the conception that the neutralization of the acid gastric juice by the regurgitant fluid through a gastro-enterostomy is due mainly, if not entirely, to the bile contained in that fluid. Whilst good results have been reported in cases of gastric ulcer so highly situated in the lesser curvature as to preclude excision, and in a number of cases of doubtful pathology with hyperacidity as their dominant symptom, the basis of the method is insecure, as bile in itself is not alkaline, and after a gastro-intestinal anastomosis it is the duodenal and pancreatic secretions rather than the bile which give the regurgitant fluid its neutralizing properties. I have carried out this operation in only two ulcer cases, one of very high lesser curvature ulcer and one of gastro-jejunal ulcer. In both cases some immediate improvement resulted, but the symptoms of acidity and pain returned.

ULCER AS ONE OF MANY SEPTIC FOCI.

No treatment of ulcer can bear the promise of lasting cure if it does not take cognizance of the other foci of infection which accompany it. The prevalence of dental infection is to my mind the most important single factor in determining the frequency of peptic ulcer. It is indeed surprising to find in the vast majority of the patients sent for surgical operation after ineffective medical treatment that gross dental infection has been left untreated. In many of these cases we recover from the pyorrhoeal pockets the same streptococcus as we find in the ulcer. Efficient dental treatment must, therefore, be a first consideration, no matter what other lines of therapy we may follow.

It is within the abdomen, however, that we so frequently find other infective foci which must be dealt with at the same time as the ulcer. The combination of an ulcer in the stomach or duodenum or both with infection in both gall-bladder and appendix is quite common. All three lesions must be dealt with if complete and lasting relief is to be obtained. The following brief note of a case will illustrate the significance of a thorough eradication of foci.

Mr. A. B., aged 57, had thirteen years previously had a gastro-enterostomy performed for duodenal ulcer. He obtained some temporary relief, but his old pain soon returned; he suffered from nausea, flatulence, and constant abdominal discomfort, and led the life of a chronic dyspeptic. On examination we found him emaciated, with a dilated stomach and tenderness over three points in the abdomen—just to the left of the umbilicus, just below the right costal margin, and in the right iliac fossa. X-ray examination showed his stomach to be dilated, the stoma stenosed and irregular, evidently from a jejunal ulcer. At operation a jejunal ulcer was found and excised and his stoma enlarged. His gall-bladder was thickened and inflamed, as was his appendix; both were removed. Regional lymph glands were taken from all three sites and from all the *Streptococcus viridans* was grown in pure culture. On injection into rabbits both cholecystitis and duodenal ulcer were produced. Since the second operation the patient has enjoyed perfect health and lost all his dyspeptic symptoms.

It may be that we shall eventually succeed by suitable inoculation in immunizing patients against these multiple streptococcal abdominal lesions, or, still better, by timely dental treatment and better dietary and hygienic treatment, in preventing them. Till then, however, surgery must continue to play a part in dealing with the full-blown lesions, and surgery, whilst conserving healthy tissue, must deal thoroughly and radically with the different foci.

An Address

ON

RADIUM AND ITS SURGICAL APPLICATIONS.

GIVEN BEFORE THE BRISTOL MEDICO-CHIRURGICAL SOCIETY
BY

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RADIUM was discovered by Madame Curie in 1898, and its discovery marks an epoch in the history of science. It destroyed at one blow the conception of the atom as an indestructible unit, upon which the whole of chemistry and the greater part of physics had been built, and it opened up a field of investigation which has provided work for physicists for the last thirty years, and has led to discoveries which have revolutionized all our ideas of the physical universe.

Soon after the element had been isolated Becquerel, by inadvertently carrying radium in his pocket, discovered its destructive action on the human tissues, but although attempts were made to turn this to surgical advantage, it was only in isolated cases and in special regions that effective results were obtained. Whilst fully recognizing the value of the work done with radium in diseases of the skin and in carcinoma of the cervix, one must admit that only lately have the surgical possibilities of radium been appreciated, or any attempt been made to exploit its powers. Indeed, those who have had the opportunity of studying the subject must feel that we are only at the beginning of what may prove to be a new epoch in the treatment of malignant disease. For the first time in the history of medical science we hold in our hands a power which beyond any question can cure cancer in many of its forms, and which can destroy a malignant growth without its surgical removal, and it is our business to explore its possibilities to their utmost limits.

This is a subject which none of us can afford to neglect, and it is essential that every surgeon should realize what can be done with radium and understand the methods by which it is applied. To use it effectively he must know something of the physical properties of the new weapon which has been placed in his hands, and I therefore make no apology in describing briefly those physical properties

which are fundamental in the action of radium when it is used by the surgeon.

The revolutionary conception involved in the discovery of radium was the idea that an element could decay, and in the process of decay be transformed into an entirely different substance. It has been established, however, beyond any possible question that certain elements possess this power, and they can indeed be arranged in a number of definite series in which each element is the product of the last. The most important of these is the uranium series in which radium occurs, and you will see the parentage and descendants of radium set out in the family tree shown in Table I. Not only do we know its family

TABLE I.—The Uranium Series.

Element.	Atomic Weight.	Radiation.	Half-value Period.
Uranium 1	238	$\alpha \beta \beta$	5,000,000,000 years.
Uranium 2	234	α	2,000,000 years.
Ionium	230	α	140,000 years.
Radium	226	$\alpha (\beta)$	1,750 years.
Radon	222	α	3.85 days.
Radium A	218	α	3 minutes.
Radium B	214	$\beta (\gamma)$	26.7 minutes.
Radium C	214	$\alpha \beta \gamma$	19.5 minutes.
Radium D	210	β	17 years.
Radium E	210	β	5 days.
Polonium	210	α	136 days.
Lead	206	—	—

history, but we know the expectation of life of each of its members, as represented by its half-value period, the time in which one-half of the element has disappeared, and you will see that this varies considerably, since while uranium 1 attains the patriarchal age of five thousand million years, radium itself is half gone in 1,750 years, and radium A in three minutes. It is indeed to this rapid decay of radon and the other elements in the centre of the table that we owe the surgical possibilities of radium. There is something which stirs me profoundly in this dry table. The

evolution of uranium occupies a period of five thousand million years, and it began perhaps when our world was a glowing nebula. For a few days only it exists as radon; for those few days perhaps—we are not yet quite certain—it offers to us the cure of cancer.

We have spoken of "decay," but in order to understand the real meaning of the term and its importance for our subject we must first say something of the modern view of the structure of the atom. We owe to Rutherford the conception of the atom as a minute solar system, in which the nucleus is the sun, whilst the electrons flying round it with inconceivable velocity are the planets. In very general terms radio-activity and mass are properties of the nucleus, whilst chemical affinities and spectroscopic properties are manifestations of the flying electrons. The electrons are all identical, each carrying the same negative charge; the nuclei are all different, but they are built up of the same units, electrons carrying a negative charge, and protons which each carry an exactly equal positive charge.

The simplest atom of all is the hydrogen atom, consisting of a single proton as nucleus, with a single electron flying round it. Next in order comes the helium atom, its nucleus built up of four protons and two electrons welded together, whilst its planetary system consists of two electrons whirling round the nucleus. To us its importance can scarcely be exaggerated, for the nucleus is identical with the alpha particle, so that an alpha particle may be regarded as a helium atom deprived of its two planetary electrons, whilst it does not require much imagination to see that it must carry a positive charge exactly double the negative charge carried by each electron. When we point out that the electron, set free to fly through space, is the beta particle, and that with its liberation is bound up the production of gamma rays, it will be realized that the helium atom carries in miniature the whole physical basis of our subject.

Contrasted with these simple structures the radium atom presents an enormous complexity. Its nucleus is a dense cluster of 226 protons and 138 electrons, some at least of which are grouped together to form alpha particles, whilst around this nucleus whirl no fewer than 88 electrons. The formation is unstable and alpha particles are being constantly discharged from the nucleus, beta particles from the nucleus and from the planetary system. As each particle is projected into space the characters of the atom are changed. It is no longer radium, but one of its derivatives, and this is the physical interpretation of "decay." Radium becomes radon; radon becomes radium "A," which is so unstable that within a few minutes it has lost an alpha particle and become radium "B." Finally stability is reached in an atom indistinguishable from that of lead, and so far as we know no further change occurs.

If nothing further were said a very false impression might be gained of atomic structure, for I have said nothing at all about the size of the atom as a whole, or the relative sizes of its parts. The atom is so minute that to form any real impression of its size we must take an entirely new unit for our measurements; the most convenient is the Angström unit, one hundred millionth of a centimetre, often denoted by the symbol A.U. On this scale the wave-length of green light, in the middle of the visible spectrum, is 5,000 A.U.; the wave-length of x rays ranges between 12 A.U. for the soft rays and 0.5 A.U. for the hard rays; and the wave-length of the softest gamma rays is 1 A.U., whilst the hard gamma rays may be as short as 0.04 A.U.

On this scale the diameter of the hydrogen atom is almost exactly 1 A.U., but this is the diameter of the orbit of

TABLE II.—Dimensions of Waves and Atoms.

Angström Unit (A.U.)	1/10,000,000 millimetre.
Wave length of green light	5,000 A.U.
" of x rays	12 A.U. to 0.5 A.U.
" of gamma rays... ..	1 A.U. to 0.04 A.U.
Diameter of hydrogen atom... ..	1 A.U.
" of nucleus	1/25,000 A.U.
" electron (β particle)	1/25,000 A.U.

the electron as it whirls through space around the nucleus. The diameters of the nucleus and electron are far smaller, each being about 1/25,000 A.U. You may, indeed, represent the hydrogen atom by one golf ball travelling around another in an orbit about a mile across. On the same scale the diameter of a single tissue cell would be about 100,000 miles. When we talk about the impact of beta particles on the tissues it is well to bear these facts in mind. Even the most enthusiastic golfer will see something remarkable in the destruction, by quite a large number of golf balls, of an object relatively

fifty times the diameter of the moon. And when, as will appear later, he sees that the destruction may equally well be produced not by the golf balls themselves but by the ether waves—gamma rays—which accompany their discharge, he will probably require the next letter of the Greek alphabet to express his feelings.

We are now at last in a position to understand the property of radium which gives to it for us its peculiar

Transparency of metals to beta and gamma rays.

value, the radiation which accompanies decay. As we have seen, it takes three forms, the alpha, beta, and gamma rays, and we may now sum up briefly the very different characteristics of these three forms.

The alpha rays consist of particles identical with the nucleus of helium, each carrying a positive charge of electricity, and they are projected from the nucleus with a velocity of 10,000 miles a second. In spite of this terrific velocity they have little power of penetration and are stopped by a thin sheet of paper. Even in air they rarely travel further than a couple of inches, so that although they carry the great bulk of the energy produced by the dissolution of radium they are of no practical value in surgery.

The beta rays are formed by electrons, of very small mass, carrying a unit negative charge of electricity, and projected with any velocity up to 180,000 miles a second, falling just short of the velocity of light. The soft rays of low velocity are easily stopped by a thin sheet of aluminium, but the hard rays of high velocity can pass through 0.2 mm. of silver. All but a small percentage of beta rays are, however, stopped by 0.3 mm. of platinum or by a centimetre of the body tissues. Their surgical action is therefore very local, and it is often better to avoid it altogether by the use of screens.

The gamma rays are ether waves of exceedingly short wave-length, less than 1/5,000 of that of light. They are set up apparently by the discharge of the beta particles, they travel with the velocity of light, and their power of penetration is so great that they are scarcely affected by the screens which almost abolish beta rays; they can pass through several inches of lead, and they are only reduced by about 50 per cent. in passing through four inches of the body tissues.

It is thus upon the beta and the gamma rays that the surgical action of radium depends. The former are destructive in their effect, and they are chiefly used in surface applicators for the production of superficial scarring. The gamma rays, on the other hand, have two very remarkable effects: they stimulate the activity of the tissue cells, and especially the production of fibroblasts, and they have a definite selective action on tumour cells, probably, at the moment of their division, causing them to disintegrate and disappear. Their total effect when they can be suitably applied is to cause the disappearance of a malignant tumour and its replacement by a scar.

I must say one word more about the process of decay. The decay of radium is so slow that where we use the element itself we may regard it as a constant source of radiation. It produces radon at a constant rate, and this by its decay produces its still less stable products with mathematical uniformity. In many instances, however, it is more convenient to use radon rather than the element itself, and the whole situation is then entirely changed. Let us consider for a moment the properties of this extraordinary substance, still more remarkable than the radium from which it springs.

Radon, the emanation of radium, is the very spirit through which it exercises its powers. It is a heavy inert gas with no known chemical affinities, and it decays with such rapidity that in 3.85 days one-half of it has vanished, whilst at the end of nine days only a fifth remains. So long as it remains in contact with radium the decay is made up by production, so that after a certain time equilibrium is established. If radium is left undisturbed this is reached in about a month, and thereafter production and decay exactly balance. At this stage radium has reached its maximum radio-active power, and the radio-active power of a milligram of element is defined as a millicurie.

TABLE III.—Decay of Radium Emanation.

Days.	Millicuries.	Days.	Millicuries.
0	100	12	11.5
1	83.5	14	8.0
2	69.8	16	5.6
3	58.3	18	3.9
4	48.7	20	2.7
5	40.7	22	1.9
6	34.0	24	1.3
7	28.4	26	0.93
8	23.7	28	0.65
9	19.8	30	0.45
10	16.5

And now we meet with the most extraordinary fact of all. This gas radon can be separated from the parent radium and packed in containers, carrying with it what, for all practical purposes, is the entire radio-active power of the radium, which is left behind for the time being entirely inert. The total volume of the gas is only a minute fraction of that of the radium from which it arose, and if you purchase one gram of radium at a cost of £12,000, wait patiently for a month, and then with the most delicate precautions pump off the emanation, you will be rewarded with 0.6 of a cubic millimetre of evanescent gas. But that minute bubble might cure fifty cases of cancer before it itself expires.

You will see at once the extraordinary convenience of using the emanation instead of the element. It carries

all the powers of its parent for a few days, and then these simply vanish; its bulk is infinitesimal; its monetary value is nil. It can be inserted into a growth and simply left to decay, and the patient can be sent home without risk to himself or to the radium capital of the hospital. It is essentially a method of curing out of income.

At any one moment the action of radon is precisely the same as that of a certain amount of radium, but there is this essential difference: that the amount is always diminishing. The effect of this will be clear from the chart, where it will be seen that in 3.85 days the value is down to one-half, in nine days to one-fifth. This can, however, be neutralized by starting with a larger dose, and it is a useful practical rule that the total radiation of 1.5 millicuries of emanation is physically almost the same as that from 1 milligram of element in a period of eight days.

APPARATUS AND MODES OF APPLICATION.

We must now turn to the apparatus used in the application of radium and to the methods by which it is applied. The apparatus itself is of the simplest description, and consists chiefly of needles containing radium element and seeds containing radon gas. Flat applicators are also used in the treatment of skin conditions, but these concern the dermatologist rather than the surgeon.

Needles are small platinum tubes varying in diameter from 1.5 to 3 mm., with a point tipped with iridium, and an eye through which a stout silk thread can be passed. A small cavity occupies the whole of the needle except the eye and the point, and this is packed with insoluble radium sulphate, the utmost care being taken to secure absolute uniformity in packing. The wall of the needle should be not less than 0.5 mm. in thickness, so as to cut off the whole of the beta rays. The length of the needle will vary with the requirements of the case. At the London Hospital our needles are 2, 3, 4, and 6 cm. in length, and we have the convenient arrangement that each needle contains one milligram of radium per centimetre of length.

Seeds are minute capsules containing radon gas. Usually the gas is sealed up into a tiny glass capillary, which is then inserted into a tube of platinum, gold, or silver, to cut off the beta radiation. Theoretically platinum is the most efficient screen, but personally I have found silver screens entirely satisfactory. Silver presents the advantages that it is cheap and easily worked, and I have recently elaborated a plan by which the radon is drawn directly into a long silver tube, which is then cut up into suitable lengths. The method of cutting ensures an absolute seal, and the saving of time and trouble, and of personal risk to the laboratory assistant, is considerable.

These needles and seeds provide small sources of gamma radiation, which may be either introduced into the tissues or fitted into external applicators.

Introduction into the tissues is controlled by the empirical observation that the gamma radiation from a milligram of radium can in a period of about five days destroy the cancer cells in a cubic centimetre of tissue. The total amount of radium required in milligrams is thus the volume in cubic centimetres of the tissue to be irradiated, although in the case of large growths, from the effect of cross radiation, a smaller amount will suffice. It must be distributed evenly, the needles or seeds being placed about two centimetres apart, and it must be placed chiefly in the growing edge of the tumour. The needles are attached to stout silk threads, since they contain radium element, and their loss would be disastrous. The seeds may be attached to fine silk threads and be removed later, or they may be simply inserted and left in the tissues, where in most circumstances they do no harm. The insertion of seeds is less likely to be followed by the slight sepsis which sometimes follows the insertion of needles, whilst they have the great advantage that the patient can go home. The action of the needles is, however, uniform, and not diminishing, and on this account they are preferred by some surgeons.

The treatment of a case of carcinoma of the breast furnishes an excellent example of the introduction of radium needles. We may describe the arrangement worked out by Mr. Keynes at St. Bartholomew's Hospital, which has given brilliant results. Two groups of needles are inserted into and beneath the tumour itself on different

planes; two rows of needles follow the lymphatics along the borders of the two pectoral muscles; a third group occupies the axilla; a fourth is inserted beneath the clavicle in the region of the costo-coracoid membrane; a fifth is placed above the clavicle; and a sixth group is inserted one in each of the upper five intercostal spaces and one in the rectus sheath. The actual number of the needles will vary between forty and fifty with the dimensions of the breast and of the tumour, and the total amount of radium between 75 and 100 milligrams. The needles are left in place for from seven to nine days and are then removed.

The tongue is an ideal site for the use of seeds. About eight or twelve are required, each containing from 1 to 2 millicuries of radon gas, and they are inserted into the base of the growth, usually through the tongue itself. In this way the actual growing edge is subjected to an intense cross-fire radiation, whilst, as access is obtained directly through the soft tissues of the tongue, the treatment of growths far back, in situations quite inaccessible to ordinary surgery, is perfectly simple. In most cases the tumour will disappear by magic and three weeks later it will have been replaced by a contracting scar. The glands on both sides of the neck are now dissected out in the most thorough manner, and three weeks later the treatment is completed by the external application of radium needles mounted on a thick wax collar made of Columbia paste.

For the irradiation of tumours or of glandular deposits by external application, it is essential that the radium should be supported at some distance from the skin, as otherwise certain areas of the skin will receive a dose which they cannot tolerate and will break down. A convenient plan is to mould a sheet of Columbia paste, a mixture of beeswax 100, paraffin wax 100, and pine sawdust 200, to the region. The wax should be 1.5 centimetres thick, and on its outer surface radium needles should be planted, screened in the ordinary way with 0.5 mm. of platinum. Small needles containing from 0.5 to 1.5 mg. of radium should be distributed at a distance of 1 cm. apart over the surface, whilst special regions, such as the eye or nose, can be protected by the introduction of thin lead plates into the wax mould. The whole appliance should be covered with a thin sheet of lead for the protection of the nursing staff. Even more convenient than wax in many cases is a sheet of spongy rubber; it has the great advantages of lightness and adaptability, and the needles are easily attached to it by strapping. The period of application varies with the strength of the needles and the requirements of the case, from a few hours to a month.

The most dramatic method of applying radium is by the concentration of several grams into a "radium bomb," which is virtually used as a source of intensely hard α rays, the patient being placed at a distance of a foot or more from the centre of the bomb. In the arrangement devised by Dr. Cheval of Brussels 4 grams of radium are embedded in the centre of a huge block of lead weighing over a ton and supported on steel girders in the ceiling of one room and the floor of the room above. A double cone cut in the lead allows of the exposure of two patients to intense gamma ray radiation, one above and one below. So long as the attendants keep outside the cones, which are marked out by circles on the floor and ceiling, they are perfectly safe, whilst by an ingenious arrangement the radium itself can retire into a recess in the lead block or be advanced to the centre of the cone. The method is costly and very extravagant of radiation, but the results are said to be extremely good.

THE CLINICAL RESULTS OF TREATMENT BY RADIUM.

Turning to the clinical aspects of radium, brilliant results have been obtained in the treatment of rodent ulcer, of carcinoma of the cervix uteri, of carcinoma of the tongue and buccal cavity, and of carcinoma of the breast, in this historical order. It is now being applied in almost every region where cancer develops, and I feel convinced that complete success is only a matter of time. Every region presents its own peculiarities and its own difficulties, and methods which succeed in one region or

with one type of growth may fail in another. The mere external application of radium may suffice to destroy a rodent ulcer or a carcinoma of the cervix; it will be futile in the case of the mouth or the breast, where much more drastic methods are required. To show, however, the range of its power I propose to describe very briefly a few of my own cases, making no claim that the results are permanent or that the methods which I have used are the best. The cases do, however, in my opinion, fairly represent the results which one may expect.

Carcinoma of the Palate.

A man of 55 came to see me last April complaining of a discomfort in the palate of three weeks' duration. At the junction of the hard and soft palate, and extending on to both and on to the alveolar margin, on the right-hand side, was a hard nodular mass of ulcerated fungating carcinoma. There was a large mass of hard glands in the right anterior triangle of the neck. The tumour was destroyed with my steam cautery, and the glands were dissected out completely. Healing was perfect in a fortnight, but three weeks later the tumour recurred.

In May I inserted into the base of the tumour six radon seeds, each containing 1.5 millicuries of radon. In fourteen days the growth had disappeared, and was replaced by granulations, in three weeks healing was complete, in six weeks there was no trace even of a scar, and he was wearing his toothplate. He remains in perfect health, with no sign of recurrence.

Epithelioma of the Lip.

A man of 65 was sent to me last September with a huge mass of growth involving the whole of the lower lip and extending almost to the chin. It had started a year previously as a small nodule at the left corner of the mouth. Six needles, each 2 cm. long and containing 2 mg. of radium, were inserted into the lip along the margin of the growth, and were left in place for a week. In three weeks the great bulk of the growth had disappeared, but a week later two small nodules still remaining were treated by the insertion of small radon seeds. A fortnight later the glands were cleared out from both submaxillary triangles, and as the margin of the lip was very ragged a narrow strip was taken from it. In such an advanced case a permanent cure is too much to expect, but the immediate result was remarkable, and from the cosmetic point of view it was extraordinarily good. A remarkable feature was the reappearance of a lip apparently destroyed by carcinoma, demonstrating conclusively the selective action of the radiation employed. No visible carcinoma remained, and, should recurrences appear, they can probably be dealt with by similar means.

Carcinoma of the Thyroid.

A lady of 70 came to me last September with the history that a small swelling, which had always been present in the neck, had for five weeks been growing rapidly, and was now producing severe respiratory obstruction. There was a hard nodular swelling involving both lobes of the thyroid, with several hard glands adjacent to it. It was fixed to the trachea and attached to the skin. It was regarded by myself and by Mr. Hayward Pinch as a typical carcinoma of the thyroid. It grew so rapidly that in ten days the circumference of the neck had increased by 1½ in. Twenty radon seeds, each containing 1.5 millicuries of radon, were inserted through two small punctures, one on each side of the trachea, and were distributed as far as possible throughout the tumour. In ten days the tumour had completely vanished, and although the neck was very thin the thyroid gland could no longer be felt. The circumference of the neck had diminished by 3 in., and all symptoms of obstruction had disappeared. She remains in perfect health.

Carcinoma of the Oesophagus.

A man of 72 had suffered from increasing difficulty in swallowing for three months, and he could now only swallow sips of water with great difficulty. A tall, powerfully built man, he had lost 3 st. in weight, and he was so weak that he could scarcely stand. An x-ray film showed that the oesophagus was obstructed by a malignant growth ten inches from the teeth. On oesophagoscopy a large ulcerated mass of growth was seen encircling the oesophagus, bulging prominently inwards on the left side. Into the substance of the growth eight radon seeds were inserted, each containing 1.5 millicuries. In twenty-four hours there was a distinct improvement in swallowing, which may, however, have been due to the passage of a bougie at the operation. In a week he was taking ordinary soft foods, and was obviously gaining weight and strength. In four weeks he was taking an ordinary full diet, with the sole precaution that he should eat slowly. In six weeks he had gained nearly 2 st. in weight, and appeared to be in perfect health.

Carcinoma of the Stomach.

A man of 53 had complained for three months of epigastric pain, increased by food, of loss of appetite, and of loss of weight, which he estimated at 2 st. On exploration a firm, smooth oedematous tumour of greyish colour was found involving the lesser curvature, and extending upwards almost to the cardiac orifice. It was regarded as a carcinoma of a rapidly growing type, and it was obviously quite inoperable. There were, however, no enlarged glands. Into the substance of the tumour were inserted six platinum needles, each 4 cm. long and containing 4 milligrams of radium element. They were so arranged as to radiate from a centre on the anterior surface of the stomach, and the threads collected here were buried in an invagination of the anterior wall of the stomach, formed as for a Witzel's gastrostomy. The threads were brought out in a bunch through the laparotomy

opening, which was then closed. Five days later the needles were withdrawn without difficulty. The patient made a normal recovery; his pain ceased, his appetite returned, and in three months he had regained his normal weight and was the picture of health.

Angioma of the Meninges.

A man of 45 had suffered for years from fits at long intervals. Recently the fits had become more frequent and severe, and they were now accompanied by loss of consciousness. They were Jacksonian in type, commencing in the left hand and spreading to the face and leg. Beyond a slight increase in the deep reflexes on the left side there was little to be made out on a neurological examination. On exposing the right Rolandic area by means of an osteoplastic flap formed with my craniotome, and on opening the dura, a mass of huge interlacing veins was found occupying the whole of the upper portion of the field, and forming a vascular tumour about three inches in diameter. As no direct treatment seemed practicable the dura was closed, and on to its outer surface were sutured six radium needles, each 2 cm. long and containing 2 mg. of element. The needles were arranged as the spokes of a wheel, and the attached threads were brought out through the central hole in the bone flap. The bone was replaced, the threads were brought through the scalp flap, and the scalp was sutured into position.

The after-history of the case was somewhat remarkable. Three days later he noticed a weakness of the left arm, which developed next day into a complete paralysis. On the following day the needles were drawn out by the threads without difficulty, having been in position for five days. A week later he had completely recovered the use of the arm. There has been no recurrence of the fits, and he seems to be in perfect health.

These cases are only chosen to show the effects which radium can produce in a great variety of situations, and under conditions where the ordinary methods of surgery are not applicable. The brilliant work of Regaud in Paris, of Hayward Pinch and his assistants at the London Radium Institute, of Keynes at St. Bartholomew's, of Cade and his colleagues at Westminster, of Birkett of Manchester, and of many others, has shown that in cancer of the uterus, of the skin, of the breast, and of the mouth and tongue, success can be depended upon as a routine. It has rather been my aim to show how wide are the powers of radium, and that where we have failed it is rather our method of application than our weapon itself which is at fault. I am convinced that we are only on the threshold of a great adventure; I feel that a new world of surgical technique is opening before us; I am beginning to believe that at last we hold in our hands the key to the cure of cancer.

SOME EFFECTS OF DEEP X RAYS UPON THE CELLS OF THE BLOOD.

▲ PRELIMINARY NOTE ON A PHAGOCYTIC TEST.

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THE experiments about to be described are the result of an attempt to observe *in vitro* the effect of the rays employed in deep x-ray therapy upon the living cells of the blood. The rays used were the hardest that it has been possible to generate up to the present. The apparatus used was the latest type of constant potential generator with valve rectification, voltage 220,000, metalix water-cooled tube, filtration 1 mm. copper and 3 mm. aluminium.

That these rays have a destructive effect upon living cells is too well known to need discussion here. It is not clear, however, whether such rapid disappearance of white blood cells as occurs, for example, in cases of leukaemia undergoing deep x-ray therapy can be accounted for purely by this destructive effect on the cells themselves, or whether other factors come into play. It is more than probable that whatever direct injury occurs to the cells is caused by the secondary rays thrown out by all elements of sufficiently high atomic weight which obstruct the path of the original hard rays in their course through the body. The greatest cell destruction would then occur in the neighbourhood of foci producing these secondary rays, and the importance of this factor was clearly brought out in our first experiment.

A large block of clean paraffin wax was cast with outside dimensions of approximately 6 in. by 4 in. by 4 in. The block was divided longitudinally so as to form a close-fitting lid over a little central chamber hollowed out in the lower half of the block. The capacity of the chamber was about 2 c.cm. Freshly drawn, oxalated blood could be placed in the chamber and submitted to controlled irradiation.

The methods used in examining the blood will be described in the next paragraph. For the moment the important point to note is that if blood was placed in the simple paraffin block described, practically no lethal effect could be produced upon the blood within one and a half hours, however intense the irradiation. If, however, the little central chamber was surrounded by a layer of material relatively opaque to x rays, damage to the cells was very soon apparent. The most satisfactory method of producing secondary rays near the blood was found to be surrounding the little chamber within the paraffin block with a layer of blotting paper soaked in a solution of metallic salts, so that the paper was covered with a thin layer of wax and was separated from the blood only by this layer. Before the metal-containing paper was inserted, blood from cases of splenomedullary leukaemia placed in the chamber was submitted to full radiation for two hours—about six times the therapeutic deep therapy dose—but no definitely lethal effect upon the white cells could be detected. When the paper was inserted, damage to the cells could be observed after only fifteen minutes' similar irradiation. The more closely the chamber was surrounded by metallic salt—in other words, the more intense the secondary radiations—the more quickly were the white cells affected.

Methods of Observing Damage to Cells.

To examine individual blood cells while the blood was being irradiated in the chamber small samples were removed at intervals and thin films spread. These were stained by all the usual histological methods, but no certain differences could be made out to distinguish normal from damaged cells. The oxidase reaction was applied to the films and vital staining with cresyl blue attempted, but again no differences could be demonstrated. The only positive results were obtained when samples of blood, before and after irradiation, were kept under sterile conditions at laboratory temperatures up to three days, at the end of which wet film preparations stained with neutral red were made. It then appeared that nuclear degeneration had occurred more quickly in the irradiated white cells. But the differences were not sufficiently sharp to justify the method for quantitative purposes. It must also be explained that blood counts performed upon the samples of blood in the chamber during and many hours after irradiation showed no reduction in the number of red or white cells present. Furthermore, prolonged agitation of the blood in a mechanical shaker did not result in any breaking up of irradiated cells. In short, no actual reduction of the number of cells, red or white, in the blood could be demonstrated and no changes in staining reaction detected.

The Phagocytic Power of White Cells.

It seemed, therefore, that, in order to demonstrate the cell damage caused by the rays, some direct biological method must be used. Experiments were then made upon the phagocytic power of the white cells towards staphylococci, and this method has, we think, given definitely promising results.

Using a marked teat pipette, small equal quantities of blood were drawn during irradiation from the chamber at five- or ten-minute intervals, and to each was added the same amount of an emulsion of staphylococci in 1 per cent. citrate in normal saline. After allowing these mixtures to remain in the 37° incubator for five to ten minutes films were spread and stained with Leishman's stain, the whole procedure following the lines of an opsonic index determination. Direct examination of the films gave a reading of the percentage of white cells in any particular sample still retaining their phagocytic power. Loss of this power was taken to indicate a lethal effect upon the white cells.