Hamblin, Ltd., 15, Wigmore Street, London, W.1

various materials used tungsten is the most powerful, but a tungsten arc requires a great deal of attention and the strength of its radiation to some extent defeats its own ends. The practice in the clinic is to have one pole of the arc composed of plain carbon and the other cored with iron and cerium; with this, after a three weeks' course of the mercury lamp, the initial dose averages fifteen minutes at a distance of four feet. This is employed until twenty treatments in all have been given, the duration of exposure increasing from twenty to twenty-five or thirty minutes. Thereafter, if the state of the eye permits it, the course of treatment is stopped, and the patient is given two or three weeks rest whilst being kept under observation; at the end of this time, if it is at all indicated, a second course is started after a manner similar to the first except that the carbon arc is introduced a week or so earlier, and the dosage has usually to be increased more rapidly. A similar rest follows, and, if necessary, further courses can be given.

General Effects of Radiation

Apart from the local effect on the diseased condition in the eye the general tonic effect of ultra-violet radiation is very marked in the great majority of cases. Almost invariably one is told that the patient feels better and stronger and is in every respect more fit. Weight is put on, sleep improves remarkably, and the appetite is increased. There seems to be a certain definite effect upon chronic constipation, apart from the relief of the symptoms of auto-intoxication. The continuous stimulation of the capillary system of the skin reacts upon the whole vascular system, stimulates the vasomotor reflexes, and assists in the adequacy of the temperature-regulating mechanism. Anaemias are benefited, the endocrine glands are stimulated, the general metabolic rate is increased, and these together with the raising of the general immunity of the body make the method of therapy a good adjuvant to other methods of treatment, and frequently seems to turn the scales in the course of a chronic illness especially in a debilitated or unresponsive patient. On the whole, the best response is seen in children, particularly those inhabiting crowded and sunless areas in industrial neighbourhoods.

Not only is this stimulation apparent on the physical side, but the mental aspect of the patient shares in the feeling of well-being and many of the exhilarating effects of a holiday in a sunny climate may be appreciated. Indeed, in the assessment of the progress of a case this factor undoubtedly leads the patient astray on occasion, giving him the impression that rapid progress is being made, and it is easy for the observer to share in his enthusiasm; but it would be difficult to deny, more especially in diseases of the

eye involving deterioration of vision, that this is a good thing; while the lessening of fatigue, the mental stimulation, and the alleviation of insomnia are undoubtedly assets of considerable value. Particularly in the case of children are these effects noticeable. It is no uncommon thing for a mother to remark enthusiastically and spontaneously soon after the commencement of treatment that her child has become altered in disposition, has become more tractable, or is getting on better at school; while more definite effects can be noted, as (in adults) the return of potency or (in hitherto sterile women) the occurrence of conception.

Dangers

The method of treatment, however, is not without its dangers. The most important of these is overdosage or injudicious dosage; it is also the most common. The absence of progress or its slow advent tempts one to increase the dosage, a procedure which usually results in making matters worse.

General Effects. Overdosage.—The symptoms of overdosage are, initially, a vague feeling of "out-of-sorts," a general depression instead of a feeling of well-being. Immediately after treatment drowsiness and fatigue are experienced followed some hours later by a loss of energy and appetite, lassitude, headache, nausea, irritability, and (which is significant) a loss of sleep. Instead of an increase, there is a loss of weight; this is one of the best methods whereby to gauge the effect of treatment and the suitability of the dosage.

Idiosyncrasy.—A certain number of people possess a definite idiosyncrasy to light, and develop these symptoms of overdosage while the exposures are kept well within the limits already prescribed. Such cases derive no benefit from the usual doses, which should be curtailed until a stimulating effect is evident. Even although no erythema is excited under these conditions, many of these subjects react quite well, a subliminal dose having the same effect as the usual dose in an individual with the ordinary response. In most of these cases there is a very sharp critical point which must not be passed, although towards the end of treatment a considerable amount of tolerance may be gained. A complete inability to tolerate light at all does occur, but it is rare; and such persons are usually similarly affected by more than the average amount of sunlight on a bright day in summer.

Low Blood-pressure.—Patients with low blood-pressure almost invariably require smaller doses than the average, and in them the symptoms of overdosage can readily be produced. Usually

after radiation in all cases the blood-pressure falls slightly, the systolic about 6 to 8 and the diastolic 3 to 4 mm. Hg.

Pyrexia.—In febrile patients great care must be taken with the dosage; and as a general rule the presence of a temperature may be taken as a contra-indication to treatment.

Menstruation.—During menstruation the bactericidal power of the blood is usually lower than normal, and in many cases ultra-violet radiation during this time appears to make this worse (Hill and Eidinow, 1925). It is frequently observed that women in the course of treatment who usually experience a tonic effect from radiation, complain of increased languor and malaise. It is probably not advisable to stop treatment altogether during the periods, but, especially if any of the symptoms of overdosage are complained of, considerably smaller doses should be given.

Special Effects. Dangers to the Skin.—Overdosage giving an erythema of the third or fourth degree gives rise to more discomfort than danger. The skin becomes very tender and oedematous, there is profuse and sometimes repeated desquamation, and large blisters may be formed; while, with very excessive doses, an acute but transient dermatitis may occur. In all cases which have been reported, however, complete healing without scarring has resulted (see McCormac and McCrae, 1925). Such a happening is usually the result of accident—the patient sitting too near the lamp, or not sitting normally to the incident rays. A new lamp gives off a very high intensity during the first few hours of its burning life and may cause a burn, or the susceptibility of a patient on returning after a lapse in the treatment may not be properly assessed: a ten days' interval usually necessitates commencing at half the last exposure, a three weeks' interval means starting again with the initial dose. The discomfort is considerably eased by the liberal use of calamine lotion where the erythema is general; in the case of a local burn zinc oxide ointment or a hamamelis compress will be found useful, and blisters may be treated with a 0.5 per cent. solution of resorcin.

Memories of the unfortunate sequelae of X-ray dermatitis have led to the expression of the fear that prolonged ultra-violet radiation might possibly lead to the development of carcinoma; Lenthal Cheate (1925), for example, hinted at the possibility of such remote effects on finding active mitosis in the basal layers of radiated skin. It would seem, however, that this is due to the active stimulation of the new formation of the skin that occurs after desquamation (Rollier, 1925), and the experience of those who have used this form of radiation on thousands of cases for periods of well over twenty years without any such untoward

results seems to put the matter at rest (Finsen and Reyn at Copenhagen, Gauvain at Alton, Rollier at Leysin, and Sequeira at the London Hospital), the more so especially when the first three of them have been in the habit since the beginning of this century of treating lupus with strong exposures over prolonged periods, a circumstance which in the case of X-rays frequently leads to epithelioma (Sequeira).

The Eye.—During radiation goggles should always be worn, and it is essential that these be provided with side-pieces. Although ordinary glass is opaque to all but the longest ultra-violet waves, it does not give complete protection against intense exposures. A more opaque glass, such as Crookes', should, therefore, be used, and it should be as dark as is compatible with vision to avoid the fatigue and discomfort of the distressing glare. If this precaution is neglected the action of the light upon the cornea and conjunctiva produces an extremely painful photophthalmia (see Duke-Elder, 1926) after a latent period of four to eight hours; upon the retina it gives rise for some time to a central scotoma which is followed by a persistent feeling of uneasiness, irritability, and headache, while with regard to the lens there is the possibility of the development of cataract. Ultra-violet light, when used with enough intensity, produces cataract; and although little damage may seem to accrue from exposures of the intensities which are used clinically, unless protective precautions are taken by those who are frequently exposed to them, there is a danger of ultra-violet light cataract having the same unfortunate associations as X-ray dermatitis. Small subliminal exposures repeated at frequent intervals over a long period give rise to a chronic low-grade conjunctivitis of the follicular type, the eyes appearing constantly suffused and bleary, and the lids red and irritable. It is frequently seen in those conducting ultra-violet light clinics—and also in the habitués of cinema studios—when adequate protection to the eyes is not conscientiously worn. (For its experimental production, see Birch-Hirschfeld, 1909.)

Cases treated

The series of 425 cases dealt with comprises 306 treated by general light-baths alone, and 119 treated, some entirely by local phototherapy, and some by a combination of the two methods. They run in chronological order as they appeared at the clinic without reference to the nature of the results obtained; for the limitations of the method of treatment are as important and interesting as its successes. They include the period up to July, 1927.

The cases treated by general phototherapy upon which this paper is based are these :

	Cases.
Iritis and irido-cyclitis	102
Choroiditis	16
Sympathetic ophthalmitis	1
Retro-bulbar neuritis	3
Vitreous haemorrhages	2
Scleritis	4
Sclero-keratitis	9
Tuberculous keratitis	2
Phlyctenular keratitis	104
Interstitial keratitis	10
Recurrent corneal ulcers	23
Acne (corneal)	1
Corneal opacities	6
Blepharo-conjunctivitis	19
Recurrent hordeola	2
Tuberculous dacryocystitis	2
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	306

Iritis and Irido-cyclitis

The cases of iritis will be considered in two sections :

	Cases.
Iritis and irido-cyclitis of infective or unknown origin	76
Iritis and irido-cyclitis of tuberculous or presumably tuberculous origin	26
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	102

Infective Iritis and Irido-cyclitis.—It can safely be said that on the whole ultra-violet radiation is an extremely valuable adjunct in the treatment of the great majority of the cases of iritis and irido-cyclitis. Local treatment by atropine, heat, etc., should, of course, be persisted in, infective foci should be dealt with, and the condition of the patient attended to in every possible way. As a general rule mild cases of acute iritis have not been dealt with; with severe acute cases the response has been very marked; but inasmuch as rapid improvement in such cases after the institution of the ordinary methods of treatment is the rule, and the effect of radiation is therefore difficult to assess, it is the chronic and intractable cases, which have been treated without success for periods of months or even years by all the known methods of therapy (vaccines, milk injections, arsenic, etc.), which have demonstrated most clearly the value of the method.

The first result of treatment is usually a relief from pain, which frequently makes itself apparent after the first few exposures. Later the injection and the angry appearance die down, and in the progress of a typical chronic case the eye has become white towards the latter part of the first course of six weeks. Coincidentally, keratic precipitates tend to disappear, pupillary adhesions stretch and give way, and about the third to the fifth week a vitreous haze tends to clear up, sometimes very rapidly, sometimes slowly. Meantime vision is improving, and the patient is experiencing the general tonic effect of the treatment, is eating and sleeping better, is putting on weight, and is feeling mentally and physically invigorated. As a rule in the more chronic cases after such a course a holiday of two to four weeks is given during which time improvement tends to go on, sometimes even more quickly, at any rate initially, than during the course; and it is unquestionably the case that the second course, when it is inaugurated, acts much more quickly than the first. It is not uncommon at the commencement of the latter for a patient to hang fire and show little improvement for some time, but at the commencement of the second course an immediate and rapid improvement is the rule.

There are one or two general tendencies which have become apparent in the experience of the clinic. It does not seem to matter what the type or source of infection is; lesions which seem definitely to be associated with dental infection or infected tonsils react on the whole irrespective of the type of bacterial flora found there, and in much the same manner as lesions whose aetiology has remained obscure. To this, however, there are two exceptions: the average response to tuberculosis is good (a point which will be dealt with later), and the almost invariable response to lesions associated with syphilis is bad. All cases do not react well, and progress does not seem to depend so much upon the nature of the eye condition as upon the general reaction of the patient to light; some few will not tolerate it at all, and others react unfavourably to any but small doses. For each individual there is a definite optimum dose which must be studied and varied with the changing immunity of the patient if the best is to be got out of the treatment; too large or ill-advised dosage is useless, and in those cases where a slow or delayed response has led to the adoption of doses beyond the limits prescribed, the result has invariably been deterioration of the eye condition and a set-back in the tonic general effect which the treatment should produce. It is probably the case that most of the failures reported in the literature are due to excessive dosage exceeding the patient's tolerance, or to the prosecution of treatment in the case of patients who are intolerant altogether. On the average in cases of iritis, if any good at all is to come out of radiational treatment, the fact is obvious at or

before the end of the first course, and if no improvement at all is then apparent, the method in the great majority of cases might as well be discontinued. A slight improvement, however, is significant, and in many advanced cases treatment has had to be continued over many months before the eye is in a satisfactory condition, a process which demands considerable patience both on the part of the therapist and the patient. This, the arrest and slow amelioration of a progressive irido-cyclitis is, however, one of the most satisfactory aspects of phototherapy in ophthalmology, for in too many of these little can be done by the ordinary methods of treatment at our disposal.

There are cases which respond initially to treatment, and then tend to fall back; and there is a certain percentage which hold their own or tend to improve under treatment, and then relapse after its cessation. Most of these are rapidly improved on a renewal of the treatment, but in all cases it is a good thing to continue treatment for some time after the eye seems settled, and in those cases which show a relapsing tendency, to give one or two short courses at intervals for some time afterwards. Finally, it is to be remembered that a large number of the cases referred to the clinic were in a very advanced and almost hopeless condition; the improvement in a few of these has been surprising, but miracles have been as remarkably few; while an eye which has shown active inflammation for many months may well become quiet, gross structural changes with their consequent loss of visual acuity are as unalterable under the ultra-violet light as under any other method of therapy.

The results of treatment may be summarized thus :

Infective Irido-cyclitis

Result.	No. of Cases.	Percentage.
1. Improved	68	90
(a) Cured	38	50
(b) Much improved	15	20
(c) Eye quiet, but with structural changes precluding improve- ment in vision	10	13
(d) Temporary improvement relapsing later	5	7
2. Not improved		
(a) No observable change ...	4	5
(b) Got worse under treatment	4	5

Illustrative examples may be cited.

Male, aged 42 years. Gonorrhoeal infection 1916 with iritis, several mild relapses with two severe ones in 1918 and 1923 in the right eye. Vision 6/24 owing to vitreous

opacities, which had persisted since 1918 in spite of all treatment. Acute relapse with much k.p., 1926. One course of 20 light treatments: after the tenth, eye quiet; after the fifteenth, vitreous haze much clearer, and k.p. away; at the end of the course, R.V. 6/5, and remained so eight months later.

Female, aged 29 years. R. and L. irido-cyclitis, aetiology unknown. History of two previous attacks three and two years previously, since which time progressive visual deterioration. Cornea oedematous, aqueous turbid, posterior synechiae and pigment on anterior lens capsule, vitreous haze. R.V. 6/60, L.V. 6/24. Atropine, hyoscine, duboisine irritation. One course of twenty light treatments: eye quiet, media clear, R.V. 6/6, L.V. 6/5.

Female, aged 33 years. Acute irido-cyclitis, R. of unknown aetiology; L. normal. Oedematous cornea, turbid aqueous, k.p., vitreous haze, R.V.=counts fingers. Atropine irritation. Twenty light treatments: eye quiet, no k.p., R.V. 6/9.

Female, aged 42 years. Rheumatoid arthritis 13 years (colon infection, cystitis). Iritis R. and L. 10 years, with recurrent attacks several times per year varying with the intensity of the arthritis. This was progressive, and responded to no treatment except travelling abroad, everything from autogenous vaccines to sea-water injections having been exhaustively tried. Eyes both injected, irides tied down in ring synechiae, k.p. profuse, left lens opaque, abundant vitreous opacities right, tension slightly subnormal. R.V. hand movements, L.V. fingers at 3 feet. In May, 1926, commenced treatment. After the first ten exposures, the eyes became painless and whiter and the pain from the arthritis became less. The condition gradually improved. After four courses (80 treatments) the right pupil dilated and the vitreous cleared largely, the vision becoming 6/9 with glasses (-3.0 sph. -3.5 cyl.); the left eye remained with adherent iris, an opaque lens, and good tension. Since then up to May, 1927, the eyes remained unaltered, excepting slight attacks of injection accompanying a mild attack of arthritis, which were readily controlled by light. A short prophylactic course was taken every two or three months in the meantime. Since May, 1927, relapses ceased, and without any further treatment the eyes have remained in the same satisfactory condition.

Female, aged 30 years. Both eyes "bad" since aged 2 years: irido-cyclitis with sclero-keratitis and corneal opacities. Bilateral iridectomy 1919. Since 1924, eyes "have never been quiet for longer than six weeks." R.V. perception of light, L.V. hand movements, the deficient perception being apparently due to corneal opacities. Eighty light treatments between March and August, 1927. After the first fifteen: eyes quiet, and have remained so since; R.V. perception of light, L.V. 6/60.

Of the four cases which showed no improvement, one was a very advanced irido-cyclitis (presumably of dental origin) with a very low tension, two had a positive Wassermann, and one appeared to react generally badly to light. Of the four which got worse during treatment, two were syphilitic, and two were intolerant to light. In the first of these last, one improved initially, and then fell back during treatment; at the end of the first course deterioration was more rapid; during a second and third course the eye condition barely held its own, remaining irritable; thereafter the patient discontinued treatment. The second had a typically bad reaction to light. At the end of the first six treatments a hypopyon appeared; a fortnight's rest was given and treatment started very carefully with small doses again, when a similar occurrence took place; whereupon treatment was stopped. The disease appeared to be due to dental infection.

Tuberculous Irido-cyclitis

The results obtained in the treatment of tuberculous irido-cyclitis are in every way comparable to those already described in the cases due to infective organisms, except that, on the whole, making due allowance for the severity of the cases, they are more satisfactory. This is the more important since tuberculous irido-cyclitis is notoriously one of the most difficult diseases to treat in the whole of ophthalmology. In the early cases the improvement has frequently been surprisingly rapid; pain has disappeared,

injection has died down, iritic nodules have gone, and massive keratic deposits have faded away towards the end of the first or during the second course of radiation. On the other hand, the cases dealt with have included a large proportion which were very advanced, and some in which one eye had already been excised for a similar disease. In these the response has often been slow, but as a rule, when established, it has been maintained, although necessarily leaving, on occasion, an eye of little functional use. In these cases treatment is worth while persisting in for many months, and should be carried on for some time after the condition seems settled, for there is a tendency to relapse. In the series of twenty-six cases all have improved, and have retained or improved upon the standard of vision which they had at the commencement of treatment, with two exceptions, which, after considerable improvement at first, have relapsed later, one in the absence of further treatment, the other in spite of it. Incidentally it is to be noted that both of these were pronounced hopeless before they were referred to the clinic. On the whole the results leave no doubt that ultra-violet light is the treatment of choice for this condition.

Female, aged 24 years. Right tuberculous irido-cyclitis. Ciliary injection, nodules on iris, much k.p., posterior synechiae, vitreous opacities, staphylomatous sclera: eight months duration. R.V. 3/60. After thirteen treatments, pain away, eye white; after three courses (80 treatments), discharged under observation: R.V. 6/18.

Female, aged 24 years. Irido-cyclitis L., three years. Cyclitic injection, lower third of anterior chamber filled with exudate, nodules on iris, posterior cortical changes in lens, posterior two-thirds of vitreous filled with an organized inflammatory mass. After forty treatments, anterior chamber free, some pigmented k.p., remnants of nodules only on iris, lens and vitreous as before. Vision unchanged (bare p.l.); eye quiet.

Female, aged 38 years. Left excised for tuberculous irido-cyclitis three years ago. Right, injection and pain with k.p. and vitreous haze three months. Twenty treatments: eye appears normal; R.V. 6/5; a further course of 20 treatments, since which time the eye has remained quiet (18 months).

Choroiditis

Of the sixteen cases of choroiditis treated four were acute; these all settled down very rapidly; but although they were left with a clear vitreous, a clean scar in the fundus, and a good visual result, inasmuch as this is wont to happen in any case, it is in the cases of persistently recurring lesions that the results of ultra-violet radiation are best seen. The remaining twelve were of this nature; two of these were considered tuberculous, two syphilitic, the remaining infective in origin. The tuberculous cases both cleared up very satisfactorily, the syphilitic showed no improvement, and the eight infective cases after treatment varying from two to three courses remained quiet (the period of observation lasting from 18 to 3 months) with one obstinate exception, which, despite eighty

treatments, persistently recurred in the intervals between courses, on each occasion with a further deterioration of vision. On the whole, therefore, the results are satisfactory, one of the most notable features being the rapidity with which a vitreous haze, sometimes of considerable standing, may clear up in the course of two or three weeks.

The one case of *Sympathetic Ophthalmitis* had a quiet eye without k.p. after six weeks' treatment; he had, however, arsenical treatment in addition.

The three cases of *Retro-bulbar Neuritis* (one of which was associated with ethmoidal suppuration, two of which were of doubtful aetiology) all cleared up with a good visual result, two after one course of treatment, the third, which had a relapse soon after the cessation of treatment, after a second course.

In the two cases of *Vitreous Haemorrhage* clearing had become quite apparent in three weeks; they were both of the type showing a uniform and fine haze. In the first (a spontaneous case) full visual acuity was regained in six weeks, in the second (a traumatic case) the clearing media revealed an extensively detached retina.

Scleritis and Sclero-keratitis

Thirteen cases of scleritis and sclero-keratitis were treated by general light-baths. In four of these the lesion did not involve the cornea; of these two were considered to be tuberculous, and two of infective origin. In all the disease subsided.

Female, aged 24 years. Scleritis right, with iritis and k.p., which had resisted ordinary treatment for three months. R.V. 6/12. After three treatments, eye painless; after the eighth, the injection had disappeared. The course of twenty treatments completed, when R.V. 6/9. Three weeks later, relapse with eye again painful and injected. After second course (20 treatments), eye white; R.V. 6/6, partly; condition unaltered six months later.

In the remaining nine cases the disease involved the cornea also, and was accompanied by a varying amount of iritis. They were all of considerable standing; five were accepted as tuberculous, in that the von Pirquet was positive and other sources of infection were excluded, and four were considered infective. Under prolonged treatment they all eventually quietened down with the exception of one who left soon after the commencement of his course. The usual result was a quiet eye, free from injection and pain, with, however, no improvement in the corneal opacities. It was found that considerably better and more rapid results could be obtained by combining general radiation with the local application of light to the cornea; this subject will therefore be discussed further in a subsequent paper.

Two cases of *tuberculous keratitis* were also treated, each involving a considerable corneal opacity with active ulceration and

ciliary injection. Although both eventually cleared up leaving a quiet eye with a large corneal opacity, the treatment of election for these also is a combination of local with general radiation.

Phlyctenular Keratitis

No disease responds better or more quickly to ultra-violet light than phlyctenular kerato-conjunctivitis. Especially does this apply to children, and the typical phlyctenular child, ill-looking, fretful, irritable, and distressed with photophobia, is frequently transformed into a different being in a week or two. The series of 104 patients dealt with embraces all manner of cases, from a first acute attack in a child to those extremely chronic cases which go on with intermissions for ten, fifteen, or twenty years, leaving an opaque cornea constantly breaking down, and an eye, to all intents and purposes, useless. Throughout, the results of treatment were good, and light may be considered almost a specific for this disease.

The average acute case shows an excellent response; pain and photophobia may disappear in the course of the first week, after (say) the third or even the second treatment, and as a rule at the end of three weeks the child is a changed individual. Experience has shown, however, that a full course of treatment should be given, and if possible, a second to prevent the liability to relapses; indeed in this class of children the ideal procedure is undoubtedly to give them a prophylactic course of artificial light once or twice a year, especially in the sunless months of winter. In the more chronic cases the response is slower, but here again it is good. In some of these, where there is much chronic corneal activity, local applications of light are of very considerable benefit.

Female, aged 12 years. Ulcers in each eye eight years, during which time she had been an in-patient in hospital three times, and had been sent to a convalescent home twice. Both corneae had ulcers carbolicized on different occasions. Acute recurrent attacks every few months, with constant injection and irritability in the intervals. R. and L.V. hand movements. After one course (20 treatments), eyes quiet, with vascularized nebulæ showing no activity; after the third course, R.V. 6/60, L.V. 6/36. Eyes still quiet nine months later.

The records of the large majority of cases are of rapid recovery: an example of the more resistant type is as follows: Female, 5. Three months duration, ulcers on each eye with blepharo-conjunctivitis. Six treatments: eye improved, photophobia away. After twelve treatments, eye white, blepharitis still present. Three weeks after cessation of course, a relapse occurred. A second course of twelve treatments: eye white. One month later, a further relapse. Ten further treatments: eye white again. Six months later, eye still quiet, with faint corneal nebulæ.

Interstitial Keratitis

The experience over a series of ten cases, which were given a trial treatment extending over many weeks, was that, apart from the tonic effect on the health generally, ultra-violet light was of no benefit.

Recurrent Corneal Ulcers

Twenty-three cases of recurrent corneal ulceration were treated by general light-baths. It appeared that the treatment aided the usual methods of therapy to such an extent as to allow the cornea to heal up in the majority of these, especially in marginal ulcers associated with a conjunctivitis; but since the response of such cases to local irradiation of the ulcer was found to be extraordinarily good, treatment by general baths alone has been largely given up. For a similar reason, the treatment of *acne* by general baths has been augmented by local phototherapy.

Corneal Opacities

On the instigation of claims in the literature, six cases of well-marked corneal opacity from various causes were given an extensive trial of treatment by general light-baths; in none was any evidence of improvement seen.

Blepharo-conjunctivitis

The type of conjunctivitis and blepharitis which occurs in debilitated patients, typically in children, say after some illness, as measles, is immensely benefited by ultra-violet light. In many of these, where the disease has resisted other methods of treatment for many months, radiation seems to have the same remarkably good effect as is seen in phlyctenular conjunctivitis.

Male, aged 6 years. Blepharo-conjunctivitis for nine months, no obvious cause; general health seemed below the average. Treatment by local lotions, ointments, and protargol with general tonics of no avail. After six light treatments, lids and conjunctivae normal. Discharged cured after twenty treatments.

Female, aged 17 years. Blepharo-conjunctivitis for three months resisting all treatment, which had appeared since coming from the country to work in a city office. Was completely cured by one course (20 treatments) of light-baths.

A second type of conjunctivitis which reacts well to general light treatment is the inflammation which tends to occur seasonally with coryza and hay-fever in its various manifestations. Many cases of hay-fever seem to be a manifestation of an abnormal sensitivity to some protein substance, and in a number of these ultra-violet light acts as a specific. The action may have something to do with the absorption from the radiated cells of the epidermis of the photochemical products of proteins, which, when they are absorbed, influence the general immunity reaction of the body. However that may be, remarkably good results were obtained in the three cases of this type which were treated.

In a series of six cases of ordinary chronic conjunctivitis occurring in obviously healthy adults general ultra-violet treatment was given a fair trial; in these no marked effect was evident.

The subject of conjunctivitis will be considered again in the report of the results of local radiation.

Recurrent Hordeola

Two cases of persistently recurring styes in debilitated children seemed to be rapidly cured by light treatment. Here again light appeared to act as a powerful tonic and germicidal agent, which enabled the patient to master an infection which could not be overcome with his unaided powers of resistance.

Tuberculous Dacryocystitis

Two cases of tuberculous dacryocystitis were treated, both of which cleared up completely after a protracted and persistent but unsuccessful attempt by the ordinary methods.

Female, aged 24 years. Phthisis R. lung in youth. Conjunctival nodules in 1921; excised; recurred; sent to Rollier (Leysin) under whose treatment (sun-baths) they cleared up. In 1925 nasal discharge: R. and L. sacs excised (tuberculous). An open discharging sinus persisted in spite of all treatment (scraping, etc.) until Feb., 1926. General light-baths started, and discharge ceased and sinuses closed in four weeks.

General Conclusions

Much that has been written about ultra-violet light is merely fantastic. With judicious use its effects can be powerful for good, but they have their limitations and they always stop short of the marvellous. It is not a cure-all: nothing is, or is likely to be. And at all times to get the best out of the method, it has to be used with considerable care and only after experience; its haphazard application in ill-considered dosage is almost certain to lead, at the least, to the opposite of the desired effect.

Neglecting the value of local light treatment, which will be discussed in the subsequent paper, it would seem that a fair assessment of the results of the treatment of ocular diseases by general radiation with ultra-violet light, in as far as they are shown by the experience at the clinic at Moorfields, is that the method is an adjunct of considerable value to the ordinary routine therapeutic measures. Particularly is this so in tuberculous diseases of all kinds: to these, as a rule so intractable and obstinate, it offers, within limits, a large measure of hope. In phlyctenular disease also it is undoubtedly the treatment of choice. In infective diseases involving any of the structures of the eye, with its general tonic effect, its psychological and physical stimulation, its reorganization of endocrine activity, and, above all, its marked influence on the immunological response of the body, it is able to exert a powerful influence. While its judicious employment in acute cases frequently leads to striking results, perhaps its greatest use is to be found in the treatment of

chronic infections which appear to resist all forms of treatment; in many of these it has been found to be the deciding factor in tipping the balance over to the side of recovery. There is much to be said for the old Italian proverb: "To bathe in water is good, in air better, but in sun-light best of all."

REFERENCES

An annotated bibliography of the literature of phototherapy in ophthalmology is appended at the end of the subsequent paper. It is not referred to serially in the text, since it is difficult to make any legitimate comparison with the writings of others, whose technique and consequently whose results, differ from those described. The references in the text are these.

- Anderson and Robinson.—*Jl. Amer. Chem. Soc.*, Vol. XLVII, p. 718, 1925.
 Anderson and Taylor.—*Jl. Amer. Chem. Soc.*, Vol. XLV, p. 1050, 1923.
 Angus.—*Brit. Jl. of Actinotherapy*, Vol. II, November, 1927.
 Balderry and Barkus.—*Amer. Rev. Tuberculosis*, Vol. IX, p. 107, 1924.
 Birch-Hirschfeld.—*Arch. f. Ophthal.*, Bd. LXXI, S. 573, 1909; *Zeitschr. f. Augenheilk.*, Bd. XXI, S. 358, 1909; *Med. Klin.*, Bd. XXX-XXXIII, 1910.
 Cheate, Lenthal.—*Brit. Med. Jl.*, p. 631, March 28, 1925.
 Colebrook, Eidinow, and Hill.—*Jl. Exper. Path.*, Vol. V, p. 54, 1924.
 Cramers and Drew.—*Brit. Jl. Path.*, October, 1923.
 Duke-Elder, W. S.—*Trans. Ophthal. Soc. U.K.*, Vol. XLVI, p. 213, 1926; *Brit. Med. Jl.*, p. 891, May 29, 1926; *Lancet*, p. 1137, June 12; p. 1926, June 19; p. 1250, 26; and p. 16, July 3, 1926.
 Eckstein.—*Arch. f. Kinderheilk.*, Bd. LXXIV, S. 1, 1924.
 Ederer.—*Biochem. Zeitschr.*, Bd. CXXXII, S. 103, 1922.
 Eidinow.—*Lancet*, Vol. II, p. 645, 1926; Vol. II, p. 963, 1927.
 Ellis and MacLeod.—*Vital Factors in Food*, N.Y., 1922.
 Frenkel-Tissot.—*Deutsch. Arch. klin. Med.*, Bd. CXXXIII, S. 286, 1920.
 Gillam and Morton.—*Jl. Soc. Chem. Indus.*, Vol. XLVI, pp. 415 and 417, 1927.
 Grant and Gates.—*Proc. Soc. Exper. Biol.*, Vol. XXI, p. 230, 1924.
 Henri.—*Comp. rend. Acad. des Sc.*, T. CLIII, p. 265, 1911.
 Henri and Wurmser.—*Comp. rend. Acad. des Sc.*, T. CLVI, p. 1012, 1913.
 Hess and Unger.—*Jl. Amer. Med. Assoc.*, Vol. LXXVIII, p. 1596, 1922.
 Hill and Eidinow.—*The Practitioner*, August, 1925.
 Hume.—*Lancet*, Vol. II, p. 1318, 1922.
 Jaulmes.—*Comp. rend. Soc. de Biol.*, T. XCII, p. 268, 1925.
 Koopman.—*Deutsch. med. Wochenschr.*, Bd. LVI, S. 277, 1924.
 Kramer, Casparis and Howland.—*Amer. Jl. Dis. of Children*, Vol. XXIV, p. 20, 1922.
 Kroetz.—*Biochem. Zeitschr.*, Bd. CLI, S. 449, 1924.
 Lesné, de Gennes and Guillaumin.—*Comp. rend. Acad. des Sc.*, T. CLXXVII, p. 191, 1923. See also Hess and Unger, *Chem. Abstracts*, Vol. XIV, p. 3709, 1920.
 McCollum and Davis.—*Jl. Biol. Chem.*, Vol. XIX, p. 245, 1914.
 McCormac and McCrae.—*Brit. Med. Jl.*, p. 693, April 11, 1925.
 MacKenzie and King.—*Practical Ultra-Violet Therapy*. Benn, 1926.
 Mathews and Curtis.—*Jl. Physical Chem.*, Vol. XVIII, pp. 166 and 521, 1914.
 Mathews and Dewey.—*Jl. Physical Chem.*, Vol. XVII, p. 216, 1913.
 Moss and Knapp.—*Jl. Soc. Chem. Indus.*, Vol. XLIV, p. 453, 1925; *Brit. Jl. Actinotherapy*, Vol. II, January, 1927.
 Orr, Holt, Wilkins, and Boone.—*Amer. Jl. Dis. of Children*, Vol. XXVI, p. 362, 1923.
 Pincussen.—*Biochem. Zeitschr.*, Bd. CL, S. 36, 1924.
 Rollier.—*Brit. Med. Jl.*, p. 203, May 9, 1925.
 Russell, E. H., and Russell, W. K.—*Ultra-Violet Radiation and Actinotherapy*, Livingstone, 1927.
 Sonne.—*Comp. rend. Acad. des Sc.*, T. CLXXXII, 1926.
 Webster, Hill and Eidinow.—*Lancet*, Vol. I, p. 745, 1924.