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THE PENETRATION OF RAYS THROUGH THE SKIN AND  
RADIANT ENERGY FOR THE TREATMENT OF WOUNDS.<sup>1</sup>

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ACCORDING to the quantum theory a point source of radiation emits "particles" of energy, called photons, which travel in a vacuum in straight lines uniformly in all directions at the velocity of light; the intensity of such radiation received by a material is inversely proportional to the square of the distance. It is important to remember, then, that halving the distance quadruples the intensity, for example, of an arc light acting on the skin. When the source is large compared to the distance of the receiving material, for example a radium plaque, the law does not apply. The shorter the wavelength according to the electro-magnetic theory the greater the energy of radiation. The interaction of matter and radiation is an atomic phenomenon. An atom is conceived as a nucleus surrounded by electrons spinning in various orbits and bound to it. The energy of short-waved radiation is transferred to electrons which being displaced and being negatively charged attach themselves to other atoms thus forming negative ions, while the atoms deprived of electrons form positive ions. Ionization, so produced, starts chemical reactions, since through thermal agitation and the force of attraction between oppositely charged ions there results the formation of neutral atoms. The tendency of radiant energy is to transform complex into simpler elements or compounds. Through absorption of a small

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amount of radiant energy chemical changes may result within the living cell, thereby setting free more energy. Radiant energy is transferred to the cells only by absorption and interaction of radiation with matter. If the cell is transparent to a particular wave-length this has no effect upon it. The retina of the eye has been evolved as a receptor of light radiation, of extreme delicacy, being sensitive to a few quanta of energy, an inconceivably small amount. The realization of the fact that the sense organs have been evolved to put us in relation with the environment enables one to reject all forms of witchcraft such as telepathy, polytergism, and dowsing. There are no mysterious rays producing effects which are outside scientific law and explanation.

The fact that radiation produces in living cells first ionization, then chemical change, and finally alteration in the living state explains the latent time which precedes the effect. For example, sunburn results not at the time but some hours after exposure of the white skin to the midday sun. Be it noted that every ionization of atoms resulting in chemical change need not influence the stability of the living cell. There must be a certain intensity to produce an effect, and weak intensity with prolonged exposure does not give the effect of stronger intensity with shorter exposure. For the cell to be affected there must be penetration and absorption of the radiation and a certain threshold of intensity. The very shortest rays of the sun, which come through the atmosphere, are those which produce sunburn, but this is only superficial, because these short ultra-violet rays have very little power of penetrating the skin and exert their effects, therefore only on the living cells which lie just beneath the horny layer of the epidermis. The skin protects itself by thickening the horny layer. Similarly, protection against visible rays which, reaching the cutaneous blood-vessels are absorbed by the blood, is gained by the brown pigment which forms in the cells of the epidermis as the result of exposure to the sun. The reaction of the living cells of the skin to injury are alike whether produced by a blow, irritant poison, or irradiation; there results a primary active dilatation of the minute blood-vessels of the derma followed by a wider spread flare due to opening up of the arteries, accompanied by oedema, the classical reactions of inflammation. Reflex effects may be evoked by way of the nerves and affect deeper parts, and metabolites, such as histamin-like substances, absorbed from the injured parts, may affect the whole body. Irritation of the skin, however produced, whether by ultra-violet rays, heat, blistering fluid, flagellation, causes more blood and lymph and leucocytes to be brought to the irritated area, and there takes place absorption of damage products followed by processes of repair. The skin thereby stimulates the immunizing power of the body.

Cosmic rays coming from the universe, gamma rays from radium, X-rays, ultra-violet, visible and infra-red rays, and "ultra-short" waves used in radio, form one continuous spectrum of electro-magnetic waves, the various regions of which differ only in wave-length, the cosmic, gamma, and hard

X-rays, being inconceivably short and the rays used in radio many metres long. Cosmic rays have great power of penetration. Such as are absorbed in the body may expel electrons from atoms, but there is no evidence that they have any appreciable effect. It has been suggested that by action on the reproductive cells, cosmic rays may cause mutations to arise. There is no proof of this, but a certain intensity of gamma and hard X-rays can produce changes in the chromosomes of ova, whence mutations do arise. Cells in a state of division are the ones most sensitive to these penetrating rays. Cancers such as have cells actively dividing are affected more than normal tissues. Hence the use of these rays for treatment of cancer, but large doses produce destruction of normal tissues such as marrow and lymphoid tissue, leucocytes, and epithelial linings, and death ensues. The latent time for signs of damage produced in the skin by X-rays is two to five days, the gamma rays of radium two to three weeks, indicating the time it takes for the secondary changes in the living cells to appear. Workers exposed to X-rays or radio-active substances suffer from dermatitis and cancer may result, as it has, from the accidental leaving of a radon tube in the body. Cancer of the lung occurs in high degree in miners who extract pitchblende, the ore from which radium is obtained. The use of radium for treatment of cancer has resulted in not a few cases in the production of intolerable and unrelievable neuralgia. It is claimed that modern X-ray methods can do all that radium does, and that dosage can be much better controlled. Since the discovery of radium by the Curies, who made not one penny out of its exploitation, enormous sums have been paid to those who have worked radium-bearing ores and placed it on the market for curative purpose, and now, after a study of many years of experience, I myself would choose the knife or X-rays for treatment of cancer. The death-rate from cancer can be lowered by prevention of the disease and by early diagnosis and treatment by these means. Radium is only available for the few. The nation would, I think, be little the worse off if all the radium in the country now buried for security from bombing in deep holes, remained therein. Very big monetary influences will cry out against this.

We all know how X-rays, when used at first by men ignorant of its dangers, produced burns, difficult to heal, and cancer. There has been put on the market apparatus for producing very weak radio-active water to be taken by the mouth or injected under the skin; radio-active pads for external use are also advertised widely. Factory hands have died through licking brushes when applying a luminous radium paint to dials of watches. The dosage of radium to be safe has, then, to be very small. The evidence shows that radium in intensity sufficient to produce an effect is always harmful to living cells. It is claimed, however, that very small concentrations such as exist in some spa waters have a beneficial effect, but there is no evidence that spas with a higher content give better curative results than those with a low one. Radio-active pads on the market contain a little of the crude mineral ore from which radium is isolated. This costs a few pence, but

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pads are sold for ten guineas, and if electrically heated for twenty guineas. An electrically heated pad which is obtainable from any store for about thirty shillings will give all the curative effect of the twenty-guinea pad. The credulity of people about mysterious ray influences is astonishing, and they ought to be protected from the rapacity of those who take advantage of their ignorance. One kind of fraud is punished severely by the law, and another let go scot free.

Ultra-violet rays, similar in action to that of the shortest rays of the sun, are afforded by carbon arcs and mercury vapour lamps. The former can be reinforced by the use of iron or tungsten in the poles. These rays sterilize the air and the skin surface when in sufficient intensity. Owing to their slight penetration of and absorption in the epidermis, their effect is limited to the living cells therein and the capillary loops of the derma just beneath.

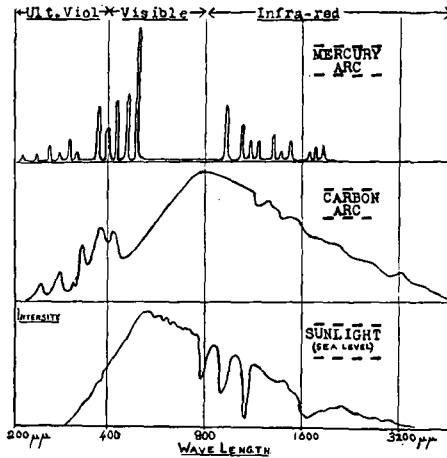


Diagram comparing the distribution of light energy from sunlight, carbon and mercury arcs.

After a latent period of a few hours the skin is reddened, and a fluid and leucocytes infiltrate the exposed area, and if the dose is intense, blistering results. The distribution of blood, lymph, and leucocytes to a wound, and the sterilizing effect has a very beneficial result; the dose must not be made too strong or the healthy granulations will be damaged. By inducing such reactions these rays have the effect of curing carbuncles and boils. To effect this result an intense dose is given to the inflamed area. Similarly, *lupus vulgaris* is cured by the immunizing power of the blood determined to the diseased area by frequent intense doses of ultra-violet rays. The rays can also be used as a blistering agent for relieving sciatica and other painful conditions, elastoplast bandage being applied immediately after irradiation so as to protect the blistered skin and prevent irritation. There are various skin diseases, acne, eczema, alopecia areata, etc., which respond

well to ultra-violet ray treatment. One of the most remarkable actions of the short ultra-violet rays is the production of vitamin D in the skin which is necessary for the growth of bones and protection from rickets. By adequate irradiation, by sun or arc lights and a supply of calcium and phosphorus salts in the diet, rickets can be prevented. Light stimulates breeding in birds, mice, and monkeys, and the introduction in the Zoo of artificial sources of such at my suggestion has made the keeping of tropical birds, lizards, monkeys, etc., easy. That great pioneer Bernhard of St. Moritz at the beginning of this century began to use light and open air for treatment of wounds, and showed in the Great War how it was possible to conserve severely injured limbs which would have been amputated by other surgeons. He used a solution of iodine to clean the wounds in all their depths and ramifications, and then exposed them to sun and air by

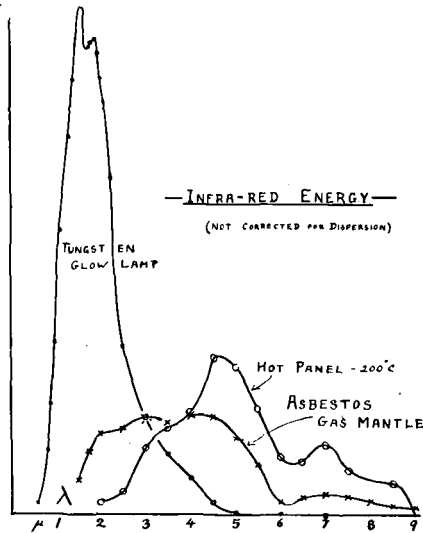


Diagram comparing the amount of infra-red energy from various sources.

day, covering them with a layer of gauze by night. To keep flies off, a covering net was used. Losing no lives from tetanus or gangrene he secured the healing of dreadful wounds. All that he did at St. Moritz can be done here by means of artificial sources of radiation, but our surgeons remain indifferent.

Bernhard uses Light Treatment for the following<sup>1</sup> :—

Traumatic wounds in which primary union from the start cannot be expected (gunshot wounds, lacerated and contused wounds).

Varicose ulcers.

Burns, frost-bites, wounds due to corrosives, X-ray burns.

<sup>1</sup> "Light Treatment in Surgery," by O. Bernhard, translated by R. King Brown. Arnold.

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Infected wounds, whitlows, carbuncles, abscesses.  
 Osteomyelitis.  
 Fractures.

He lays stress on the analgesic action of irradiation, on the fact that change of dressing is not required, and the economy of the means employed.

The short infra-red and red rays are of particular value as well as the ultra-violet rays. How far the red rays penetrate can be seen by putting a glow-lamp in the mouth in a dark room in front of a mirror, when a faint red glow will be seen to come through the cheek of a white, but not through that of a black man. Irradiation, by bringing blood into a painful part and warming and relaxing the tissues, lessens tension of the nerve-endings and relieves pain. The pain that may follow extraction of a tooth can be relieved, for example, by irradiation of the gum. For painful fibrositis, rheumatic affections of joints, lumbago, the pain accompanying herpes zoster, etc., radiant heat is most effectual.

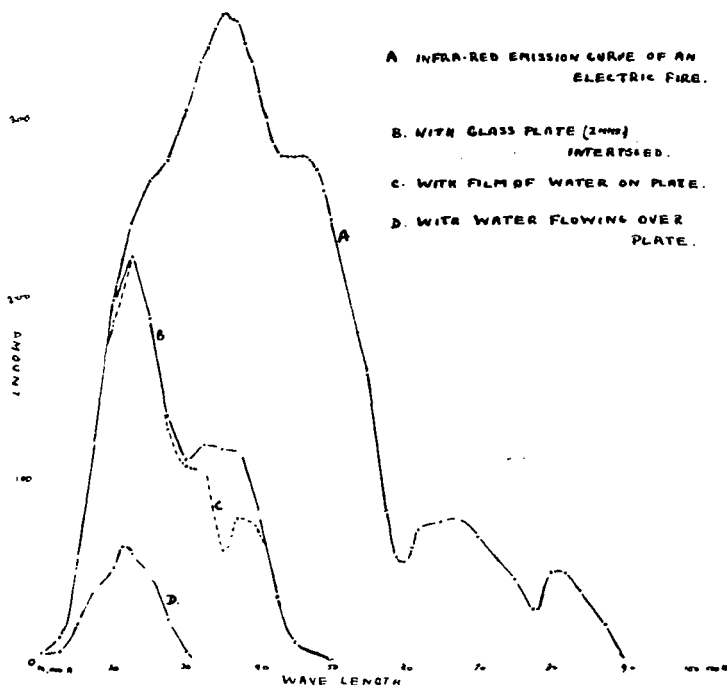
The longer infra-red rays do not penetrate the epidermis, but warm the surface of the skin whence the heat is conducted inwards. It has been claimed that the penetrating red and short infra-red rays coming from luminous sources heat the subcutaneous layer even more than the surface, but researches now being carried out by Dr. H. J. Taylor and myself show that a very sensitive thermo-electric junction introduced as a needle into the substance of the epidermis is, in fact, heated a little more than a similar junction inserted subcutaneously beneath the derma. In the case of a dark heat source, the

*Table showing Temperature of Various Parts of a Rabbit when exposed to a Carbon Arc and in a Cool Room.*

Condition	Region	Temp. °F.
Head exposed to carbon arc (50 mins.)	Fur	142·0
	Under skull	107·0
	In brain	105·5
	Rectum	101·5
In cool room (2 hours)	Fur	79·0
	Brain	95·0
	Rectum	96·0

rays of which are non-penetrating, the surface is heated notably more than the subcutaneous tissue. I have made the discovery that dark sources of heat such as steam pipes, stoves, and dull red sources, such as electric fires, by reflexly causing congestion of the mucous membrane of the air passages of the nose and lungs, tend to narrow these. Bright luminous sources have the opposite effect, the greater comfort of such sources felt by many people being thus explained. The stuffy feeling of warm rooms is due largely to the character of the radiation. The stuffy feeling in crowded rooms has nothing to do with the chemical quality of the air, neither the carbon dioxide being increased nor oxygen diminished sufficiently in such rooms to have the least physiological effect. Ventilation by cool air counteracts the stuffy effect of long infra-red rays. A greenhouse heated by the

sun feels stuffy compared with the open air, because the sunlight is absorbed by the objects within and turned into dark heat, and this is trapped by the glass, while there is no movement of cool air. My work has been confirmed by W. A. R. Thomson and by Dutch and German research workers. It has been shown by the last that dark heat rays also cause a reflex dilatation of skin areas other than that irradiated, while bright sources have the opposite effect. The difference is to be ascribed to the greater warmth of the surface of the skin produced by the dark heat sources. By acting on the epidermic nerve-endings this surface warmth produces the reflex effects. It is claimed that 1 millimetre of flesh is penetrated by 0.5 per cent of the



Infra-red emission spectrum of an electric fire.

rays from a dark heater, 15 per cent of those from a carbon arc, and about 30 per cent of those from a tungsten arc or the sun. The visible rays apart from the red are absorbed by the blood in the derma and warm this, the heat being circulated over the body.

While radiation treatment of wounds can be carried out by a mercury vapour lamp in combination with a ring of incandescent lamps, or by infra-red lamps alone, one of the best methods of applying heat to painful parts is by a wax bath at 130° F. The melted wax solidifies at skin temperature and forms a glove on the submerged part of the body, which protects the skin from over-heating, the vapour of sweat under the glove acting as an insulator. The part becomes flushed with blood bathed in transuded fluid

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and raised in temperature. The whole body may be heated up a degree or two by immersion in the wax bath of the legs up to the knees. To chilblains, aching feet, and rheumatic pains, the wax bath gives great relief. I call attention to the fact that a dark electric heater was not long ago put on the market and advertised very widely and sold for ten guineas. The advertisement claimed that this heater gave off curative rays of a wave-length which corresponds in fact to rays coming from objects colder than the body! The claim for the penetrating power of rays from this heater was based on the fact that after half an hour's irradiation there was some evidence of heat having passed through a beef steak. There would, of course, be some conduction of



Patient receiving radiant heat from clinical gas lamp.

heat from the warmed surface. Such a source is no better than an ordinary electric bowl heater which can be purchased at a store for, say, 15 shillings. Electric heaters placed on silver-plated stands and made of impressive shape are sold for many guineas for treatment purposes, when an ordinary electric or gas heater gives just as good results. At my suggestion an infra-red source, of an effective and economic pattern, has been made to run on gas. There is a disc made of a radiating material which gives off a fair percentage of short infra rays heated to incandescence by a bunsen flame; the rays are concentrated by a concave metal reflector. The rays from such a source can be kept on as long as the patient likes, the intensity of course being such as



not to burn him. For inflammatory conditions such prolonged irradiation is of great value.

Beyond the infra-red rays are those long-wave lengths which are used in radio. The invention of the short-wave vacuum tube oscillator has allowed us to study what are called "ultra-short" waves, but it is not possible as yet to generate any intensity of wave-lengths less than one metre. The "ultra-short wave" instrument giving a wave-length of six metres puts the living tissues placed in the field between condenser plates into electrical stress, the electrons of atoms being driven first one way and then the other. This results in heating of the tissues. Artificial fever can be produced by putting the whole body with the exclusion of the head in the field; the temperature can be raised even to 105-106° F. in an hour or so. Great care has to be taken of the patient. Gonococcal infection is thus destroyed, while general paralysis of the insane can be treated successfully by this method in place of the induction of malarial fever. Local heating can be produced by placing the electrodes (not touching) on either side, for example of the face, and the temperature of the mouth and nose raised thereby to 101-102° F. in some twenty minutes. Similarly the rectum, and the urine in the bladder, may be heated by placing the electrodes on either side of the hips. This shows how the heating effect penetrates through the body in contrast to other sources of radiant heat, including diathermic ones with longer wave-lengths such as 300 to 400 metres, which penetrate only a little distance and heat deeper parts, if at all, merely by conduction. The "ultra-short" wave machine affords a new and most valuable method of treating all kinds of inflammation, for example sinusitis, tonsillitis, appendicitis, pneumonia and pleural infection, carbuncles, and inflamed wounds, etc. There is no evidence of any specific effect, as has been claimed, apart from that of heat. Dr. H. J. Taylor and I have shown that infusoria, the living heart, ciliated cells, and muscle nerve preparations of the frog, when put in the "ultra-short" wave-field suffer no change so long as they are kept cold. When allowed to be heated by the field they become affected just as they are by a rising temperature brought about by any ordinary means of heating. Claims are made that an apparatus giving an "ultra-short" field too weak to have any heating effect, exerts a beneficial effect on patients. The power of suggestion must be taken into account. Thus, for example, almost any new form of treatment will relieve asthmatics for a time. The psychological effect of suggestion is the main stock-in-trade of quack remedies, while nature cures many ills.