ment of the ultra-violet radiation of wave-lengths shorter than about 3600 Å. by making use of their bleaching effect on a solution of methylene blue in acetone.

The standard solution is exposed in a quartz tube and the 'exposure' measured by comparing its tint with some standard tints calibrated in terms of the lethal effect on infusoria. The scale adopted is quite an arbitrary one.

Janet Clark has suggested using the blackening effect of ultra-violet radiation on lithopone (a pigment containing zinc oxide, zinc sulphide, and barium sulphate) for intensity measurements. This substance, when moistened with water, darkens under the influence of rays of wave-lengths less than 3200 Å. It thus appears to afford a simple colorimetric method of measuring those rays which can produce an erythema of the skin.

ELECTRICAL METHODS.

These generally make use either of the photo-electric property of some metal—generally zinc or cadmium—or the fall in electrical resistance of selenium when illuminated. A glance at Table II. will show what metal is best suited to the particular radiation to be measured. In principle, a photo-electric cell consists of an insulated plate of metal connected to an electrometer or gold-leaf electroscope, the system being negatively charged. Under the influence of a suitable radiation, the plate loses its charge at a rate dependent upon the intensity of the radiation.

The action of a 'selenium cell' is somewhat different. As ordinarily used, the change of resistance of the cell when illuminated is measured by the change in current through a microammeter connected in series with the cell and an energising battery. This effect can be produced by infra-red, visible, ultra-violet, Röntgen, and gamma radiations, and is not the normal photo-electric effect.

It is easily seen that any of the instruments described above can readily be used to give a trustworthy check on the emission of a given source at different times. Their value in comparing the

different emissions of different sources is not quite so certain.

INVERSE SQUARE LAW.

The intensity of the radiation falling on a surface can only be assumed to diminish according to the law of inverse squares (1) when the active dimensions of the source are small compared with its distance from the surface, and in addition (2) when no reflector is used.

DANGERS AND PRECAUTIONS.

Three common sources of danger in connexion with the use of artificial sources of ultra-violet radiation, and the precautions necessary to avoid them, are :

(1) The production of a severe conjunctivitis, through looking directly at an arc. Operators and patients should always wear protective goggles or shades.

(2) Over-exposure through continuing a course of treatment after replacing an old mercury vapour arc-lamp by a new one, or substituting different electrodes in an open arc. An intensity measurement should always be made when using a new source.

(3) Electric shock through touching 'live' electrical conductors. Several fatalities have occurred through the use of electrical apparatus in bath-rooms, where the conditions for short circuiting the supply through the body are almost ideal.

No installation should be set up in such a position that a patient can touch a 'live' electrode and a water-pipe or 'earthed' conductor at the same time. It is advisable to use a floor covering of linoleum or carpet.

CONTRA-INDICATIONS TO LIGHT THERAPY.

In addition to the purely physical dangers mentioned in the last paragraph, there are many physiological and pathological conditions—such as menstruation in women, low blood pressure, fever, hyper-photo-sensitiveness, etc.—which are contra-indications to the therapeutic use of ultra-violet radiation. The discussion of these lies outside the scope of the present article.

Biological Action of Ultra-Violet Rays.

By Prof. LEONARD HILL, M.B., F.R.S.

RADIATIONS from sources of energy—sun, stars, etc.—are conducted by waves in a hypothetical ether with a velocity of 186,000 miles per second in the case of light. Ether radiations include the Hertzian waves used in radio with wave-lengths extending to a thousand

metres or more, then the infra-red, with wave-lengths from 60,000 to 700 $\mu\mu$, then the visible with wave-lengths from 700 $\mu\mu$ (red) to 400 $\mu\mu$ (violet). Beyond the visible lie the invisible ultra-violet rays with wave-lengths from 400 $\mu\mu$ to 100 $\mu\mu$, and beyond these come the soft X-rays and

then the hard X-rays and the rays of radium with wave-lengths so short as $0.01 \mu\mu$.

The body of a man is screened by the horny layer of the epidermis, varying in places from some 0.02 to 0.5 mm. thick, beneath which lie the living cells of the epidermis in layers of corresponding thickness to the thin horny layer. These cells are myriad in number, and are naturally exposed to the influence of light in wild naked men. Beneath these comes the derma or true skin, in which circulates the blood through close woven networks of capillaries, in streams some 0.01 mm. thick. Among the living cells of the epidermis and in the derma are nerve endings. The epidermis reflects and scatters a part of the rays which fall upon it, but some of the visible rays penetrate and are absorbed by the blood beneath, warming this. The infra-red rays, on the other hand, are absorbed by the least layer of water; caught therefore by the wet layer of the epidermis, they warm this and warm the blood in the derma indirectly by conduction. The biologically active or middle ultra-violet rays are also very largely absorbed by the epidermis, and exert their effect there. The shorter ultra-violet rays, powerful to kill microbes, fail to penetrate the horny layer and so have no action on the skin. The longer ultra-violet rays, like the visible rays, reach the blood in the capillaries of the derma and are converted into heat.

The skin screens itself from excessive light by its horny layer and by pigment. The horny layer is thickened by ultra-violet rays killing the living cells of the epidermis, and protection is thus quickly afforded from sun burning. Pigment lying in the deeper cells of the epidermis, by absorbing visible and ultra-violet rays, screens these deeper cells and the blood in the derma. It converts visible rays into heat, and this heat, stimulating the nerve endings in the skin, may reflexly lessen body heat production while increasing body heat loss by provoking sweating and dilatation of cutaneous blood-vessels. Increased transpiration of water is the chief method of warding off excessive radiant heat when shade is not available. The increase of heat and transpiration by the visible rays is important in the treatment of wounds, etc.

The sterilising power of the ultra-violet rays, first established by Downes and Blunt (1877), is not nearly so important as has been thought, for the rays can only kill the surface bacteria; they cannot penetrate into filth any more than through the epidermis. Tubercle bacilli rotated in serum in a quartz flask under a mercury vapour lamp are not killed, so great is the protection afforded by

the proteins of the serum which absorbs the ultra-violet rays (Eidinow). In the case of tissues or infusoria screened by mesentery, there is a partial, by the skin complete, protection from the lethal action of ultra-violet rays. The penetration of the biologically active ultra-violet rays is not more than 0.25 mm. in an organ exposed to the mercury vapour lamp for an hour or two, as is demonstrated by the depth of the lesion thereby produced.

The intensity of illumination received from a point source of light is inversely proportional to the square of the distance from the source. The law is only accurate from a source sufficiently small or far enough off to be treated as a point. It does not hold for sources with reflectors behind or lenses in front of them. Only these rays which are absorbed exert an effect. When light passes through a layer of absorbing substance, the fraction transmitted depends on the nature and thickness of the substance and the wave-length; the transmission coefficient is the fraction transmitted by a layer 1 cm. thick.

If light passes two absorbing layers successively, the final fraction transmitted can be calculated by multiplying together the fraction transmitted by each layer alone. Thus, if each layer transmits $1/10$ th, two in succession transmit $1/100$ th. Epidermis 0.1 mm. thick transmits about $1/10$ th, and therefore epidermis 0.2 mm. thick transmits only $1/100$ th of the amount of active ultra-violet rays.

The biologically active region of the ultra-violet rays is round about $300 \mu\mu$. Hausser and Vahle, using equal energy values, found the maximal erythema effect at $297 \mu\mu$. Four per cent. of this effect was found at $313 \mu\mu$ and 16 per cent. at $256 \mu\mu$. The longer ultra-violet rays are little absorbed by the epidermis, and so have little action; the shorter ones are very active, but are absorbed by the horny layer of the epidermis and so do not reach the living cells. Owing to the absorption by the horny layer of the epidermis and its screening action, the living cells beneath are protected from the short ultra-violet rays of artificial sources which penetrate into and are most powerful in killing microbes, infusoria, and ciliated cells of the wind-pipe. The ultra-violet rays of the sun extend scarcely beyond $300 \mu\mu$, and the sun exerts its sun-burning action by ultra-violet rays longer than those of artificial sources such as the long flame metal cored carbon arc or mercury vapour lamp, the active rays of which are mostly of wave-length shorter than $300 \mu\mu$. Vita-glass lets 75 per cent. of the active ultra-violet rays of the sun

through, but largely reduces the active rays of the mercury vapour lamp, so that the lethal exposure for infusoria is made much longer when this screen is interposed. The rays which activate ergosterol and form vitamin D are in the region of about 280-300 $\mu\mu$; it is, then, clear skies and high sunlight, which afford rays about 300 $\mu\mu$, having this effect.

Mist, smoke-pollution, glass windows, walls and roofs, and clothes, cut out the sunlight and deprive us of the effect which the sun naturally exerts on naked wild men and animals, for example, on ergosterol, which, eaten in the food, is present in the skin, and there awaits activation into vitamin D by sunlight. It must be borne in mind that the bright sky shine is a source of ultra-violet rays, affording more (from the whole sky) than the high sun affords directly. Owing to this fact, cool ultra-violet treatment can be had from the sky without exposing febrile patients to the direct hot sun. Skyshine and earlier morning sun can be used by febrile cases of tuberculosis. To heat such patients is a disadvantage, hence the excellence of the alpine climate. Exposure to cold air stimulates the tone of the muscles and the appetite, and works, under proper control, as much good on the naked body as light does.

Rickety, weakly children kept in an open-air shed without artificial heat throughout the winter do wonderfully well, and become robust and full of life and energy. The clean cool air, absence of crowd-infection, and indoor dust, heat, and noise, work their good effects as well as light. It must always be borne in mind that the open cool air is at least as important as light in treatment of tuberculosis, wounds, etc.

We can take in vitamin D from cod-liver oil, or nowadays eat it in tabloids, the product of laboratory irradiation of ergosterol.

Not only rickets, but also osteomalacia, prevalent in the purdah women of Kashmir (Vaughan), is due to want of sunlight and vitamin D. With rickets go decay of teeth, liability to catarrhal and low infections. Open-air treatment and ultra-violet irradiation are powerful to prevent these troubles. In fowls kept under glass, ultra-violet irradiation improves the egg laying and hatching, and prevents leg weakness of chicks. Similarly, it improves the stamina and milk of cows kept in byres.

In the treatment of surgical tuberculosis and wounds, carbon arcs have advantages in yielding abundantly visible and infra-red rays as well as the ultra-violet rays. The mercury vapour lamp is relatively a cold source, but incandescent lamps can be added to it so as to make good the defi-

ciency. The monkeys, iguana lizards, and tortoises at the Zoo do well under incandescent lamps. The monkeys are also given access to open air. The conversion of visible light into blood heat is most important to all these animals. The lizards, heated up by the visible rays of the lamps, become active, hot-blooded animals as they naturally do by day under the tropical sun. Babies exposed naked under incandescent lamps and given also exposure to cool open air, would thrive as well as the monkeys do, the diet chosen being of course one fully provided with the necessary vitamins, and those other qualities required for growth and health.

The ultra-violet rays reaching the living cells of the skin and absorbed therein, cause change in atomic structure (displacement of electrons from their orbits with consequent rearrangement of molecules), which result in chemical changes ending in coagulation and death. The increasing granulation of the protoplasm of infusoria can be observed under the microscope when these animals are exposed in a water-cooled quartz chamber to the mercury vapour lamp. The same sort of change is produced whether longer or shorter wave-lengths of the active region of ultra-violet rays are used to kill. There is no evidence of specific changes set up by one or other of the different wave-lengths absorbed by the skin, other than possibly in the case of activation of ergosterol. There is no evidence that one group of the active ultra-violet rays is more or less harmful to living cells than another; the result depends on penetration and absorption. Given a sufficient dose of rays absorbed, coagulation and death takes place. The damage of the living cells in the skin produced by sunburn provokes secondarily a local hyperæmia, œdema, and leucocytosis, followed by desquamation and pigmentation. The inflammatory reaction increases the power of the blood to kill staphylococci as tested *in vitro*. In some way, as yet unexplained, it provokes better feeling of health and vigour, but overdosage may have the opposite effect. The inflammatory reaction helps the skin to recover from infections such as lupus. This terrible disease is cured by local and general light baths. Surgical tuberculosis is benefited by light and open air.

The ultra-violet rays can be used successfully for certain affections of the eye as well as skin, but all this is the province of the medical practitioner skilled in such treatment. By the general public light baths should only be used in mild doses for taking the place of natural sunlight. The body

can conveniently be divided into four parts: 1, front of body; 2, back of body; 3, front of legs; 4, back of legs. One part is bathed at a time. Two baths a week suffice. Using a long flamed arc with iron-cored carbons or a mercury vapour lamp, a 5-minutes' exposure, 2 ft. away, suffices. Large doses result in a thickened horny

layer and pigmentation which prevents the reaction of the skin. It may be as well to intermit the light bath for a month at the end of two months, and then start again. If a vita-glass screen is used, the artificial sources are made more to resemble sunlight and much safer to use. Overdosage can do more harm than good.

The Physiological Action of Ultra-Violet Radiation and its Use in the Home.

By W. KERR RUSSELL, M.D., B.S. (Dunelm).

THE founder of the science of actinotherapy was Finsen, and he published his first paper on the subject of ultra-violet radiation in 1893. His efforts were directed to the cure of lupus (the wolf), that disfiguring disease of the skin caused by the tubercle bacillus, a disease which so often causes those attacked by it to hide themselves away in order to avoid the gaze of their fellows. This new local form of treatment devised by Finsen was a wonderful success, and it was only Finsen's early death, at the age of forty-three years, that prevented him from carrying out other most important applications of the treatment. He left at his death the complete designs for a clinic in which investigations were to be undertaken for the purpose of ascertaining more exactly what affections would lend themselves to treatment by general light baths, and among the diseases in which this treatment was to be used, he expressly mentioned tuberculosis.

Describing his proposed carbon arc bath, Finsen said it consisted of a circular room in the middle of which were two gigantic arc lights of 100 amperes, suspended about six feet from the floor; by numerous radiating partitions, bath chambers were arranged in which the patients could lie naked on couches. It was, however, only after a visit to Switzerland, where Reyn, Finsen's brother-in-law, saw the successful work of Bernhard and Rollier in the cure of extra-pulmonary tuberculosis by regulated exposure to the sun's rays, that he instituted the general light bath treatment at the Finsen Institute in 1913. Then came the War, and though it is true that hundreds of thousands of wounded men were treated by physiotherapy, and that the conflict was largely responsible for bringing physical methods of treatment into prominence, it has only been during the last few years that general ultra-violet treatment has received the recognition in Great Britain which it deserves.

Actinotherapy is still in its infancy, and a great deal of research work is necessary before the

reproach of empiricism can be removed. This makes it imperative that it should only be employed with great care and discrimination. One must also remember the cruel fate which has overtaken so many of the pioneers of X-rays, and though, judging by the experience of the Finsen Institute, it is very improbable that a similar catastrophe will befall the actinotherapist, the need for the exhibition of great caution is obvious. Dosage is a very important factor in all forms of medical treatment; we make use of the beneficial action of heat when we apply a poultice to relieve the pain of inflammation, but in excess, those same heat rays can act destructively and cause a painful burn. This is the case with X-rays, where ulceration and even cancer can be caused. Ultra-violet rays, too, are harmful in excess; the same applies to drugs, most of which, given in too great doses, can act as dangerous poisons.

It is obvious that the prevention and cure of disease should principally be the concern of those who have been specially qualified by suitable training to perform this important work. Therefore, the only persons at the present moment who should undertake ultra-violet treatment are members of the medical profession. Unfortunately, anyone can at the present time administer ultra-violet or X-ray treatment to others. It is no longer fashionable for the quack to sell pills in the market-place; he much more probably nowadays administers physical treatment in some fashionable part of the town. It has been said that there is no part of medicine which is so nearly allied to quackery as is physical treatment, and this stricture will last so long as the present chaotic state of affairs is allowed to continue. The quack, with his power to issue blatant advertisements, will continue in his present affluent state, indiscriminately maltreating suffering humanity. It all reminds one strongly of a character in Shaw's sparkling play, "The Doctor's Dilemma," whose procedure was to give his advice free, the fee for the course of treatment to be paid in advance, and cure guaranteed. A correct diagnosis is the essential