left knee could be flexed and extended, and the right knee very slightly so. Fig. 2 shows the sensory disturbance at this time; in addition the sense of position of movement was lost in the whole of the right lower extremity, but was present in the left, except in the great toe.

Fig. 2.—January 21st, 1914, before radium. Deeply shaded areas = loss of sensation to pain, light touch, heat, and cold; elsewhere light touch normally felt. Oblique lines = heat and cold not distinguished; both called "warm." Horizontal broken lines = pinprick not felt, or only as touch.

She was unable to stand or walk, and was therefore paraplegic, with considerable loss of sensation and with retention of urine.

On applying to Mr. Hayward Pinch, of the Radium Institute, he kindly supplied 50 mg. of radium in a specially devised tube, so that it could be placed alongside the spinal cord in the spinal canal. On January 28th, 1914, the wound was reopened, and the tube placed alongside the cord over the tumour, outside the dura mater, fixed in this position, and left there for twenty-two hours.

Some days later she began to show slight signs of improvement, and there was great relief of pain. On February 18th, although there was still complete foot-drop, she could move the toes of the left foot, she could draw up either leg, raise it off the bed, could flex and extend the knees, and could also raise both legs off the bed at the same time. She could also sit up in bed and raise herself to a sitting posture without the aid of the arms. The legs were no longer drawn up, but could be kept extended in bed in a natural condition without pain. For the first time for many months the feet felt warm.

Shortly afterwards she was able to sit up in a chair, and by March 3rd she could sit up for some hours, could stand unsupported for a few moments, and was able to take a few steps without support. The double foot-drop which persisted was, however, a great hindrance to movement. The muscles below the knee on the right side were degenerated, and did not react to faradism, and on the left there was a feeble reaction in the tibialis anticus and peronei only. The improvement in sensory disturbances is manifest from Fig. 3. The retention of urine continued, and no urine was evacuated without the catheter, which was always carefully sterilized.

Unfortunately at this time the bladder again became more irritable, and she had an attack of acute cystitis, with alkaline, offensive urine containing a quantity of pus. There was also much bladder pain, and, being always a nervous girl, and now weak from her long illness, the pain and loss of sleep upset her altogether. She was constantly crying out for the catheter, and at times was in a greatly excited, semi-delirious state, when it was very difficult to pacify her. The temperature was only slightly raised at first, but about March 18th and afterwards it rose to 102° and 103° every night. The urine was found to

Fig. 3.—February 18th, 1914, twenty days after radium. Tactile sensation (cotton-wool) normal, except over dark shading. Right leg, dark shading = sensation lost to pain, light touch, heat and cold. Right leg, broken horizontal lines = pin felt as touch only. Left leg, oblique lines = heat and cold (ice) not distinguished, both called "warm." Localization good.

contain *B. coli*, and the amount of pus and blood was so great as to suggest the severe cystitis that accompanies a stone or growth in the bladder. An autogenous vaccine was prepared as soon as possible; two doses were given, but without effect. She rapidly lost strength, and died on March 27th, apparently from exhaustion. No *post-mortem* examination was permitted.

Conclusion.

This result was very unfortunate and most disappointing, as it seemed before the onset of the cystitis that the treatment by radium was likely to result in a considerable degree of recovery, possibly nearly complete recovery; and it is for this reason that the case is published, as it seems to show that it would be worth while to try a similar procedure in a case of the same kind.

The progress of recovery after the use of radium can be best compared to that seen in cases of extra-medullary tumour of spinal cord after the removal of the growth, and was proceeding at about the same rate and in the same way and order as in those cases—that is, relief of pain, recovery of sensation in least affected areas, recovery of power in least affected muscles, and in those which had not undergone degeneration. In the muscles below the knees which had been wasted and degenerated for some time, recovery could in any case not be expected for many months, and probably would not be complete. The bladder disturbance was throughout one of the chief difficulties in dealing with the case; it may have been aggravated by the fact that she had worked for a long time in an office where there were no sanitary conveniences, and she would go all day without passing water. In the early part of her illness she often did not pass water for twenty-four hours.

Lastly, a word of reference may be made to the yellowish pigment, lutein, in the cerebro-spinal fluid. In our experience at the Bristol General Hospital this pigment has never been found in the cerebro-spinal fluid except in cases of tumour, and its presence may be taken as a valuable confirmatory sign.

ON THE RESPECTIVE ADVANTAGES AND DIS-ADVANTAGES OF X-RAYS AND RADIUM IN THE TREATMENT OF CANCER.

By FRANCIS HERNAMAN-JOHNSON, M.D.,

CONSULTING RADIOLOGIST TO THE DARLINGTON EDUCATION COMMITTEE; LATE SURGEON, ROYAL NAVAL HOSPITAL, PLYMOUTH.

THE activity of radium is often looked on as something mysterious and apart—as a phenomenon having no parallel elsewhere in nature. The truth is, that a very close similarity exists between the radiations of radium and those given off by an x-ray bulb.

Sir William Crookes, by whose name the modern x-ray tube is still sometimes called, announced more than thirty years ago that substances may exist in a state where atomic—that is, elemental—distinctions no longer hold; and in speaking of his discoveries he used the prophetic term, *radiant matter*. The best known form of radiant matter is the electron, or particle charged with negative electricity. Normally, electrons are bound up with atoms, but they may be set in linear motion either artificially, as when a current of high potential electricity is passed through a vacuum tube; or spontaneously in certain elements, notably radium. When an electron is either violently accelerated or suddenly stopped, a pulse or wave is produced in the ether, which, when proceeding from a highly exhausted Roentgen bulb, or from a piece of radium, has remarkable powers of penetrating matter. In the case of the former, a stream of electrons from the cathode or negative pole is made to impinge on a platinum target, and the desired ether pulse is produced by their stoppage; but in the case of the radio-active elements, atomic explosions are continually going on, and electrons are shot out with extreme violence. At the moment of emission ether pulses are generated comparable with those proceeding from the target of a Crookes tube.

* Read before the Darlington Division of the British Medical Association.

In these days a Roentgen bulb is practically never allowed to act on the skin except through a sheet of aluminium; similarly, radium is nearly always used in metal tubes of silver or platinum. This greatly simplifies comparisons, as it means that in both cases therapeutic results are looked for only from the ether pulses previously referred to, and not from the electrons themselves. To the waves from a Roentgen bulb the term "*x* rays" has been applied; while certain penetrating waves from a radium tube have been called "*gamma* rays." These terms are convenient, but arbitrary; as physicists are of opinion that the ether pulses in each case are identical in all save penetrative power.

When *x* or gamma rays penetrate into the tissues, a number of them give up their energy to set free electrons within the body. These electrons in turn produce ionic and chemical, and, finally, physiological effects. Within certain limits, the higher the speed of the liberated electrons, the more intense is their effect—in fact, *a comparatively small number of rapidly moving electrons seems able to produce more striking results than slow-moving ones in any quantity.*

The rays from a Roentgen bulb or a radium tube obey the general law of the conservation of energy—they can endow electrons in the tissues only with the energy originally put into their own creation. The energy imparted to an electron expelled from an exploding atom of radium appears to be at least four or five times greater than anything we can produce in a Roentgen bulb. Thus the gamma ray penetrates four or five times as deeply, and gives rise to electrons moving four or five times as fast as those produced by the hardest *x* rays. Here, then, we have some sort of physical basis for any difference of therapeutic action which may be observed with radiation from the two sources.

Clinical experience has shown us that to get the best results from *x*-ray treatment we must use the most penetrating tubes we can obtain; and in some instances gamma rays have effected a cure where the Roentgen bulb has failed. It would be a mistake to think that this is often seen, but it does occur. Sir Alfred Pearce Gould, speaking at the Brighton Meeting of the British Medical Association, gave it as his opinion that for surface conditions it does not matter much whether *x* rays or radium are used; but I have occasionally seen a rodent ulcer which resisted Roentgen treatment subsequently yield quickly to radium. The idea underlying Sir Alfred Pearce Gould's statement seems to be that the superiority of the radium tube lies solely in the fact that it can be brought into more intimate contact with deep-seated tumours than is possible with a Roentgen bulb; but there is more in the matter than a mere question of accessibility. Gamma rays liberate in the tissues faster electrons than *x* rays, which means that their physiological effects can never be precisely the same.

But while this is so, it would not be correct to assume that rays so penetrating as those of radium are necessarily the best possible for therapeutic purposes. We know that hard *x* rays give, in the majority of cases, results quite as good as those to be obtained from radium, despite the fact that their penetration ratio is only as 1 to 5. It is, indeed, quite reasonable to think that the various rays of *x* type may be arranged in a curve of therapeutic value, this latter rising up to a certain degree of penetration, and then gradually falling again. To quote an analogy, if we apply a continuous current to a muscle, no contraction takes place after the first contact; but if we make and break the current, a gradually increasing tetanizing effect is produced up to a definite point, after which a further increase in the number of interruptions per second causes a falling-off of efficiency.

To return to the question of *x* rays and radium: between 1 and 5 there must exist a whole gamut of frequencies, any one of which may prove to be the therapeutic optimum. Put in another way, the curve ascends regularly from soft, through medium, to hard *x* rays. Between these latter and gamma rays there is a very wide gap; and whether gamma rays should be plotted as on the still ascending portion of the curve, or on its summit, or on its descending portion, we are as yet ignorant.

* Under exceptional experimental conditions the electrons in an *x*-ray tube may more nearly approach the speed of the radium electron (beta ray). But such penetration cannot as yet be obtained in therapeutic work.

Writers on radium treatment, when they give any recognition at all to Roentgen therapy in cancer, claim that the former possesses two great advantages over the latter.

First, they assert that the intrinsic therapeutic value of gamma rays is superior to that of *x* rays. This may be to some extent conceded; but the superiority, such as it is, is not due to any mysterious or unbridgeable difference between the two, the gamma ray being, physically considered, merely a very hard type of *x* ray. The limit of penetration in *x* rays has not yet been reached even on existing lines of development; and investigations are at present in progress in America which may give us a much more powerful Roentgen bulb than any hitherto considered possible. Unlike *x* rays, the gamma rays of radium are of fixed penetration. Thus the scientific future of the *x*-ray bulb is more promising than that of the radium tube. In the latter case, therapeutic experiment can proceed only on the lines of varying dosage; whereas in coming years the physicist may be confidently looked to to provide us with *x* rays of almost infinitely varying quality.

Secondly, it is urged on behalf of radium that tubes containing it can be brought into intimate contact with malignant growths—can, in fact, be buried therein by the surgeon. *X* rays, on the other hand, as generally applied, have to pass through the skin and superjacent tissues in order to reach the site of disease. Radium tubes can also be readily introduced into the rectum, vagina, and uterus; the oesophagus, and even the stomach.

Although this is an advantage that will probably always rest with radium so far as very small cavities are concerned, yet it is possible to construct *x*-ray bulbs which can be introduced into the vagina and rectum, and, through appropriate incisions, into the interior of tumours.

They are made with only one terminal—the cathode—and need a special form of apparatus to excite them. A long narrow tubular projection is provided for insertion into the natural cavity or artificial opening as the case may be.

The production of a powerful *x* or gamma radiation in the interior of a malignant neoplasm appears at first sight to be a proceeding having everything to recommend it. In a large number of cases, however, the method of tube burial is quite unsuitable; but even where there exists an inoperable tumour of considerable size, the insertion of tubes is by no means all that should be done from a radio-therapeutic point of view.

When a small amount of radium is inserted into the middle of a growth, we have practically a point source of radiation. Rays proceed in all directions, and, according to the law of squares, their intensity falls away in a curve of rapidly increasing steepness, so that at a distance, say, of 4 cm., their value is only one-sixteenth of what it is at 1 cm. Leaving aside the question as to whether gamma rays in weak doses may actually stimulate a malignant growth, it is yet quite obvious that a destruction of tumour cells, proceeding even to necrosis, may take place in the centre of the tumour, while the outlying parts are not even temporarily checked. This disproportionate effect may be to some extent modified by enclosing the radium tube in a celluloid case at least half an inch in diameter, and also by burying several tubes in various parts of the growth. Such methods demand the possession of large quantities of radium, and even then do not secure anything like uniformity of action throughout the growth.

So far I have considered only the effect of gamma rays on the tumour itself. But this is only half the problem. The local spread of a cancerous growth is normally resisted by the surrounding tissues, and it is possible either to raise or lower their defensive powers. The clinical effect of judicious irradiation of a rodent ulcer is interesting to watch. At one and the same time normal epithelium is induced to grow across the raw surface, while outlying ridges and nodules of cancer cells gradually disappear. I laid stress on this dual action in a paper read before the annual meeting of the British Medical Association at Liverpool in 1912; and Dr. E. H. Shaw, writing independently, pointed out upon the same occasion that a microscopic examination of irradiated tissues shows degeneration of malignant cells proceeding coincidentally with vigorous defensive reaction on the part of invaded structures.

The efficient treatment of any cancer case by radio-therapeutic means demands that the stimulation of normal adjacent tissues to increased resistance be kept

in view equally with the destruction of cells actually malignant. Herein lies the weak point of all burying methods. If a single tube be inserted into the centre of the growth, its activity at the circumference is too feeble; whereas if other tubes be buried near the periphery, the effect on the surrounding parts cannot be accurately gauged. The literature of the radium therapy of cancer contains numerous instances, on the one hand, of failure to destroy outlying portions of a neoplasm; and, on the other, of injury and sometimes massive destruction of healthy cells. It may be argued that unless some vital organ is injured such destruction is not a very serious matter, as the wound will ultimately heal, while the outposts of the cancer will certainly be annihilated. The matter is, unfortunately, not so simple as this. For while it is true in general that gamma rays, in common with x rays, destroy cancer cells in doses which not only do not hurt, but may even stimulate normal cells, yet there is reason to believe that here and there, in accordance with the biological law of variation, malignant cells occur which are not killed, but only paralysed for the time being. These, recovering after a few days or weeks, and finding only damaged tissues to oppose them, multiply and spread more rapidly than if no treatment had been applied.

With our present knowledge of radium it is impossible to be reasonably certain of doing no harm to normal structures; but sufficient experience has already been accumulated to enable us to give an x -ray dosage which shall depress cancer cells, while at the same time aiding the resisting power of the body. So far from seeking to limit x -ray dosage to the tumour itself, we should endeavour to bring as wide a surrounding area as possible into the field of irradiation. As there is practically no limit to the quantity of x rays which we can produce within a reasonable exposure time, it is possible to suspend the Roentgen bulb at least a foot above the skin. A large area is thus affected, and, so far as spreading is concerned, the loss of activity below the surface is trifling. For practical purposes the beam may be considered as consisting of parallel rays. Such diminution as occurs is due almost entirely to absorption in passing through the tissues. For instance, one half the activity may be gone at a distance of between one and two inches. In most cases, however, this difficulty may be got over by using two or more "ports of entry"—for example, a tumour of the lung may be attacked simultaneously from in front and from behind. In the case of radium, loss by absorption may be disregarded, owing to the extraordinary penetrative powers of the gamma ray; but loss by divergence is so enormous as to outweigh entirely the advantages of relative hardness.

Whatever risks may be involved in the treatment of inoperable cancerous growths by radium tubes are naturally very much increased when we are dealing with pre-operative or prophylactic post-operative raying. In the latter case we are dealing with normal structures in which we fear a few scattered malignant cells may be lurking; and our object is to stimulate the tissues to expel the enemy, rather than to attack him directly. Again, the treatment must include all organs which experience teaches are likely to be invaded, thus rendering a very extensive irradiation necessary. If we are going to irradiate previous to operation we must be careful to do nothing which shall interfere with the quick healing of the wound. The effects of radium on normal tissues are so little under control that its use is quite unjustifiable for either of the above purposes.

It must be admitted frankly that many of the advantages of x rays over radium would vanish if the latter could be obtained in bulk. But there appears to be no immediate prospect of any great increase in the world's radium supply, and it behoves medical men to be very careful that patients are not denied the advantages of radio-therapeutic treatment because radium itself is not available. The technique of deep Roentgen therapy has made enormous strides of late years, and many independent observers—for example, Professor Bumm—are of opinion that x rays, properly applied, will in most cases give results as good as those of radium itself.

"Cures" of cancer by x rays are now seldom reported, while descriptions of the wonderful results of radium treatment are frequent. Experience over a number of years has taught x -ray workers to look for temporary improvement as a matter of course. In breast cases, for

instance, anything from one to three years' prolongation of life is so usual as to be almost the rule. One is accustomed to seeing recurrent growths disappear in a few weeks, with apparent complete restoration to health. Such results, when produced by radium, are looked on as marvellous, chiefly because they are now seen for the first time by men who had no previous belief in the efficacy of radio-therapeutics in any form. The surgeon can himself obtain and bury a tube of radium, and, if he is lucky, may get a brilliant result. But true progress can come about only by the co-operation of the surgeon and the professional radiologist. I have tried to show that radium therapy is only a part of the great subject of radio- and electro-therapeutics—a subject which is in itself already almost too wide to be compassed by any single mind. Workers who are spending their lives in this study, and finding it every day more complex, are sometimes appalled at the light-hearted manner in which experiments are made and rules laid down by men whose specialities avowedly lie in other directions.

SUMMARY.

In early cases, whether for pre-operative or post-operative irradiation, the Roentgen bulb is to be preferred to the radium tube.

When surgical removal is impossible, a tube of radium should be buried in the centre of the tumour, but x rays should be used, in addition, to the surrounding area, and to any organs where a metastasis is likely to occur. This combined treatment may result in some actual necrosis in the immediate neighbourhood of the radium, but so long as this is confined to the interior of the neoplasm, no harm will result.

Finally, radium therapy is the method of choice in cancer of the vagina, uterus, and rectum; but even here x rays form a useful adjunct, so far as adjacent parts are concerned. Also, in practice one finds that one has to wait at least three or four weeks to obtain a supply of radium. Nothing less than 50 mg. is of much value, and the market price of this is £800 to £1,000. Consequently, most people have to hire their supplies, and pending their arrival x rays should be used vigorously in all cases. Even uterine, rectal, and oesophageal cancer can usually thus be held in check during the unavoidable period of waiting.

There are to-day thousands of cancer patients who believe, and whose friends believe, that they are being left to die because sufficient radium is not available to treat them. This belief adds greatly to their mental distress, and I have endeavoured to show that it is for the most part erroneous.

The Roentgen rays skilfully applied are of service in relieving pain, preventing ulceration, and causing the shrinkage or disappearance of external growths. Active life can be prolonged almost always for months, and sometimes for years. In pelvic cancer the insertion of a radium tube appears to be of greater value; but there is as yet little evidence to show that the results of the new therapy are, on the whole, more lasting than those of the older method.

PAINFUL SHOULDERS AND THEIR TREATMENT BY PHYSICAL MEASURES.

BY

JOHN J. GRACE, F.R.C.S.,

CHIEF ASSISTANT, x -RAY DEPARTMENT, ST. BARTHOLOMEW'S HOSPITAL.

THE subject of painful shoulders is one of abiding interest to those who suffer from them. For more years than I like to think of I suffered on occasions from pain in the left shoulder. This came on after walking a few miles, and more particularly after standing about, but not at games or any active exercise, except walking. It began with a few slight twinges and progressed to severe pain, which increased until I was compelled to sit down, when it was relieved in a few minutes.

I consulted various people about it and had various treatments. At Rotorua, New Zealand, I had massage with the constant current and the Rotorua douche, a combination of the Vichy and Scotch douche, on alternate days, with marked temporary relief. Two years ago I had