RADIUM

AND

RADIOTHERAPY

RADIUM, THORIUM, AND OTHER RADIO-ACTIVE ELEMENTS IN MEDICINE AND SURGERY

BY

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TO

MY WIFE

PREFACE.

The creation of this work has been prompted by the many solicitations of the author's friends and the inquiries of many others as to where it might be possible to obtain authoritative information upon the subject of radium and its scientific and medicinal properties. The reason for these queries is that if the medical literature of the day is carefully examined, it will be found that articles upon radio-activity in the English language are exceptional. This is in marked contrast with the literature of other languages, particularly German and French, in which the most active interest prevails.. While this contrast is very apparent it is not altogether without foundation, for in this country it has been difficult to procure the radio-active materials. It is possible that the relation of our public institutions to their attendant physicians may be a factor; for wherever these valuable salts have been acquired, the investigator has been obliged, in almost every instance, to bear the expense. Another fact that has to some extent discouraged American investigation is that most of the radium brought to this country has been in the hands of private speculators; and in some instances, which have recently been brought to the attention of the profession, an exorbitant price was paid for an extremely poor quality of radium. The purchaser, laboring under the delusion that he had obtained a specimen of sufficient strength to treat a certain condition, applied it and obtained an unfavorable result; then, after repeating the operation several times, only to meet with defeat and final discouragement, deserted the whole field, believing it worthless. Therefore it is necessary to warn those who enter upon this study either to familiarize themselves to some extent with the physics involved, or have some physicist of standard reputation assist them in their work. If, therefore, this volume saves the novice from the errors which have been so common in the past, the author will feel that its mission has not been in vain.

Considerable space has been devoted to the chemistry and physics of these radio-active elements, in the belief that some conception of their properties will aid materially in the interpretation of their therapeutic action, and that they should be studied exactly as a drug that is employed in medicine, where the knowledge of its botany and chemistry is not only considered useful but necessary. The details and mathematical calculations have been largely omitted; for this information the reader is referred to books dealing alone with radio-activity. In the medical portion the details of many different processes for the same indication are often given; the reason for this is that, though they may apparently give the same result, it may be impossible always to use a given form of application. Therefore a knowledge of several methods makes it possible for the physician to select one which meets the requirements of the individual, and while some methods mentioned are not always the most approved forms, this fact has been duly noted. In short, the object of this volume is to place the subject of radio-activity before the medical public in a clear and comprehensive manner.

The author desires to make acknowledgment to the following authors whose works he has consulted in the preparation of his text: Rutherford, Frederick Soddy, Wickham and Degrais; to Mr. Pinch and Mr. Alton of the London Cancer Institute; to Professor Lazarus of Berlin, Bayet, Loewenthal, Wichman, and others mentioned under the different headings of their articles; to the Trustees and my associates of the American Oncologic Hospital, who have made it possible to continue the study, and especially Dr. C. B. Longenecker for his many and able suggestions.

W. S. N.

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RADIUM AND RADIOTHERAPY.

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Periodic Law of Matter—Early Philosophers—Crookes' Phenomena—Radiant Matter—Roentgen Rays—Becquerel Rays—Discovery of Radium—Introduction into Medicine.

THE casual observer might regard the discovery of radium by Madame and Professor Curie as one of those fortunate accidents which often bring a world-wide fame. This, however, was not the case, for if one should take the trouble to seek the facts, it would be found that this discovery was rather the culmination of a chain of more or less remarkable events that lead us back to the remote period of a century and a half, when Mendelieyeff advanced his theory of "the periodic law of matter;" and while this philosopher was not an alchemist, and possibly did not believe in the actual transmutation of elements, he regarded all things as being composed of one essential base, "matter," and pointed out that there existed a given relation between all elements known at that day, which were very few, possibly only between twenty and thirty of the more common ones, such as oxygen, hydrogen, sulphur, gold, and others of that nature; and he still further predicted that as other elements would be discovered, they would take their place in line according to a given relation, and in their order they would have certain qualities.

This theory at that period was not accepted, and being far in advance of the time, his ideas were regarded as fanciful; however, as one element after the other was discovered, each taking its place in this table, according to his "periodic law," the truth was finally established. Later the atomic theory of matter was adopted, and each element was supposed to be composed of a great number of minute particles having certain characteristics, and they became known as atoms. About this time a number of other philosophers contributed their portion in advancing the more intricate principles of physical details so essential for these future experiments: Franklin, with his electrical experiments; Michael Farraday, with his batteries; and a debt of gratitude is due von Guericke for development of the air pump with the later-day improvement to Sprengel; also to Geissler for his studies in the low vacuum tubes and the characteristic of the electric discharge in air at different pressures, which might be said to have been the forerunner of Sir William Crookes' discoveries in the high vacuum tube, afterward known as Crookes' tubes.

While studying these tubes some peculiar phenomena were noticed, which at that time were supposed to be due to matter in another condition, to which Crookes gave the name of "radiant matter." In this form it was found possible to penetrate solids, and it was supposed that the atoms of one mass passed between the atoms of the other, or that matter in this ethereal state existed in a much more rarefied state than even the lightest of gases. Wiedermann, J. J. Thomson, Hertz, and others, continued their studies, but it was not until two decades later that Lenard pointed out the true character of these particles as cathode rays which, a year or two later, led Roentgen to discover the x-rays.

With the explanation of the character of these peculiar phenomena, which had for some time so completely baffled physicists, the way was opened to the discovery of a number of other mysteries, and the year following Henri Becquerel, in Paris, observed that similar rays to the x-rays were given off by certain minerals and chemicals which contain uranium; to some extent they resemble the x-rays from the Crookes tube. From his study and description of these rays they were for the time known as the Becquerel rays; the fact that they were a bundle of three different rays led to confusion, which was augmented by the misunderstanding of the relation of these rays to those of the Crookes tube. Further misinterpretation was caused when it was found that the active portion of the mineral or salt-containing uranium element, or that portion giving off these rays, could be separated and that in time these uranium bases from which it was obtained would regenerate.

Many physicists and chemists were at this time giving this problem their greatest attention, and four years after the discovery by Becquerel, in 1900, M. Schmidt, with Professor and Madame Curie, working independently of each other, were able to isolate radium, which has revolutionized the whole scientific world, added thirty or more new elements to those already known, and created an entirely new field for active study—radio-activity. For its advancement we are indebted to such men as Razet, Sagnac (particularly for his studies of the secondary rays), Rutherford for explanation of the relation of the different rays and gases eliminated by these radio-active substances, Debierne, Giesel, Lord Kelvin, Meyer, Frederick Soddy, and many other physicists.

Strange as it may seem, yet like many of our other most useful tools in medicine, the actual suggestion for the use of radium as a therapeutic agent came from two physicists, Henri Becquerel, who observed a decided inflammatory reaction upon the skin beneath the site of his pocket, in which he imprudently carried a small tube of radium; and secondarily to Professor Curie, who loaned a sufficient quantity of this valuable element to M. Danlos, of the St. Louis Hospital in Paris, for study of its action upon cases at that institution. While the advancement in this field has not been rapid, due mainly to the difficulty in procuring a sufficient supply of radium, steady strides have been made, and the demand is now far in excess of the supply. There is a prospect of gaining a certain amount of relief through the application of thorium preparations, which, according to some authorities, are claimed to be superior to those of radium, due to their more rapid disintegration, and therefore greater activity within a certain mass. There are, however, wide differences between these preparations, and it would seem that both will have a given range of usefulness.

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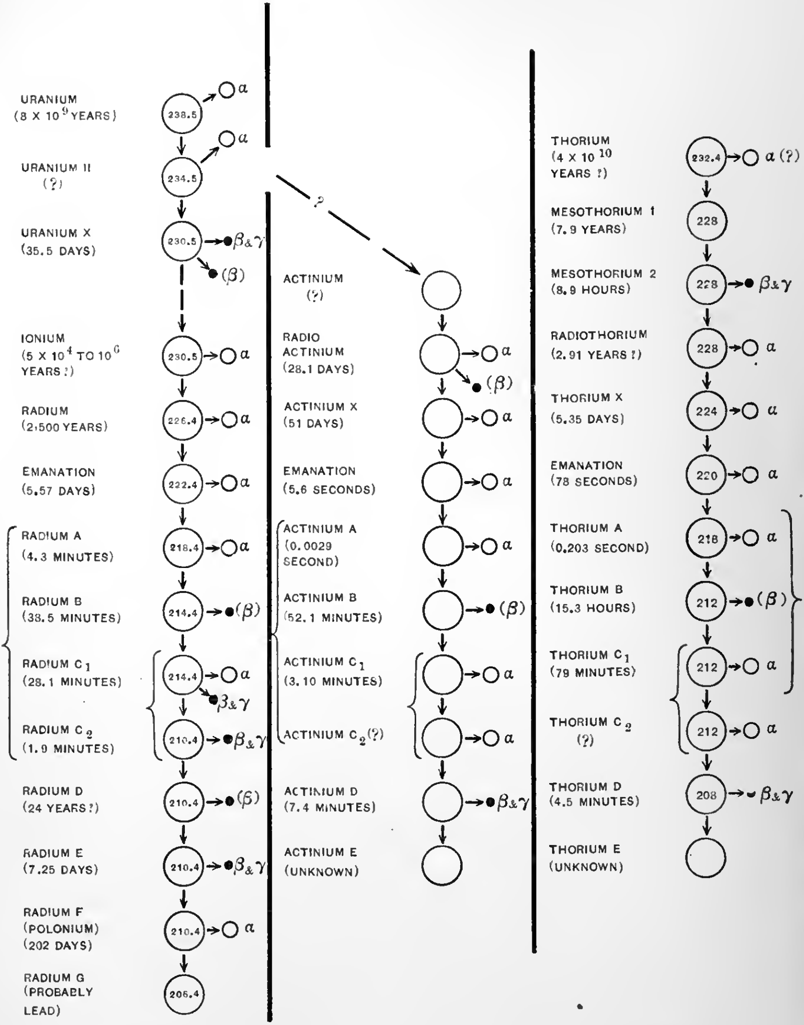
There are over thirty elements which are radio-active, and while the existence of some of them is a matter of only a few seconds, or even the cycle of a second, they are to be regarded in the same light as iron, copper, or calcium, having all the properties of other elements, in regard to atomic weight, capacity for heat, specific gravity, and existing in such forms as solids, liquids, or gases. The majority of these elements belong to three distinct groups, known as that of uranium, thorium, and actinium, and while there may be other common elements which are radio-active, they exist in a form which at the present day we do not recognize. It may surprise many to learn that potassium and rubidium are

FIG. 1



Disintegration series of uranium, radium, thorium, and actinium.

radio-active but very feebly, and at present it is only an interesting physical fact. But it is for the future to develop, and no doubt in time our common potash may be a peer of radium, or perhaps analogous to uranium at the head of the disintegration series.

URANIUM.

Uranium.—Atomic weight, 236.7. Specific gravity, 18.6. Period of average life about 8,000,000,000 years. Found in nature as black oxide, pitchblend; also as uranates in combination with calcium, and often associated with mica ores, clevite, the hydrated oxide, and in carnotite where it is combined with vanadium. Other rocks contain it as gummite, autunite, samarskite, and many other forms. It is widely disseminated throughout the world's crust, but only found in workable quantities in Hungary, Bohemia, and in the United States in a few widely separated places.

Chemically it forms two combinations with oxygen, UrO_2, and UrO_3; forming two classes of salts, the uranic and uranous. Most of the salts are possessed of a brilliant canary-yellow color; some, however, are a bright red. A few of them become brilliantly fluorescent under the influence of certain rays.

The separation of uranium from the different minerals in which it is found is effected by dissolving them in nitric acid, then adding an excess of sodium carbonate; this forms a combination of sodium uranate which is afterward purified by repeating the process.

Radio-activity.—Pure uranium, and all uranium salts that are freshly prepared, give off only an α-radiation; two α-particles for each atom of uranium; but at the end of three weeks from the time of preparation they have gained about one-half their equilibrium, from the accumulation of uranium X, which gives off β-rays of fair strength and a rather feeble γ-radiation. The perfect equilibrium is gained in about one year.

Uranium II has an atomic weight of 234, although it has not been definitely separated; there is reason to believe its period of life is about 2,000,000 years and is closely associated with uranium; it gives off α-particles.

Fig. 2

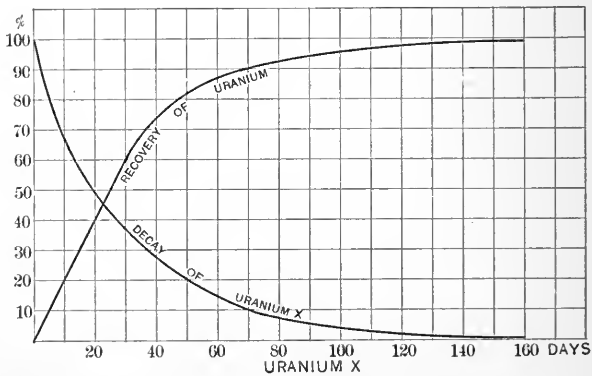


Diagram illustrating the decay of uranium X, and the recovery of uranium.

Uranium X, to which reference has just been made, is the disintegration product of uranium II. The average period of life is about 35.5 days. Its disintegration product is unknown, and while a uranium Y has been described with the short life of 1.5 days, from a medical standpoint its usefulness is *nil.*

The radiation of uranium X is principally a β-radiation with a rather weak γ-ray; in fact it is all cut off by the thickness of 0.95 cm. lead. The period of half-change is 24.6 days.

Uranium X is prepared by allowing a hot solution of uranyl nitrate, 2.05 specific gravity, to crystallize; upon cooling the mother liquor will contain about six-sevenths of the uranium X. Another method is to add a small quantity of ferric chloride to a solution of uranium and then precipitate the iron by ammonia carbonate; the uranium X fixes itself to this hydrated iron carbonate, the solution may be filtered, and the activity is entirely in the iron precipitation.

In medicine, from a therapeutic stand-point, uranium nitrate has been employed in the treatment of diabetes; its use seems to be purely empiric. Radiologically it is the uranium X that is of some value, and, has been used in the treatment of surface epitheliomas and lupus, either compounded in ointments or the mineral containing uranium (crystal of autunite) applied directly to the diseased part. However, it has not been generally accepted and, therefore, its practice is extremely limited.

Ionium.—Ionium stands between the uranium group proper and radium. Very little is known of this element, which is most difficult to separate; it possesses a low range of a rather fair amount of α-radiation, which is entirely lost in 2.8 cm. of air. Its parent is supposed to be uranium X, which has not been proven. Its life is about 1,000,000 years, and its disintegration product is radium. Chemically it is so much like uranium X and thorium that it is doubtful if pure ionium has even been produced.

RADIUM.

Radium.—Radium is found in all minerals containing uranium, although in somewhat different proportions, depending upon the formation from a geologic standpoint; the older the mineral the greater the accumulation of radium with its series of disintegration products. In the great majority of specimens, however, the proportion of radium to uranium is 3.2×10^{-7}, or about 320 milligrams per ton. Radium is much more widely disseminated than is usually supposed, practically all the rocks, water from springs, and even sea water contain an infinitesimal quantity, which is detectable by suitable apparatus.

AMOUNTS OF RADIUM CONTAINED IN DIFFERENT ORES.

Pitchblend from Johanngeorgenstadt	8.3×10^{-11}
Pitchblend from Joachimsthal	7.0 "
Pitchblend from Pzibran	6.5 "
Pitchblend from Cornwall	1.6 "
Clevite	1.4 "
Chalcolite	5.2 "
Autunite	2.7 "
Carnotite	6.2 "
Thorite	1.4 "
Orangite	2.0 "

Production.—The first step in the manipulation of a radium-bearing ore depends somewhat upon the other associated elements, such as silica, lead, barium, etc. They are first converted into sulphates, and then into carbonates; finally, after sufficient purification, they are dissolved in hydrochloric acid and then the process of fractionation or recrystallization is started for the further separation from the barium salts which chemically they so closely resemble. The crystals contain the most radium and the mother liquor the least, but both the mother liquor and crystals must be subjected to this manipulation a number of times until pure radium chloride is obtained. The older process was to use hydrobromic acid instead of hydrochloric, and in some places it is still employed.

The manipulation of this process would seem to be extremely easy, but when one realizes a ton or more of material must be dissolved in fifty tons of water, and five tons of acid, with the total quantity of radium being 300 milligrams or less, it is not difficult to see with what care this procedure must be carried out.

Radio-activity.—Radium free from its products of decay possesses a fair α-radiation, penetrating 3.13 cm. of air. With this there possibly exists a very feeble β-radiation which need notbe taken into consideration. The retention of the products of disintegration depends to some extent upon the salt; as for instance, the sulphates retain them to a greater extent than the other forms, while the carbonates allow them to escape freely. If, on the other hand, any of the salts are in a sealed tube, the disintegration products are practically all retained. Radium gains its equilibrium in about one month, of which one-half accumulates in four days. After the removal of the products of disintegration from radium the decay of its activity is exactly the reverse. One-half the power is lost in four days and then gradually, until at the end of one month it has disappeared.

Properties.—Radium has been produced in its metallic state but rapidly disintegrates. The most common salts, which are to be found in the market, are the chlorides, bromides, carbonates, and sulphates; the chlorides and bromides being soluble, and under some circumstances slightly deliquescent; the carbonates and sulphates are insoluble in water. Chemically its analogue is barium except that its salts are slightly less soluble in water; therefore radium sulphate is the most insoluble salt known.

All the salts of radium are luminous, which is independent of their radiation, or the production of luminescence upon other substances. Radium salts color the flame a carmine tint. Its spectrum exhibits a close analogy to the alkaline earths, the strongest line being in the ultraviolets ($\lambda = 381.47\mu$). Heat is liberated spontaneously and at the rate of one small calorie, melting the amount of ice equal to its own weight every hour. This is continued for about 2500 years which is the average period of its life. To show the enormous amount of energy stored in radium, it has been calculated if the energy could be employed in the same manner as coal, a quantity the size of a pinhead would be sufficient to light London for one year. The atomic weight of radium is 226.5; it belongs to the fourth group of elements or the alkaline earths.

The methods usually employed for estimating the amount of radium in combination with other substances are by means of an electrometer, which will be considered under another heading; but where the quantity warrants a chemical examination, it can be done by first obtaining the radium in solution as chloride or bromide; under some circumstances it may also be obtained as a sulphate but the objection to converting it into this form is, that the sulphate is extremely insoluble and difficult to restore to solution. The disintegration product of radium is the emanation.

Radium emanation (Sir William Ramsey proposed the name Nitron) is a gas; its parent is radium. It belongs to that class of inert gases which do not seem to enter into chemical combination with other elements and therefore is like nitrogen, but still more inert, being an analogue of xenon. The atomic weight is 222.5; density, 111.25; and is so heavy that some elements, such as mercury or lead, would float upon it. Heat generated from its disintegration is intense, so much so, if any considerable quantity could be collected in a pure state, there is no known substance which could serve as a container. The average life is 5.57 days; period of half change, 3.86 days. While this gas has a rather short life it conforms to all the natural laws of other gases. It can be condensed by liquid air, at a temperature near —152° C. It is soluble in pure water at ordinary temperature; however, the solution of certain salts makes it less so.

Fig. 3

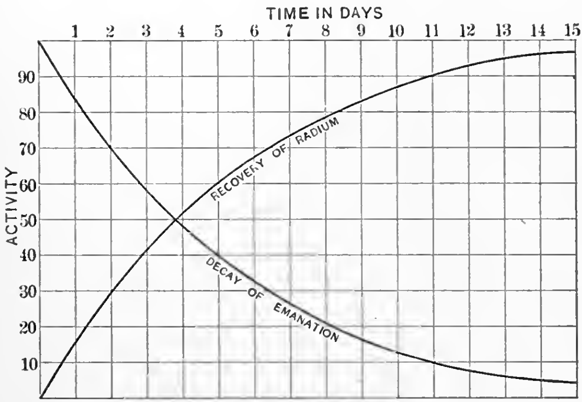
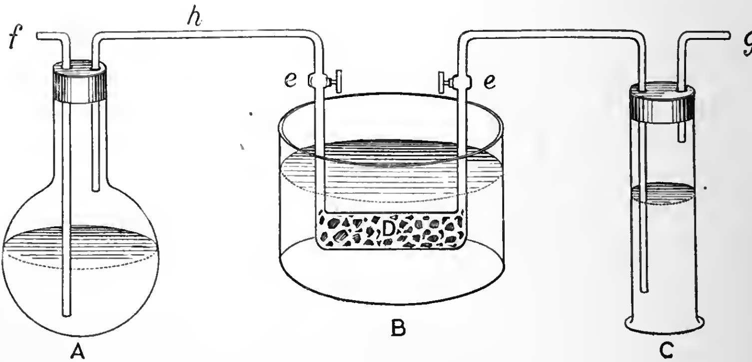


Diagram showing the recovery of radium, and the decay of the emanation.

Glycerin, petroleum, and other liquids also absorb it; cocoanut charcoal has the power of absorbing it at ordinary temperature; by heating it strongly the emanation is driven off. Other porous substances, even dense metals, have the effect of absorbing this gas to some extent, which often leads to error in the calculation of radio-active discharge. The volume of emanation under normal conditions in equilibrium with 1 gram of radium is about 0.585 cubic millimeter. It possesses the same quality of discoloring objects as radium; and likewise the violet tint is given to glass tubes which are used as containers. Water is separated by the radioactivity of these elements into hydrogen and oxygen, and in the presence of oxygen the emanation becomes a powerful oxidizing agent upon organic compounds. These facts may

FIG. 4



Diagrammatic apparatus for collecting the emanation. A given quantity of radium salt is dissolved in water slightly acidulated in flask *A*. Pure air is then drawn through the solution by pump attached to tube *g*. The air entering *f*, passes out through *h*, charged with the emanation, and may be collected in *D* if *B* contains liquid air, which causes the emanation to condense. If the tube *D* contains a few broken pieces of willemite (zinc silicate), the presence of the emanation causes it to emit a brilliant glow. After all the emanation has been abstracted from the radium the stop cocks *e e* may be closed until it is desired to use the emanation. Water, glycerin, charcoal, or other substances may be charged in *C*.

play a most important part in the therapeutic value of this gas when used internally. Care should be taken not to allow the emanation to escape into the air of the room, for, being a gas, it diffuses rapidly, and as it ages it covers the walls and all objects contained in the room with the lower disintegration products, rendering them radio-active and leaving them so for an indefinite period. While the amount of radio-activity of these objects is very small, it interferes to such an extent that instruments of precision can no longer be used in that building.

Radio-activity.—This gas gives off an α-ray which has a range of 3.94 cm. in air, it is one of the strongest of its class. The radio-active constant is 0.00751 $(\text{hour})^{-1}$.

Production.—In a flask a given quantity of radium salt is dissolved in water that has been slightly acidulated with hydrochloric acid, through this water is passed a slow stream of air (better by suction); as the air passes through the solution a small amount of the emanation is carried along with it. If this mixture is then passed through a vessel cooled by liquid air, the cold sides of the tube condense the emanation contained, allowing the air to pass on. The proportion of emanation contained in the salt of radium depends entirely upon its age. Where it is desired to collect the emanation for medical use, this process must be slightly modified, and is described in Chapter V.

The product of disintegration is radium A, and in view of the fact that the next few elements undergo a very rapid change and that there is still some doubt as to the details concerning their actual relation to one another, they are generally considered under the head of "active deposit of rapid change." The activity from a therapeutic standpoint is chiefly due to the "products of rapid change;" here are obtained the valuable γ (gamma) rays and with it the β (beta) rays of different values.

The "active deposit of rapid change" is composed of the following elements: **Radium A,** atomic weight, 218.5; period of life, 4.3 minutes; radiation α (alpha) with a range of

4.5 cm. in air. Its decay is very rapid and passes into **radium B**; atomic weight, 214.5; period of life, 38.5 minutes; radiation β (beta) ray of which one-half will pass through a sheet of aluminium 0.09 mm. thick. This element then passes into **radium C^1**, which also has the atomic weight of 214.5, and compares with radium C_2, as do the two more familiar elements, cobalt and nickel; the life of this element is 28.1 minutes; alpha- beta- and gamma-rays are given from its activity. The alpha-rays have a range of 6.57 cm. in air, and it will be observed that these are projected with more force than any of the others. The β-rays are also projected with greater force than any that have preceded and it requires a sheet of aluminium about 0.5 mm. thick to obstruct one-half of them. The gamma-radiation is here established and it requires a thickness of 1.38 cm. of lead to obstruct one-half of the rays. This element disintegrates into **radium C^2**, or possibly it may be coincidently formed, and has a supposed atomic weight of 210.5. Its period of life is extremely short, being only 1.9 minutes; in its change it gives off a beta- and gamma-radiation which so far has not been thoroughly studied.

The majority of these different elements can be separated by extremely elaborate chemical and physical means, but at times it is often rendered impossible by certain impurities being present; their separation is of no importance from a medical point of view, as most of the therapeutic property of radium is due to the "active deposit of rapid decay." These elements are principally of value as a whole and not separately. After this very active cycle the product of disintegration is radium D, which is the beginning of the group of "active deposit of slow change."

The "**active deposit of slow change**" adds a little more activity to the old specimens of radium; the change being so slow and the length of time so great that from a medical standpoint there is very little difference between a specimen of radium that has gained its equilibrium from the products of the active group, and a very old one that has in addition to it, the products of slow decay. It must be remembered that the maturation of radium starts with the day that the crystals are separated from the solution, and it makes very little difference how old the crystals are; if they are redissolved, at that time an entirely new cycle is started. The "active deposit of slow change" starts with radium D, with a life of about twenty-four years, it then passes into radium E, with a life of a little over seven days, then becoming radium F, and in two hundred and two days disintegrates into what is supposed to be lead.

Radium D (radio-lead) has an atomic weight of 210.5, and an average period of life of about twenty-four years; it gives off a very insignificant β-radiation. This element is, in some ways, closely associated with lead and is found in all lead and most uranium ores. While radium D has never been obtained directly from lead, it does exist in all new lead and where electroscopes are to be constructed from sheet lead, the oldest lead possible should be obtained. While radium D is not very active its disintegration products will be seen to possess a fair amount of radiation which to some extent is a hinderance to accurate experiments performed with new lead.

Radium D is obtained from old specimens of radium or where the emanation of radium has undergone disintegration in an enclosed glass vessel, the radio-lead covers the inside as an invisible film. The disintegration product is radium E^1 and E^2. Here again there seems to be a double product that is more or less confused, and while it is known as **radium E** it may be split into E^1 and E^2. The atomic weight is supposed to be about 210.5. The average period of life is 7.25 days, with a β- and γ-radiation. Very little is understood about its chemical nature and, while fairly active, the double nature of this element produces some confusion in the different processes for its separation.

Its disintegration product is polonium or radium F. Polonium is of interest for the reason that, when these elements were first discovered, it was supposed to belong entirely to a series of its own and was studied directly from the minerals. Not until after careful observation was it found to be one of the radium series. The fact that it had a longer life than most of the others, led to its identity.

Radium F (polonium—the name radiotellurium was proposed by Marckwald). Atomic weight about 210.5; average period of life, 202 days. The quantity of polonium reaches its maximum in radio-lead in about two years when it starts to disintegrate and steadily decays with its parent, but where it is formed from radium, confined within a closed tube, the quantity of polonium steadily increases for about thirty years; in the first ten years however, very little polonium is formed.

Production.—Radium F may be obtained from minerals containing uranium and it is associated with the same class as bismuth to which it is closely allied. It may be separated by several methods. Combined with bismuth oxychloride it can be fractionally precipitated with a strong solution of hydrochloric acid or nitric acid; the fractionation and precipitation being carried out as the subnitrate. Another process is sublimation in a partial vacuum, the polonium being more volatile.

Radio-activity.—Radium F is worthless from a medical stand-point, possessing only an alpha-ray, having a penetration of 3.58 c.c. in air, and which is obstructed by a thin sheet of paper.

Its disintegration product is probably lead.

Radium Commercially.—When radium is purchased in the open market, the product that is obtained is one of the different salts in a more or less impure state. The freer it is of impurities the more active it is within a given mass; however, as these impurities only obstruct the low rays, they do very little harm from a medical stand-point. The most common salts to be obtained are the carbonate and sulphate, which are insoluble in water, and the chloride and bromide, which are soluble, and somewhat deliquescent; therefore, if the last two are to be exposed to the air, they must be carefully protected.

Fig. 5

A bottle that contained a tube of radium for about two months. Notice the violet color midway between the round end and the label.

The color of these salts is a light yellow, modified more or less by the impurities, and they become darker with age. It will also change the color of the glass container in a short time, causing it to become a violet color, this effect is noticed also upon minerals. It changes colorless rock crystals to yellow, then to brown; rose quartz, brown; gypsum, yellow; diamonds, blue or brown; calcium chloride, yellowish brown; potassium chloride, violet; and gives amethysts and aquamarines a deeper color.

These salts contain, according to their age and the manner in which they are preserved, the different products of the emanation, "active deposit of rapid change;" and old salts more or less the activity of the "active deposit of slow change." When radium has gained its maximum power of throwing off these rays, it is spoken of as having gained its "equilibrium;" it is, in other words, giving off its maximum quantity of all three rays and will continue to do this for some two thousand years with very little change, but when the radium salt has been freshly crystallized, it requires about one month to gain its "equilibrium." (See table, page 60.)

The impurities contained in most radium salts are principally barium, from which it is very hard to separate and with which it forms a double salt.

All radium salts are luminous in the dark and they will cause a brilliant fluorescence of many minerals and salts, the most important of them being the diamond, scheelite (calcium tungstate), platinum, barium cyanide, zinc sulphide (zinc blend), willemite, and many to a lesser degree, as gypsum, calcite, etc.

When estimating the amount of radium contained within a given specimen it should always be calculated upon the basis of pure radium element, not as a salt, in which the actual amount of radium element varies with the proportion of the salt-forming acid; this is readily seen in comparing the following:

1.87	milligrams	radium	bromide	contains	1	milligram	radium	elements.
1.31	"	"	chloride	"	1	"	"	"
1.26	"	"	carbonate	"	1	"	"	"
1.42	"	"	sulphate	"	1	"	"	"

It is here shown that the commonest salt of commerce, the bromide, contains the least radium. This salt is easy to handle in the chemical manipulation for the recovery of radium and therefore, it is usually placed upon the market in this form.

Some of the more common radium-bearing ores are:

Pitchblend, or uraninite, is a uranium oxide. The mineral looks like pitch but is very heavy, usually found in deep mines, in the older geologic formation, where the amount of radium runs somewhat higher than in other forms. Some pitchblends are comparatively free from thorium, but always associated to some extent with actinium. Torbernite uranite and uran-mica which contains the uranium phosphate is associated with copper and mica, giving it a grass-green color. Autunite, uranium, calcium phosphate, usually are in yellow crystals. Samarskite, a compound of the oxide associated with columbic and tungstic acid. Carnotite, oxide of uranium associated with vanadium.

Other rare forms are uranospinite, uranvitriol, uranociveite and while many other minerals such as pyomorphite, contain more or less radium, the source of supply is entirely from the silver uranium-bearing ores.

It is most unfortunate that so much difficulty exists in the separation of radium from the by-products with which it is so closely associated in its native state and in the recovery of it by these most tedious chemical processes; this fact is particularly true in the case of its association with thorium, and it has been pointed out, that under some circumstances the separation is impossible. Thorium, as it will be seen, disintegrates rapidly and while undergoing this rapid change it gives forth a very powerful radiation. If, therefore, a given preparation of radium has a considerable quantity of thorium mixed with it, it would for the time be extremely active; however, in a few years this activity would cease, then the specimen would contain only the radium radiation. The radium being the most valuable, as its period of life is about two thousand years, while the thorium is only worth that value for the unexpired radiatory period. Therefore, in the purchase of radium, its admixture with thorium should be fully understood.

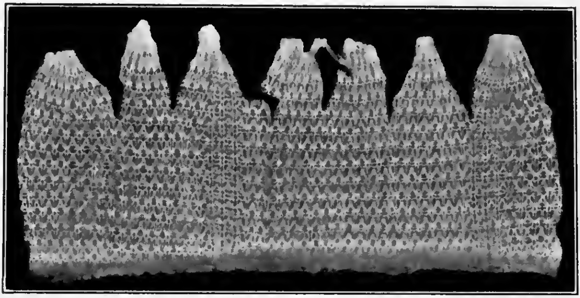
THORIUM.

Thorium stands in its group much the same as uranium in the radium group; it is doubtful if thorium, as a pure element, gives off any rays, and if so, they are extremely feeble and belong to the alpha group.

Thorium has an atomic weight of 232.5. Its period of life is unknown, and is probably much longer than that of uranium. Chemically it belongs to the group of rare earths. It is found as thorite in the monazite sands of North and South Carolina, in Brazil, and in Ceylon, in combination with other minerals, such as rutile, zircon, in some granites and under most circumstances it is also associated with uranium. Thorium-bearing minerals are more prone to be contaminated with a relatively high percentage of radium, than are the radium-bearing ores with thorium, and on account of the difficulty of separating the thorium elements from the radium elements, production of the pure thorium element at the present time is impossible. It is used extensively in the arts and it is refined by many technical processes, one being the heating of the sand with twice its weight of sulphuric acid; the cold mass is dissolved in water and left to settle. The solution is then fractionally precipitated with magnesia, the thorium being concentrated mainly in the first fractions precipitated.

The most useful agent for precipitating thorium from aluminium and iron is oxalic acid with which it forms a most insoluble compound. It may be separated from some of the other rare earths by its precipitation of dimethylamine. Potassium hydrazoate precipitates thorium hydroxide in the presence of cerium upon boiling. Thorium forms a compound with acetylacetone $Th(C_5H_7O_2)_4$ which is soluble in chloroform and alcohol and can be distilled in a vacuum. This method is employed in the purification of this element.

Fig. 6



A radiograph made of a Welsbach gas mantle by its own radiation.

Fusion with soda carbonate, as is usual with most refractory minerals, results here in the formation of the highly insoluble thorium oxide ThO_2.

Thorium, aside from its radio-activity, has been used in medicine in the form of oxalate and oxide to control vomiting. Its action is astringent and at the same time somewhat irritating; this is particularly noticeable in the soluble salts which, when given intravenously, produce decidedly toxic symptoms and even death. Solutions of the thorium salts precipitate proteins, bleach and harden muscles and other tissues. And, while these salts have no effect where the skin is unbroken, cases of dermatitis have been reported among workers in these earths which perhaps were due more to the radio-activity than to what is usually understood as direct irritation.

Thorium gives to steel a peculiar property of causing the emission of extremely bright sparks when filed or struck a sharp blow.

The fusion of the thorium compounds reduces permanently their radiability. The disintegration product of thorium is mesothorium. On account of the admixtures of radium with thorium, as they are found in nature, a careful study of this group of elements has thus far been impossible; therefore, very little is known of their atomic conditions; and, while it is possible to separate most of the elements and recognize them by their peculiarities, there seems to be no way open at the present time of obtaining this information until some entirely new methods have been devised.

Mesothorium 1.—Its period of average life is 7.9 years, it has the characteristics of an alkaline earth, is rayless, and simulates radium so closely that it has never been separated from it. This also applies when it is in combination with ionium or radiothorium. They are all identical in their chemical natures. Mesothorium may be separated from the monazite sands by the same methods employed in obtaining radium from pitchblend. A small amount of barium is added, which is precipitated with sulphuric acid and the mesothorium is found in the insoluble material. The disintegration product of mesothorium 1 is mesothorium 2.

Mesothorium 2, has a period of life of 8.9 hours, and probably belongs to the class of rare earths. It is easily separated from its parent by the addition of a little ammonium hydrate and, like the precipitation of uranium X, requires a nucleus to which it may cling; therefore, it is advisable to add a small quantity of a xirconium salt. This precipitate, however, will contain also all the radiothorium present, therefore this precipitation from the mesothorium 1, must be continued at intervals of two days each, until most of the radiothorium has been removed. The difficulty of separating these elements is evident and illustrates how impracticable it would be to separate them upon a commercial basis; therefore, where they are to be employed in medicine, the strictest supervision is enjoined.

Radiation.—The beta-rays are of moderate penetrating power, but are apparently heterogeneous, one-half being absorbed in 0.34 to 0.18 mm. thicknesses of aluminium. The gamma-rays are somewhat weaker than those given off by radium and compare largely with those of uranium; about one-half will be cut off by 1 cm. of lead. The disintegration product of this element is radiothorium.

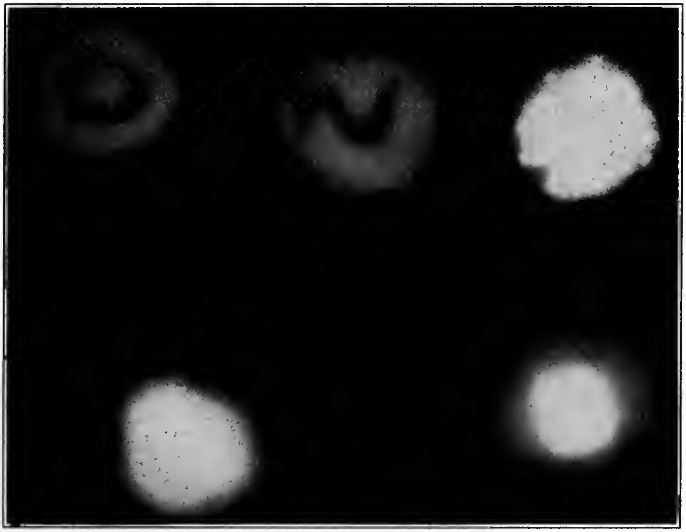
Radiothorium has an average life-period of about three years. It resembles its parent and was recognized by merest accident; its chemical properties being so identical that most careful physical procedures are required for its recognition. It gives off an alpha-ray which penetrates 3.9 cm. of air, and its disintegration product is thorium X. **Thorium X** has a period of life of 5.35 days; it belongs to the class of alkaline earths. If, after the precipitation of the thorium with ammonia, the filtrate is evaporated to dryness and the excess of ammonia carefully driven off, there remains a non-volatile residue, being thorium X. Under some circumstances the products of the emanation of thorium, and the "active product" are likely to be contained in the thorium X, but if the solution is kept in an open vessel for two days, the product of this change will be eliminated to a great extent.

Radiation consists of an alpha-ray and possibly a feeble beta-ray; the alpha-ray has a penetration of 5.7 cm. in air. The disintegration product is the emanation.

The emanation of thorium is a gas with an extremely short life, seventy-six seconds, its radio-active constant is 0.0131 $(\text{sec.})^{-1}$. It resembles the radium emanation in all its physical properties, being condensed by liquid air, absorbed by charcoal, and does not enter into chemical combination. It escapes freely from all thorium compounds but not with the same ratio. The best source of the emanation is from radiothorium. The range of the alpha-rays is about 5.5 cm. in air. Its product of disintegration is thorium A. With this element **thorium A** begins the thorium "active deposit of rapid change." The activity of thorium is so rapid that but few of its physical properties are understood. The period of average life is 0.203 seconds, and it is supposed to give off alpha-rays, the speed of which have not been determined. This element passes rapidly into **thorium B,** where the period of life is somewhat longer, being about 15.3 hours, and gives off beta-rays, one-half of which are absorbed by the thickness of 0.05 mm. of aluminium. The next disintegration product is **thorium C,** which like radium seems to be a double element C, and C_2; however, the latter has not been established, but there are given off two alpha-rayswhich have a range of 5 and 8.6 cm. in air. The end of this series is **thorium D,** with an average life-period of 4.5 minutes and a strong beta- and gamma-radiation. One-half of the beta-rays are checked by a sheet of aluminium 0.44 mm. thick, while it requires a sheet of lead 1.5 c.c. thick to cut off one-half the gamma-radiation. By more or less elaborate physical means, these elements of the "active deposit of rapid change" may be separated, but as some of them have an extremely short life, and the whole group is more or less confused, it is still only of scientific value like the radium group, the active product need only be con-

Fig. 7

1 2 3



4 5

Radiograph. 1, made by 5 gm. thorium oxide commercial; 2, made by 5 gm. thorium sulphate commercial; 3, made by 5 gm. thorite; 4, made by 5 gm. uranium acetate; 5, made by 5 gm. pitchblend.

sidered as a whole and, in this instance, as the emanation undergoes such a rapid change, it cannot be employed in the same manner as the emanation of radium.

Thorium Commercially.—The radio-active portion of thorium has been placed upon the market as **mesothorium**; on account of the difficulty in deriving a pure product of anyone of the different thorium elements, the activity is usually rated upon that of radium. In other words, radium element in equilibrium is also the standard for thorium. As it undergoes a rapid disintegration, the age of the salt is most important. While there is considerable contention as to the exact time of life of these thorium preparations, the one that appears to

FIG. 8

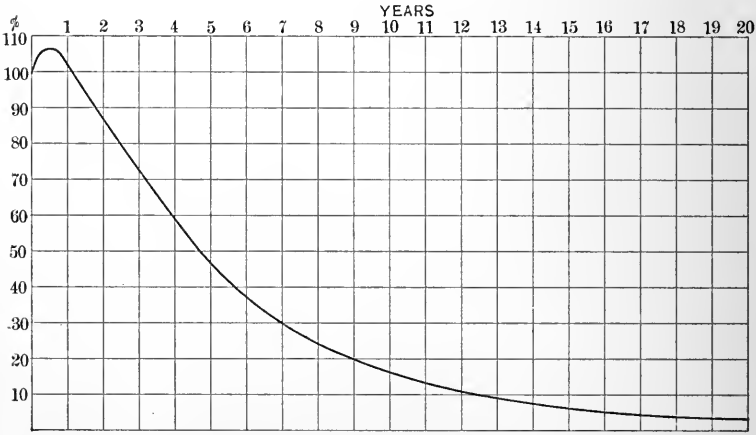


Diagram showing the possible rate of decay of commercial mesothorium.

be most accepted is that during the first year it gains considerably, then undergoes a rapid decline, until, in the fourth year, about one-half its energy has been lost; this steadily declines, until at the end of the tenth year, all the radiation from the thorium has been dissipated, and whatever activity remains, is due to radium. This disintegration curve has by no means been accepted and there are some who believe that it should be extended to fifty years.

There has been an effort to market the "active product" of thorium disintegration, under several trade names. It compares in its life to a great extent with the radium emanation, but instead of being a gas, it is a solution of the "active products;" like the radium emanation it undergoes a very rapid decay, and for that reason it cannot be shipped to a point any great distance from the laboratory in which it is made. While it is principally known as thorium X its activity is due to the rapid disintegration of the elements of the group composing the "active deposit." The ordinary physical properties of mesothorium are much the same as those described under radium and therefore need not be repeated.

ACTINIUM.

The Actinium Group.—The remaining group of these radio-active elements is mentioned merely for contrast; while some reports have been made where it has been employed in medicine, it was purely in the nature of scientific interest. It possesses all the properties of the two preceding groups and would be equally useful as a therapeutic agent, if it were possible to procure it in sufficient quantities. Actinium was discovered by Debierne in pitchblend; associated with the other radio-active elements; it takes its place in the iron group. Its nearest chemical analogue seems to be lanthanum. The period of average life is unknown and it appears to be rayless. Its parent is unknown and in some ways uranium seems to be associated with it in this respect; the difference in the activity of uranium minerals and uranium favoring this supposition. To produce a preparation of actinium with its products of disintegration, that would compare with radium, requires ten or twelve times as much mineral product. It has never been procured in a pure state and is always associated with lanthanum.

The disintegration product of actinium is **radio-actinium**, which has a period of average life of 28.1 days; it may be separated from its parent by adding a little sodium thiosulphate in a strongly acid solution. The acidification of this sulphate causes a precipitation of sulphur which carries down with it the actinium X. Very little of its chemical nature is known, but it gives off an alpha- and beta-radiation. The range of the α-ray is 4.55 cm. in air while one-half the β-ray penetrates a thickness of 0.04 mm. of aluminium. Its disintegration product is **actinium X,** which gives off an α-radiation, having a range of 4.17 cm. in air. Chemically it compares with radium and has a life-period of 14.8 days. It resembles thorium X and is separated from actinium by precipitation with ammonia, but differs in this respect that, when ignited to drive off the ammonia, the active product is also volatilized, but it immediately starts to produce a fresh supply. Its disintegration product is the **emanation** with an average period of life of 5.6 seconds. It has, like the emanation of radium and thorium, an alpha-radiation and its disintegration product is actinium A.

Actinium A begins the list of the "active deposit of rapid change" exactly the same as in the other two series but the existence of this element is extremely short, as the "period of average life" is 0.0029 second; it, however, gives off an alpha-radiation which has a range of 6.1 cm. in air. Its disintegration product is **actinium B,** with an average period of life of fifty-two minutes and gives off a fair β-radiation. Next in order is **actinium C**; and here again there seems to exist the same double element as in the two other groups, but the same doubt exists here as it does in thorium. Its period of life is about three minutes and is followed by actinium D, the end of the series of the active product. This is followed by actinium E, which like that of the thorium group is unknown. Actinium D gives off both a beta- and gamma-radiation. Its period of average life is 7.5 minutes, while the actinium group follows in order, exactly the same as the other two; the beginning and the end still remain unknown.

The present knowledge of these series of disintegration has been gained from uranium and radium which, by a careful technique, can be obtained in the pure state. This is not true, however, with regard to thorium and actinium, which so far have not been separated in a condition pure enough to obtain such details as their atomic weights or their spectra. It should also be remembered that most of these radio-active salts upon the market, contain more or less of all these elements which, in the case of radium, is usually so small as not to be detectable. Where the radium is to be used for such purposes as the study of the spectrum, the "active products" and gases from thorium and actinium degenerate so rapidly that they offer very little interference. While, on the other hand, with thorium there is usually a fairly high percentage of radium associated, this in no way interfering with their therapeutic value, and after the period of disintegration, which is rather short, from twenty to thirty years, the specimen still contains some activity.

CHAPTER III.

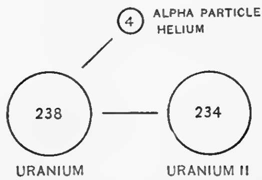
RADIO-ACTIVITY.

Definition—The Alpha-ray—The Beta-ray—The Gamma-ray—Helium—Comparison of the α-, β- and γ-rays with the rays generated in a Crookes Tube—Equilibrium—Period of Life—Ionization—Properties Causing Fluorescence—Phosphorescence—Heat and Other Physical Phenomena.

A DEFINITION given to this new department of science, radio-activity, is, "The dynamic property found in certain bodies of high atomic weight, of spontaneously emitting peculiar and characteristic rays, invisible to the eye, and capable of penetrating objects opaque to ordinary light" (Standard Dictionary). While this definition partly defines the word, it in some way promotes confusion as to the quality of these rays. A clear, concise definition has as yet not been given, but it might be expressed as the phenomenon observed in the interchange of the component particles of the atoms, simultaneous with their rearrangement and formation of new atoms. During this disturbance small portions are projected from the mass, giving rise to so-called rays; these rays in no way resemble ordinary light.

Most of the radio-active elements which are known today belong to a class with a very high atomic weight; there exists an instability of their atoms, which are constantly changing their nature, producing, in other words, other elements. For instance uranium, with an atomic weight of 238, splits off an α-particle which forms an atom of helium, with the atomic weight of 4, leaving uranium II the second product, with the atomic weight of 234. An interesting experiment shows that when the alpha-ray is projected through a tube with thin walls, helium is formed upon the outside of that tube; but if helium is placed in the same tube as helium, none escapes. Again if the tube is incased in lead, the α-ray, being liberated from the inside, strikes against these walls of lead where it is absorbed. If now the lead is melted in vacuum, helium is liberated from the lead.

Fig. 9



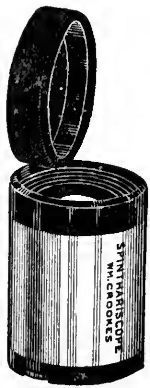
Showing the relation of the alpha-particle and helium.

In this interchange a certain amount of disturbance has taken place, with the manifestation of energy, exactly the same as in some of the more common physical processes such as combustion, and strange as it may seem, the amount of energy given off as heat is many times greater, but being eliminated so gradually over a space of many years, reaching up into the millions, it is not perceptible to ordinary methods of observation. If the energy given off in this change that is constantly occurring in uranium, could be burnt as coal, the heat supplied by one gram, or fifteen grains, would be sufficient to produce enough steam for a locomotive to pull a train of cars to Mars and back again.

During this process of the transmutation of these elements there are three distinct sets of rays to be observed; known as α (alpha), β (beta) and γ (gamma), after the first three letters of the Greek alphabet, and they differ as widely in their physical nature as they do in their therapeutic effect.

The alpha particle, or α-ray is a particle of matter one-fourth the size of a hydrogen atom and discharged from the mass at one-tenth to one-twentieth the velocity of light; these particles are positively charged and feebly deflected by the magnet. There seem to be four or more distinct groups, and those given off by uranium differ from those emitted from radium;

FIG. 10



Spinthariscope of Sir William Crookes.

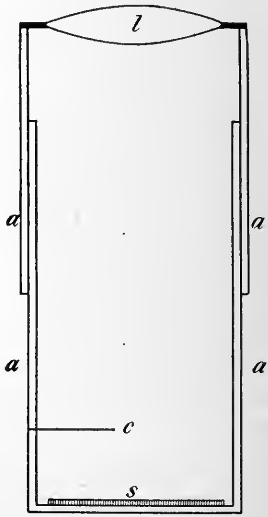
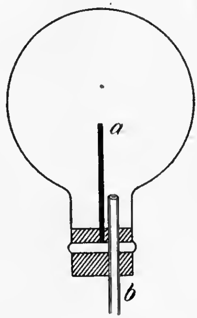


Diagram of spinthariscope. An infinitesimal amount of radium is held by a needle (*c*) over a screen of zinc sulphide (*s*). The lens (*l*) is mounted so as to focus upon the screen; inside of box should be black.

these in turn from those of thorium, depending to a great extent upon the speed by which they leave the mass. One milligram of radium gives off 136,000,000 alpha-particles per second. They are expelled from the radio-active element much as bullets shot from myriads of little guns. The projection of these particles may be shown by a small instrument devised by Sir William Crookes and called by him the spinthariscope; constructed from a lens, a screen of (Sadot's hexagonal blend) zinc sulphide, and a needle or some other object, with an infinitesimal amount of radium upon it. If the radio-active salt is too strong, instead of seeing the individual sparks, the bombardment will be so rapid that a continuous glow will result. As each particle strikes upon the screen, there appears a bright momentary flash of small sparks or scintillations, like a diminutive piece of hot iron being hammered upon a small anvil, or myriads of shooting stars. With this form of apparatus and more refined technique, it is possible to count the number of particles given off by any of these radio-active elements. From this constant bombardment the screen of zinc sulphide becomes in time worn out or, in other words, undergoes a fatigue, and the scintillations are by no means so bright or numerous in an old screen as in one that has been freshly prepared.

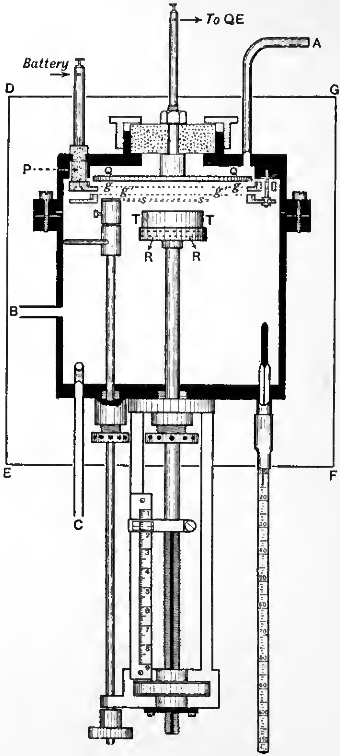
Fig. 11



Apparatus to show the range of the α-radiation at different air pressures. The inside of the glass globe is coated with zinc sulphide and upon *a* is placed a small amount of radium; the tube *b* is attached to an air pump.

While these bodies move with the velocity of about one-tenth that of light, they possess little power of penetration, most of them being entirely cut off by a thin sheet of tissue paper. Usually one element gives off only one type of alpha-rays; however, under ordinary conditions, several of these elements are found together, due to the disintegration of the parent. There will be found, emitted from a particle of salt, several of these alpha-rays, differing in their penetrating power, usually measured by their range in air. The strongest are usually completely blocked in a

FIG. 12



Apparatus for finding the range of the α-ray. The radium is placed in a very thin layer on a platinum plate (*R*, *R*). Over this stands a bundle on about 150 upright tubes (*T*, *T*) made of thin copper, each 1 cm. long and 2 mm. in diameter. Only such α-particles emerge from these tubes as leave the plate in an almost vertical direction. The ionization chamber is the space between the plate (*Q*, *Q*) and the parallel sheet of gauze (*g*, *g*). It is 3 mm. in depth and its diameter is such that the whole of the α-ray stream enters the chamber. The gauze is carried on three glass pillars, one of which is perforated along its axis to allow electrical communication between the gauze and the battery. The pillar which supports the plate (*Q*, *Q*) passes through a glass plate made air-tight by india-rubber washers. The plate (*Q*, *Q*) is connected to an electrometer and the gauze (*g*, *g*) to the battery, so that the gauze is at a high potential compared with the plate, which is earthed through the electrometer. The case of the instrument is grounded space of 6 cm.; this range, of course, is under normal atmospheric conditions, and this is well illustrated by having a flask covered on the inside with a film of zinc sulphide; in the centre is a small needle, the point containing a small amount of radium (it being understood that from the point where the radium is suspended the radius is considerably more than 6 cm.). Under ordinary atmospheric conditions nothing is observed, but as soon as this flask is exhausted to some extent, causing the air to become rarefied, the alpha-particles, meeting with less obstruction, impinge upon the crystals of zinc sulphide and cause them to glow in the same manner as when they were within range under normal conditions.

The path of these rays and their speed have been studied by a similar method, so arranged that, as these particles travel through dust of this material, during their flight they are photographed and timed by comparison with electric

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permanently, so that no electricity can pass over from the battery to the electrometer. In order to prevent accidental and troublesome electrostatic effects, the interior is so arranged that no lines of force end on Q, Q, but only such as have proceeded from metal surfaces of definite and unaltering potential. For this purpose glass pillars which support g, g are buried in cavities in the body of the case; if there should be any leakage over the pillars, there cannot be any resulting electrostatic action on the plate (Q, Q). The gauze sheet (g', g') is grounded, and is placed as far below the gauze (g, g) as the plate (Q, Q) is above it; thus the electrical field is made symmetrical, and no ions from below can make their way into the chamber, as it must be remembered that there is heavy ionization below the gauze, that must not contribute to the current measured. A screen (s, s) of very thin copper is mounted on a rod which passes into the apparatus through a stuffing box, and can be raised, lowered, and turned around. The screen can be used to cut off all the α-radiation from the radium, or can be turned aside when it is desired to allow these rays through the above screens for measurement. The case of the apparatus is made in two parts, the upper one carrying the gauzes and ionization chamber. The tubes A, B, and C, are for the purpose of filling the case with any desired gas or vapor. The whole apparatus is surrounded by an outer case (D, E, F, G), and the joints in this case must be protected in the same manner as those in the inner case, particularly when the radiation of a gas is to be studied.

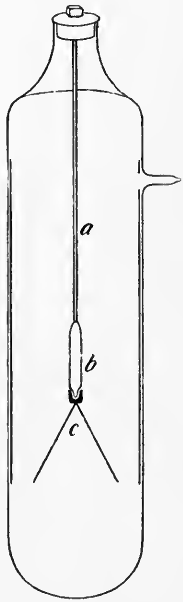
flashes. The range of the alpha-particle is proportionate to a third of its velocity. There is some doubt as to whether the alpha-ray itself possesses the power of ionization, or whether it is due to the formation of secondary rays of another variety.

The beta (β) **ray** is an electron or a small particle charged with negative electricity moving with almost the same velocity as light. It would require about 4000 beta-particles to balance one alpha-particle, as the mass of an electron is equal to $\frac{1}{1000}$ part of a hydrogen atom; but, small as they are, they cause more or less disturbance in the matter through which they pass. The effect of gravity upon these particles is still unknown. Electrons have been spoken of as being disturbances in ether; they were first observed by Sir William Crookes as the cathode rays and given the name of "radiant matter." They are not homogeneous, varying in most part from 40 per cent. to 80 per cent., and are, for practical purposes, arbitrarily divided into soft, medium, and hard rays. The hard rays are of extreme tenacity and it is doubtful if 1 cm. of lead will completely block them. They all ionize the gas through which they pass, leaving a column of ions in their tracks. The magnet causes them to be turned in their path clockwise; consequently they are deviated to the north pole.

The cathode ray and the beta-particle carry the same electrical charge as the hydrogen atom. They are, in other words, atoms with the mass removed. The cathode ray travels with a velocity of about 5000 to 10,000 miles per second while the beta-particle travels many times faster; the highest will approach 185,000 miles per second. The speed with which the beta-particles are projected from these radio-active elements varies with each one, and here again, under the ordinary circumstances of any salt containing the products of disintegration, there will be a wide variation of all the beta-rays.

The discharge of these beta-rays from the radio-active salts gives rise to many curious experiments, one of which is illustrated by what is known as Professor Strutt's radium clock which works by the continuous charge and discharge of these beta-rays. It is constructed by placing a small glass tube, containing radium, suspended by some insulating material, in a glass flask, which is exhausted to a vacuum of high degree. At the lower end of the radium tube two sheets of gold leaf are hung, which act as an electroscope. As the beta-rays are shot away from the radium, carrying their negative electricity, they leave behind the positive charge, which gradually accumulates until the leaves of the electroscope touch the sides of the flask, discharge the electricity of the mass of radium, and collapse; they then gradually expand again, as the charge accumulates until they are again discharged. This continues indefinitely and with utmost precision, the rate being in proportion to the discharge of the mass of radium contained within the small tube.

FIG 13



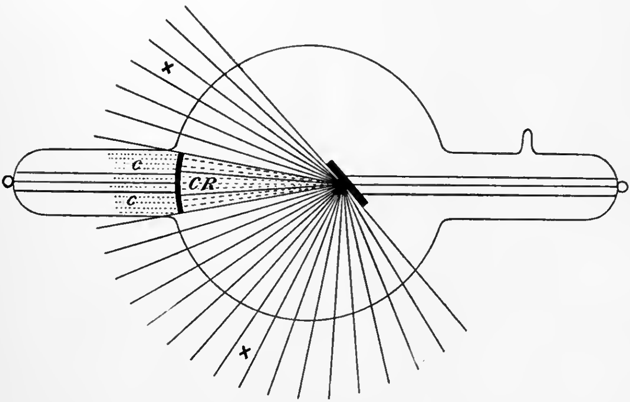
Prof. Strutt's clock: *b*, tube of radium; *c*, gold leaf; *a*, quartz thread insulator.

The gamma (γ) **rays** have been described as pulsations of ether of extremely short wave length, or a secondary electro-magnetic disturbance of ether due to the motion of the beta-rays; however very little is known about them. At one time they were thought to be secondary pulsations to the beta-ray, but it is now known that secondary beta-rays are formed along the path of the gamma-ray, and it was also inferred that where the beta-ray was given off it was also accompanied by the gamma-ray. These views are all more or less confused as they depend upon each other. The gamma-rays might be compared to the high x-rays, and simulate them in many of their physical properties. They have the same velocity as light and are not deflected from their path by any agent so far known. They are not polarized, nor has the magnet any effect upon them. Their power of penetration is extreme, passing through many centimeters of lead, and they are practically only annihilated by space.

The ultraviolet rays ranging above the high end of the spectrum are often confused with these rays but have absolutely nothing in common with them, therefore the ordinary light rays, with the infra reds and ultraviolet that differ so widely in their physical characteristics, must be considered under an entirely different classification.

While the alpha-, beta-, and gamma-rays have their individual, physical properties, there are some which they all seem to have in common, and even with the other different rays observed in and about an x-ray or Crookes tube. It has just been mentioned that the gamma-rays compare with high x-rays, and that the cathode rays are analogous to the beta-rays; while the alpha-rays compare with the canal rays; the difference always being that the rays given off by these radio-active elements are invariably of higher velocity than those from an artificial source. This is the essential difference between the use of x-rays, from artificial sources, and the rays derived from nature's laboratory; as to their other physical properties they resemble each other, if they are not identical; one of the most interesting of them being the deviation of the cathode ray from its path by the magnet, exactly in the same direction as the beta-ray.

FIG. 14



c, c, canal rays analogous to the alpha-rays observed back of the cathode; *C, R*, the cathode ray analogous to beta-rays, passing between the cathode and the point of the anode; *x, x*, *x*-ray analogous to the gamma-ray, formed at a point upon the anode.

All these rays have the effect of reducing the silver of photographic plates and producing radiographs; however, it will be noticed that radiographs made from radio-active salts always lack the definition of those made by the Roentgen rays. This is due doubtless to the secondary radiation which is more prevalent, not only from surrounding objects of a material nature but also from smaller objects, such as microscopic dust, that ordinarily are not taken into consideration. If by means of a magnet the β-radiation is turned aside, the radiograph will have much sharper outlines, while removing it by filtration has not the same effect.

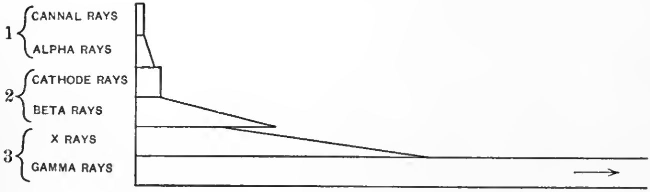
Secondary radiation, from a medical stand-point, requires more consideration when these radio-active salts are used than would be necessary with the Roentgen rays. The cause seems to be principally due to the β-radiation which is always so extremely active.

The penetrability of these rays, Rutherford has placed at the following values: $\alpha=1$ $\beta=100$ and $\gamma=1000$; they, however, overlap to some degree, in other words, the most penetrating alpha-ray passes beyond the soft beta, while the hard beta passes beyond the soft gamma.

	Ionizing power.	Penetration.	Absorption of ½ by thickness of aluminium.
α	10,000	1	0.005
β	100	100	0.5
γ	1	10,000	80.0

The amount of radiation eliminated by radium in equilibrium is principally in the form of the alpha-ray and it exceeds both the beta and gamma; the amount of beta radiation is far in excess of the gamma; therefore the gamma radiation, which is so desirable in medicine, is given off in such small quantities that, from an experimental standpoint, it hardly needs to be considered. The proportion between the α- and γ-rays is illustrated by the fact that the alpha-rays, forming 1 mg. of radium, more than equal the gamma-radiation of 136 mg.; therefore it is easily seen why such enormous quantities of this material are used in the treatment of disease; where the α- and β-rays must be removed by filtration.

FIG. 15



Showing the penetration of the different rays.

Equilibrium of these radio-active elements is that cycle or continuation of them, when the processes of disintegration have become balanced and the amount of radiation from the salts becomes more or less continuous at a given ratio. When fresh salts of radium, thorium or any of the other elements are freshly crystallized, the new material is only very feeble or entirely lacking in its radio-activity. As these crystals age (perhaps the aging is only the matter of a portion of a second, or it may be many years) up to a given point they gain in activity. This process is continued until the rate of decay of its final disintegrating element becomes balanced; then the whole salt is in equilibrium. If, for some reason, the crystals are re-crystallized before they reach the stage of equilibrium it in no way influences the new cycle, in other words the stage of gaining equilibrium begins with the age of the crystals and with that alone. To illustrate: let Z, a salt in equilibrium (ε) be composed of 5 per cent. of A that requires one day to form in full amount; B 10 per cent. within two days after A; C 10 per cent. within ten days after B, and so on. The salt *Z*, when one day old, would only give off 5 per cent. of radiation; at the end of five more days it would have gained the 10 per cent. *B* force and some from *C*, making possibly between 18 and 20 per cent., depending upon the rate of formation of *C*. Most of these radio-active elements gain their greatest amount of radiation in the first half of their average period of life. This gaining process, therefore, would be continued until the last disintegrating element of that series had gained its balance, and the full salt would be in "equilibrium;" in other words, it is the point of radio-active saturation where the process of gain on the one hand equals the decay on the other. Most of the radio-active elements used in medicine gain their equilibrium in a comparatively short space of time; otherwise the activity would not be sufficient for therapeutic purposes; for instance, the slow change of uranium and the rapid change in radium. The latter gains most of its activity in about a month, and, while it gains a little more after the lapse of twenty-four years, it is rather feeble, and from a therapeutic stand-point is not worth considering.

Table Showing the Gain of Radiation during the Different Periods.

	Alpha particles.	β- and γ-rays.
I. Freshly prepared. (First period.)	1. Due to pure radium.	None.
II. After thirty days. (Second period.)	4. Due to radium emanation. Radium A, Radium C.	2. "Active deposit of rapid change."
III. After a century. (Third period.)	5. Same as second period and one added by Radium F.	3. One added by Radium E.

The "average period of life" is a term used to express the time of existence of an atom of any one of these radio-active elements. In some this existence is extremely short, even the fraction of a second, while, on the other hand, it may extend over 1,000,000 years. This relates to the future life of the atoms, does not consider the past, and is merely the sum of separate periods of future existence. It may be expressed by the following equation:

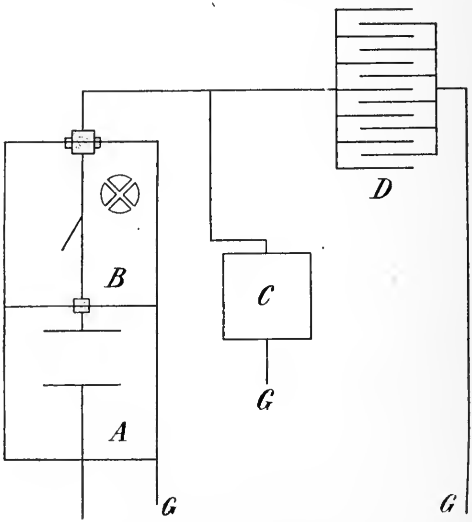
$$\frac{I_t}{I_0} = \varepsilon^{-\lambda t}$$

Where I_0 is the initial activity I_t, the activity after any time t, λ a constant known as the radio-active constant, and ϵ the number 2,71828 in the case of polonium.

It appears, however, that when these elements first form the disintegration varies. These atoms may change in a shorter space of time, but the "period of half change" is by no means used to express half of the average period of life; insofar as time is concerned it may be almost as long as the average period of life. These terms must not be confused with the practical application of the elements. An example of this is illustrated by the life of the radium emanation, which has a period of average life of 5.57 days. Period of half change is 3.86 days, which might seem to imply that when the emanation was removed from the radium in 5.57 days its usefulness would cease, but it must be remembered that at the time there are atoms of all ages present and added to this are the various periods of average life of other products included in the "active deposit of rapid change," and therefore the curve of disintegration, insofar as its practical application is concerned, is decidedly altered, and follows that given in Fig. 16, page 62. When radium emanation is separated from its parent it has gained its equilibrium in three or four hours; in four days it has degenerated to one-half its full value, and from here on the process is somewhat slow, but at the end of fifteen days its radiation has practically disappeared.

Therefore the change in a single atom of one of these radio-active elements must not be confused with the disintegration mass of a whole series.

FIG. 16



Apparatus for estimation of radio-activity: *A*, ionizing chamber; *B*, electroscope or electrometer; *C*, changing apparatus; *D*, condenser.

The rate of change in any single case of atomic disintegration is proportionate to the quantity of the substance which is changing. By determining the different factors an algebraic proportion may determine these facts; but before reaching the factor for solving this problem "*the radio-active constant*" must be established which signifies the amount of that mass which undergoes change in one second, and in the case of radium emanation is $\frac{1}{481250}$ of the total. For the consideration of this "constant" the change of these elements must be considered at different periods of their lives, as atoms disintegrating first have a much shorter period of life, while those in the latter part of the decay have a much longer period than the average.

Ionization.—One of the most important properties possessed by these radio-active elements is the ionization of gases by their radiation. This phenomenon is manifested by the discharge of electrified bodies, either positively or negatively charged, and is the basis of all analytical analysis in the study of radiation.

The general supposition is that the process of the ionization in gases is due to the removal of a negative corpuscle or electron from a molecule of gas; the electron becomes attached to another molecule and becomes a negative ion. The molecule from which this negative corpuscle was removed retains its positive charge.

The amount of current needed to balance the ionization of a given mass is known as the current of "saturation," the variation depends upon the velocity of the ions and their state of re-combination. The negative ions are decidedly more active than positive ions, the former causing particles of water or organic vapors to collect about them while the latter act only to a very limited extent; from this phenomenon it has been possible to calculate the charge of the ions.

The α-rays produce from 2000 to 6000 ions per millimeter of path, while the β-rays produce not more than 20 to 30 per millimeter. It has been supposed that ionization is principally due to the β-rays or to secondary β-radiation, formed by either the α- or γ-rays; this, however, is open to objection and possibly the ionization may be directly from either source of radiation.

Properties Causing Fluorescence and Phosphorescence.—The rays given off by these radio-active elements have the remarkable power of causing certain substances, chemical salts and minerals, to emit light; some only while the rays impinge upon them, which has been termed *fluorescence;* and others continuing to glow for a time after their exposure, this being termed *phosphorescence.* The rays have by no means an equal action upon the same or different minerals or chemical salts: some will glow under the influence of the alpha-ray that fail to respond to the beta-ray, and even while the x-ray and the γ-ray are almost identical, in some of these substances the light emitted by them differs to a considerable degree.

The action of the α-ray upon Sadot's hexagonal blend zinc sulphide, has been previously explained; the others, β-, γ-, or x-rays, fail to excite it in any such degree, with the peculiar individuality which has been described.

Willemite (zinc silicate) and platino-barium-cyanide, become most brilliant under the influence of the β- and γ-rays, as well as the x-rays, but magnesium-platinum-cyanide responds brilliantly to the x-rays, but not to either the β- or γ-rays. The artificial zinc silicate does not possess these fluorescent properties. By the use of these different articles it is possible to have brilliant light produced by the different rays and in this way to separate them to some extent.

There are many other substances, such as most natural crystals, the diamond, emerald, calcite, gypsum apatite, also the aniline dyes, quinine, metol, and a wide range of other organic chemicals, which become fluorescent and some of them phosphorescent under the influence of these rays.

The color of this fluorescence may vary from a bright yellow to deep orange, and some will even show a dull red. Others, like the scheelite (tungstate of calcium), have a more bluish cast. As a general rule most of these substances, especially the more brilliant ones, glow with a peculiar bright opalescent canary-yellow color. It would be extremely difficult to draw a line between the fluorescent and the phosphorescent substances, for in most instances those that are fluorescent have what is technically spoken of as a "lag;" that is, the light does not disappear with the cessation of the exciting cause, in other words, they are slightly phosphorescent. Here again we notice a difference between the rays which cause the effect. The beautiful effect of the alpha-ray upon zinc sulphide is lost if the rays impinging upon it are too numerous; or, if there be too many β- and γ-rays, the screen becomes phosphorescent and remains so for some time afterward. This is also noticed with scheelite, when exposed to any of these rays, while some of the substances retain phosphorescence for days.

The action of these minerals and chemicals must not be confused with the natural luminosity of many of these radio-active elements, for some of them are extremely brilliant in the dark; even the emanation, when concentrated, has quite a bright glow.

Wherever a chemical or physical change takes place, it is well known that it is always accompanied with some disturbance in the element of heat; in other words, heat is given off, or else there is an absence of heat, which causes the object to become what is commonly known as cold. This disturbance in the disintegration of these elements is manifested as heat. For instance, the amount of heat for 1 gram of pure radium is about 133 calories per hour; this becomes 1,160,000 calories in one year, which continues for the life of radium, which is 2500 years; and, therefore, the total disintegration of 1 gram of radium would give off $1{,}160{,}000 \times 2500$ calories, equal to the burning of about

1,000,000 tons of coal. It is rather interesting to notice the distribution of the source of heat for the different radium elements and the amount given off by the different forms of radiation.

	Heating effect of gram calories per hour. corresponding to 1 gram of radium.			
Radium.	α	β	γ	Total.
Emanation	25.1	..	..	25.1
Radium A	28.6	..	..	28.6
Radium B	30.5	..	..	30.5
Radium C	39.4	4.3	6.5	50.2
Totals . .	123.6	4.3	6.5	134.4

The radio-activity of the air is due principally to the emanation which arises from radium in the earth and has been estimated by different physicists. The two methods of collecting the emanation were by passing air over cocoanut charcoal and heating it, then collecting it in a suitable container, or by passing air through liquid air, thus causing the emanation to liquify and afterward collecting it and estimating by routine methods. The results were:

Eve 60×10^{-12} gr. = Ra. 0.000000000060 gr. per cubic meter.
Satterly 100×10^{-12} gr. = Ra. 0.000000000100 gr. per cubic meter.
Ashman 89×10^{-12} gr. = Ra. 0.000000000089 gr. per cubic meter.

The amount in the air at different times seems to vary with atmospheric conditions, there being less present in cyclonic weather, when accompanied by considerable moisture; however, before cyclones or rapid thaws of snow it seems to be the greatest.

While all these radio-active elements are constantly undergoing this degeneration it should be supposed that in time the supply would become exhausted, but if it will be remembered that uranium starts this group with a degeneration period lasting over eight billion years, it can be easily seen that the supply of radium will at least be a factor to be calculated for many thousands of years. However, the fact that the degeneration of uranium is eight billion years and that of radium twenty-five hundred years, gives us the assurance that the yield of this very valuable article will never be excessive; there must be an enormous amount of uranium slowly undergoing disintegration to form these extremely small portions of radium. This fact is observed in the yield of the different uranium elements, the older formations, such as pitchblend, are richer in radium than those formed at later periods, as, for instance, the crystals of uranium found near the surface; under normal conditions the amount of each element is expressed by the following table:

	Period.	Amount.
Uranium I . .	8,000,000,000 years	1,000,000,000 mg.
Uranium II . .	2,000,000 years	250,000 mg.
Uranium X . .	35.5 days	0.0125 mg.
Ionium . .	200,000 years (?)	25,000 mg. (?)
Radium . .	2,500 years	312.5 mg.
Emanation . .	5.6 days	0.002 mg.
Radium A . .	4.3 minutes	0.000001 mg.
Radium B . .	38.5 minutes	0.000009 mg.
Radium C . .	28.1 minutes	0.000007 mg.
Radium D . .	24 years	3,000 mg.
Radium E . .	7.5 days	0.00025 mg.
Radium F (Polonium)	202 days	0.071 mg.

CHAPTER IV.

METHODS OF ESTIMATING RADIATION.

The Standards used in Estimating the Amount of Radiation and Methods Employed to Obtain Them—The Alpha-ray Unit—The Curie—Mache Unit—Other Units—Methods of Estimation—Ionization—Electroscopes of Various Forms—Fluorescent Method—Photographic Method.

The finest analytical balance could not weigh the infinitesimal amount of a radio-active element contained within a mineral or salt, that would be easily detectible by such means as are employed for the estimation of these activities. The many forms of apparatus depend upon the simple electroscope, modified in some way to suit the exigencies of the occasion. The $\frac{1}{50000000}$ mg. or $\frac{1}{3000000000}$ gr. of radium is easily demonstrated by an ordinary apparatus and well-trained technique. Even amounts considerably more infinitesimal may be demonstrated under certain conditions.

Until the International Committee established the Curie unit for the measurement of radio-activity there were numerous methods and standards employed, all more or less confused, depending upon ideas developed in different countries by societies and individuals, and as some of these standards still have a degree of usefulness and are quoted, it will be necessary for one reviewing the subject to have an understanding of their usefulness and limitations. One of the earliest methods of estimating the radio-active energy of a salt was by calculating the ionization and comparing it with a standard that ranged from uranium the base, as 1, to pure radium bromide, as 2,000,000. This means that the same amount of radium bromide would ionize 2,000,000 times faster than the same amount of uranium. The difficulty in establishing this standard was to know from what base it was calculated if radium bromide was considered as $RaBr_2$ or as $RaBr_2 2H_2O$; or in some instances it was reckoned upon pure radium, and from the stand-point of uranium, the calculations were as often made from uranium oxide, U_3O_8.

Uranium is still the basis for the standard for α-ray activity on account of the constancy of this form of radiation, as it is not affected by the different chemical manipulations as much as the other radio-active elements, and it is convenient for the standardization and calibration of electroscopes, electrometers, and other measuring instruments employed in this field. For the preparation of the disks, a thin film of uranium oxide is prepared by reducing uranium nitrate with ammonia carbonate in a platinum crucible. This is ground to a very fine powder mixed with enough chloroform to make a paste, and then applied to the bright and clean metal disk. The surface must be covered completely, otherwise errors will result from uncovered spots. After the disks have been properly prepared, they should be allowed to stand for a month or so, being protected from dust. Comparisons are then made by preparing disks of the same size from the mineral or salt under investigation.

If uranium, taken as a unit standard, is considered as 1, and radium bromide as 2,000,000, then the pure radium element would have an activity of 3,731,000, the other ordinary salts such as the chloride, sulphate, and carbonate would all rate above the activity of the bromide, as the proportion of radium to the salt-forming acid is somewhat less in bromide. The method was usually applied in practice to signify the purity of a radio-active salt, as for instance, if 10 mg. of powder possessed an activity of 100,000 units, it contained 5 per cent. of pure radium, or radium bromide, depending upon the unit used, which was purely arbitrary from the point of view of the examiner. In most instances it was considered as radium bromide, $RaBr_22H_2O$, and the activities were always in proportion to the percentage.

0.5 per cent. of radium salt would give an activity of about	10,000
1.0 per cent. of radium salt would give an activity of about	20,000
5.0 per cent. of radium salt would give an activity of about	100,000
50.0 per cent. of radium salt would give an activity of about	1,000,000

The basis of activity would always give the amount of radium, but the percentages of salt would depend upon the acid in combination, which, however, is a small factor considering that the activity alone depends entirely upon the metallic radium.

Kilo-uranium or *kilurane* was suggested by M. Beaudoin to relieve the number of figures in speaking of the strength of powerful radio-active salts in comparison with uranium; in other words, the unit represented 1000 uranium units. The letter U is therefore supposed to designate the standard of 1000, and therefore 500 U would equal 500,000 uranium units, 1000 U would equal 1,000,000 uranium units, etc. This standard has not been generally accepted and is rarely used.

Under all circumstances calculation should be made upon the basis of *pure radium element* and its radio-activity in

Curie units; the adoption of this standard was due to the International Society of Radiology and Electricity, meeting in Brussels, 1910, where a committee was appointed to review the field and propound a proper standard for the measurement of radio-activity. This committee requested Madame Curie to prepare a specimen of pure radium salt, and from this make the deduction as to the amount of activity derived from it. The preparation contained 22 mg. of pure radium chloride, and from it calculations were made for the adoption of the unit known as a "curie."

The Curie.—*One curie* is that quantity of radium emanation derived from 1 gram of radium element in equilibrium: equal to 0.6 c.mm. at a temperature of 0° C., and a barometric pressure of 760 mm., correction for vapor densities, etc. This standard is maintained at Paris; the original being maintained alone, away from all influences that in any way could affect its equilibrium. From this one standard secondary standards are made and sent out to different centres such as Vienna, London, etc., and from these again others are made for measurements and for comparisons in ordinary laboratory work.

On account of the amount of radium required to develop one curie, it was thought desirable to have smaller standards. This led to the adoption of the millicurie.

The *millicurie* represents the quantity of radium emanation in equilibrium with a milligram of radium element, under the same normal conditions of temperature and pressure.

The *microcurie* is a still smaller unit and uses the microgram or the millionth part of 1 gram as the unit. It is principally employed in expressing the amounts of radiation existing in earths and waters that possess very little activity.

The Mache unit expresses the saturation of the emanation of radium, free from products of decay, from 1 liter of solution or gas. It equals the number of electrostatic units multiplied by 1000. This unit is of value in expressing the amount of radiation in water or air, but care should be exercised to mention the degree of concentration, which often is overlooked thereby making the term useless; in other words, when the number of Mache units is given, the amount of gas or water should also be mentioned, as, 100 m. u. per liter in a bath of 300 liters capacity, making a total of $300 \times 100 = 30{,}000$ m. u.

One curie of emanation per liter would equal a concentration of 2,670,000,000 m. u. (Mache units).

One Mache unit (10 liter condensation chambers) = 0.00632 mg. minutes radium bromide; $RaBr_2$, or 0.465×10^{-9} (= 0.000000000465) curie. All authorities do not agree upon these figures.

One Mache unit = 75—150 volt per hour.

1000 Mache units = 1 electrostatic unit or 2.86×10^{-7} (= 0.000000286) curie.

2.15 Mache units = 0.0137 mg. minutes $RaBr_2$ or 10^{-9} curie.

The **electrostatic unit** is frequently quoted by the Germans. It represents that quantity of current equal to 0.000000000333 ampère. Thus solutions of mesothorium and thorium X for internal administrations are rated by the number of electrostatic units they contain.

One curie gives a saturation current in an ionization chamber of uniform standards of size, temperature, and air pressure, of 2,670,000 electrostatic units = 0.89 milliampère.

1 electrostatic unit = 1000 m. u., or 2.86×10^{-7} (= 0.000000286) curie.

It has been suggested that the value of the emanation ionization current be expressed as the *billionth of an ampère.* This has not been generally accepted.

The **milligram minute** represents the quantity of radium emanation which 1 mg. of pure radium bromide (anhydrous) produces in one minute, and equals 0.73 microcurie, or about 180 Mache units per liter.

1 milligram minute of emanation of radium element = 125.0×10^{-9} curie.

1 milligram minute of emanation of radium bromide, $RaBr_2$ = 157.9 Mache units, or 73.4×10^{-9} (= 0.0000000734) curie. (This is disputed by some authorities as not exact.)

The **milligram second** represents the quantity of radium emanation produced in 1 second by 1 mg. of radium bromide in the anhydrous state, and equals about 0.00122 microcurie, or about 2.4 Mache units.

1 milligram second emanation of radium element = 2.08×10^{-9} (= 0.00000000208) curie.

1 milligram second emanation of radium bromide ($RaBr_2$) = 1.22×10^{-9} (= 0.00000000122) curie.

1 milligram second emanation of radium bromide ($RaBr_2 + 2H_2O$) = 2.4 Mache units or 1.116×10^{-6} (=0.000001116) curie.

These last two units have been employed to express the amount of radiation from natural sources, such as springs.

1 gram second emanation of radium element = 2.08×10^{-6} (= 0.00000208) curie.

1 gram second emanation of radium bromide, $RaBr_2$ = 3.54×10^{-6} (= 0.00000354) curie.

Milligram hour is a term suggested by Turner, of Edinburgh, and is likely to be confused with the milligram minute and milligram second. However, its purpose is entirely different. He suggested it in order to give the amount of radiation in the same manner as that employed in denoting the flow of electricity, as the ampère hour; for example, a 10-milligram specimen of pure radium, applied for one hour, would be called 10 milligram hours, and corrections made according to the time and strength of the radium. If, for instance, a 1,000,000 unit, 5-milligram salt of radium be applied for one hour, the total would be $2\frac{1}{2}$ milligram hours. The unit is employed in therapeutics.

Volts per hour is a method of expressing the amount of emanation from a liter of solution or gas as observed from the movement of the electroscope. The scales of some instruments are so calibrated as to correspond to the inpotentials and read as volts.

Volts per minute is employed in exactly the same manner, but does not give such enormous figures as the preceding.

Both these terms are confusing and, like many of the others, should be abandoned.

Uranium unit expresses the amount of ionization from the radiation of uranium oxide, Ur_2O_5, chemically pure and properly aged, spread upon a plate 6 cm. in diameter, in an ionizing chamber of definite dimensions. Calculations are made upon the basis of metallic uranium. It equals about 22.02×10^{-6} millicuries.

At the present time there is no direct method of comparing, from a medical standpoint, the amount of radiation from these radio-active salts, with that developed by artificial means, as for instance, Roentgen rays. Such units as Holzknecht, Sabouraud, Keinböch and others used in obtaining the amounts of *x*-ray, fail to give the correct interpretation of the radiation from these natural products. However, the means used in estimating the amount of radiation give far more uniform standards than those adopted for the measurement of the Roentgen rays.

When the radiation from a certain amount of radium has been once ascertained, it continues to give off the same proportion of α-, β-, and γ-rays continuously, without variation, for a definite period. The different metal screens interposed may cut off a given amount of ray, but it too can be measured, and it will cut off the same amount of radiation under similar conditions when or where applied. It is constant, and therefore, under all circumstances, the amount of radiation can be estimated for any degree of penetration. It is possible to measure the amount and penetration of the Roentgen rays, but they are by no means constant and vary between limits under the most skilled manipulation, and while it is possible to obtain an approximate idea of the total amount of radiation, both in quantity and quality, an exact idea is impossible, and all the methods devised for reading the quantity of x-ray are subject to some variation.

Methods of Estimation.—There are three ways of estimating the amount of radiation from these radio-active elements. They are:

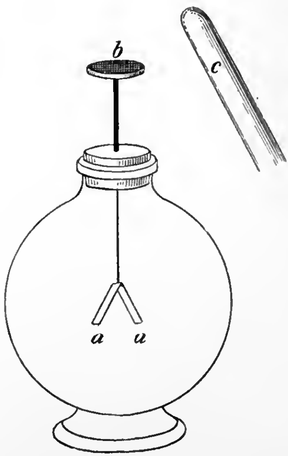
1. The ionization method, which is the most accurate, and is employed where exact measurements are desired.

2. By the effects of these radio-active salts upon the photographic plate. This method is rather tedious, but the results are permanent and can be used for comparison.

3. By the brilliance of different fluorescent substances produced from the radiation of these elements. This, like the second method, is subject to personal equation, much depending upon the operator's judgment. The first gives accurate results, while the other two are extremely crude and only give a relative idea of the actual amount of activity.

Electroscope.—The measurement of all the radio-active salts depends upon the electroscope, and on account of its extreme sensitiveness, the amount of radio-active elements must be extremely small not to be detectable, and while these electroscopes are open to many sources of error, if they are handled with any degree of care, under skilled manipulation these errors are not likely to occur.

Fig. 17



Electroscope charged by rod *c;* it is never necessary to touch plate *b*, as it would likely tear the thin gold leaf *a*, *a*.

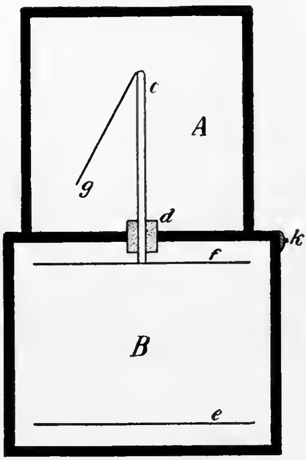
The general principle upon which these electroscopes measure the quantity of radiation is from the ionization of the air by these radio-active elements, thus causing the discharge of the charge held within the insulated portion of the apparatus. The stronger the activity, the more rapidly the gas about the electroscope is ionized; the greater the ionization, the sooner the charge is dispersed.

RELATIVE IONIZATION PRODUCED IN VARIOUS GASES BY α-, β-, AND γ-RAYS COMPARED WITH AIR.

Gas.	Density.	α	β	γ	x
Air	1.	1.	1.	1.	1.
H	.069	.24	.115	.16	0.114
O	1.11	1.15	1.17	1.16	1.39
N_2O	1.53	1.53	1.55	1.55	...
CO_2	1.53	1.59	1.6	1.58	1.6

The ordinary electroscope of the laboratory consists of two thin strips of gold-foil, suspended by a brass rod within a glass globe properly insulated, and extends outside so as to

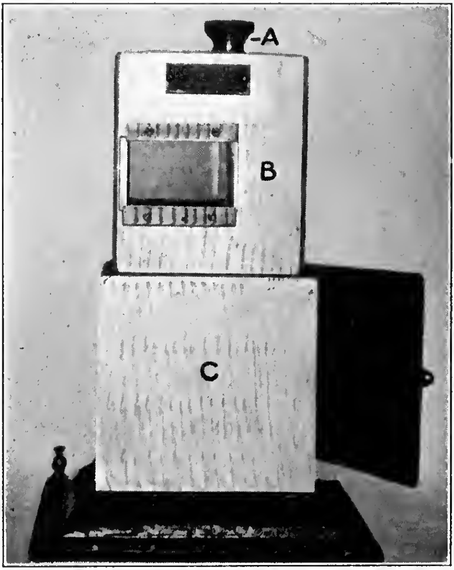
FIG. 18



Diagrammatic sketch of an electroscope made of lead 3 mm. thick: *B*, the ionizing chamber; *A*, the electroscope proper; *g*, the gold leaf attached to the metal rod *c*, which is connected with plate *f*, which is exactly opposite and the same size as the ionizing plate *e*, upon which the material to be tested is placed; *d* is an insulating button of sulphur or amber.

receive the charge. The charging is usually accomplished by rubbing a rod of hard rubber, sulphur, or amber with a piece of wool or silk and bringing it into close proximity with the rod upon which the gold leaf is suspended. The charge must not be too great or it will cause the two sheets of gold-leaf to separate too rapidly, which is very apt to tear them.

FIG. 19

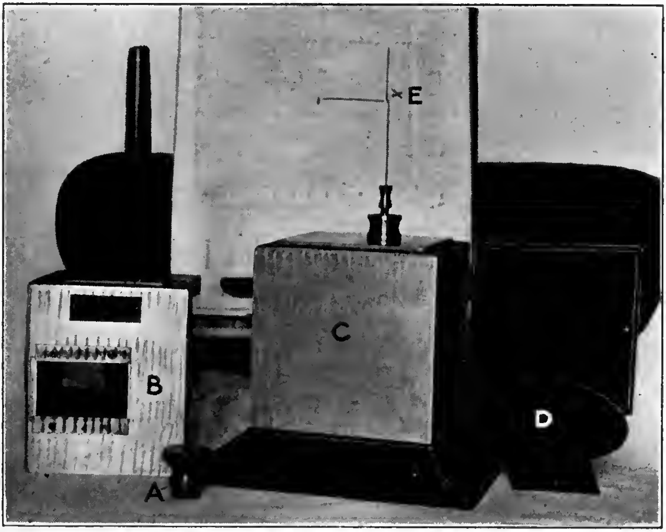


An electroscope used at the Oncologic Hospital: *C*, the ionizing chamber; *B*, electroscope proper; *A*, cap covering the insulated rod holding the leaf.

For the calculation of radio-activity electroscopes must be made of lead boxes to cut off all radiation except that portion under observation. The lead from which they are built should be preferably old lead that has had sufficient time to allow the radio-lead, which is always present in new lead, to disappear. While radio-lead is not especially active, its products of disintegration are, and they deliver a radiation that will cause some trouble in accurate calculations.

It must also be remembered that where these instruments are to be used the radio-active elements should never be exposed. They must always be enclosed in some form of container, otherwise the emanation escapes, diffuses through the air of the room, and coats everything with an invisible film

FIG. 20



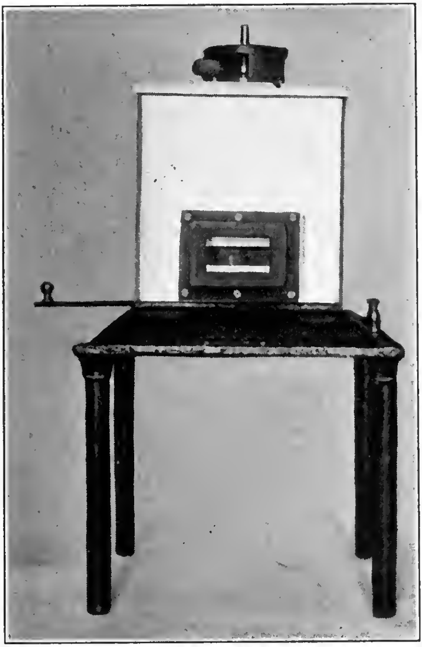
Same electroscope taken apart to show construction: *B*, a plate upon which the substance to be studied is placed. The leaf at *E* is held out by the charge of the hard rubber rod.

of the product of decay, causing it to become radio-active, and ruins that building and everything in it for future experiments which depend upon delicate electric discharges.

With the ordinary electroscope a fair idea of the amount of radiation can be easily studied. For the calculation of the alpha-radiation the flat disk in the ionizing chamber of the electroscope, opposite the disk attached to the electroscope proper, is covered with a thin layer of the material to be studied, and although the β- and γ-radiation are included under these circumstances, the α-radiation so greatly predominates that they need not ordinarily be taken into consideration. Where the radio-activity is extremely small, calculations are always made upon the basis of the α-rays. If, however, the β-rays are to be estimated, a covering sufficient to cut off all α-rays is placed over the disk of radio-active elements. Finally, for the study of the γ-rays, a thick layer of lead is placed over the disk, in this way eliminating the α- and β-rays. While this method gives an approximate idea of the different rays, it is by no means exact, and where it is desired to obtain an accurate measurement of each of the rays, it must be substituted by a complicated electrical method for their separation.

Specimens of radio-active salts containing a fair percentage of activity are always studied by the amount of γ-radiation in comparison with a specimen of known standard. The process is as follows: The electroscope is charged, and note made that it retains its charge. The specimen of known standard, covered by a piece of lead 3 mm. thick, is placed at a certain distance from the electroscope. The drop in the gold-leaf (known technically as the leak) is carefully observed, during a given cycle of time, usually one minute, and taken by a stop-watch; this reading is made several times for accuracy and to avoid mistakes. For instance, the microscopic scale shows that at the first reading, it dropped 14.5 points; at the second, 15.5 points; and at the third, 15; proving that the conditions were nearly equal, with no great variation, and would give a common factor of 15. The specimen to be examined is now substituted for the known standard, and readings are made from it, in the same manner; and the common factor found to be 20; the standard contained 10 mg. of radium

FIG. 21



Electroscope for testing β- and γ-radiation.

salt of 30 per cent. radium element. The salt on trial weighs 20 mg. The percentage of radium is found by the following calculation:

Standard	leak 15	weight 10	percentage 30 per cent.
Specimen	leak 20	weight 20	percentage ?

$$x = \frac{10}{20} \div \frac{15}{20} \times 30 \text{ or } x = \frac{10}{20} \times \frac{20}{15} \times \frac{30}{1} = 20 \text{ per cent.}$$

Any movement near these sensitive instruments is likely to cause some influence upon the result; therefore absolute quietness must be maintained while readings are being made from the electroscope.

Under some circumstances the weight of the mass cannot be definitely ascertained, as for instance, where the emanation is employed for treatment. Then the amount of radiation can only be compared with the standard and spoken of as an amount of radiation equal to a certain quantity of radium element. The estimation of thorium preparations are made in like manner, the radio-activity is based entirely upon "radium element" and not upon the percentage of thorium element, and as these thorium preparations are more active than the preparations of radium, it is not unusual to go above the 100 per cent. mark in these readings.

Liquids and gases demand a somewhat different form of electroscope. The ionizing chamber is made so it can be sealed, and the emanation is carried into it as a gas (if a liquid it is slowly boiled); through it a current of air is passed, rather slowly. This is accumulated in the ionizing chamber and measured in the same manner as before.

There are, however, several special forms of electroscopes upon the market that are calibrated to read in electrostatic units or Mache units, and have been given the technical name of *Fontactoscopes.* Some are so arranged that the water is introduced into the ionizing chamber before the air is passed through, thus preventing escape of the emanation in the transfer. (See Fig. 46, p. 170.)

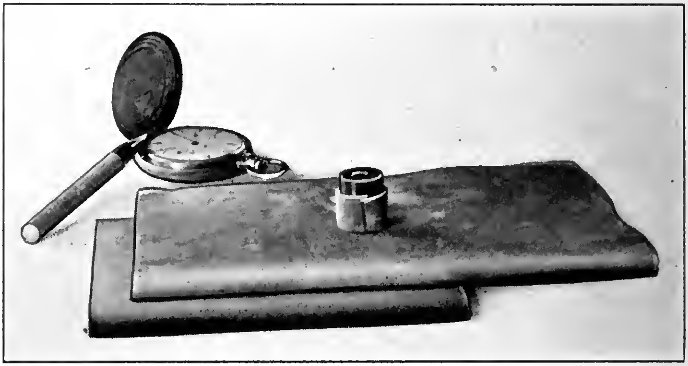
Another form of measuring apparatus employed for the study of these radio-active elements is the electrometer, and while there are as many modifications of these instruments as of electroscopes proper, the general principle is practically the same, and depends upon some form of charging device that delivers to the electrometer a variable current, capable of being increased or diminished according to the ionization of the air in the ionizing chamber. From the saturation of the apparatus the amount of radiation from the article under examination is estimated.

There are several methods of showing the value of radium which can be easily carried out by those not experienced in the use of such a delicate physical apparatus. While these methods are not dependable for estimating the actual amount contained, they may be of use in showing the relative value of the radio-active specimens under examination by the actual strength of radiation contrasted with another known specimen.

Fluorescent Method.—The simplest of all methods is the comparison of the amount of fluorescence produced by the action of the radio-active salt upon certain chemicals, such as platinum barium cyanide or willemite, and from the effect upon the specimens examined to determine which causes it to glow the brightest. By removing the radium about 4 inches or 10 cm. practically all the α-radiation is lost and at this point the β-radiation can then be calculated. By removing it still further, usually about 2 feet or $\frac{1}{2}$ meter, and covering the salt with a thin sheet of lead, the α- and β-radiation is obstructed and the γ-radiation alone may be estimated. For the α-ray it is best to use a small screen of zinc sulphide.

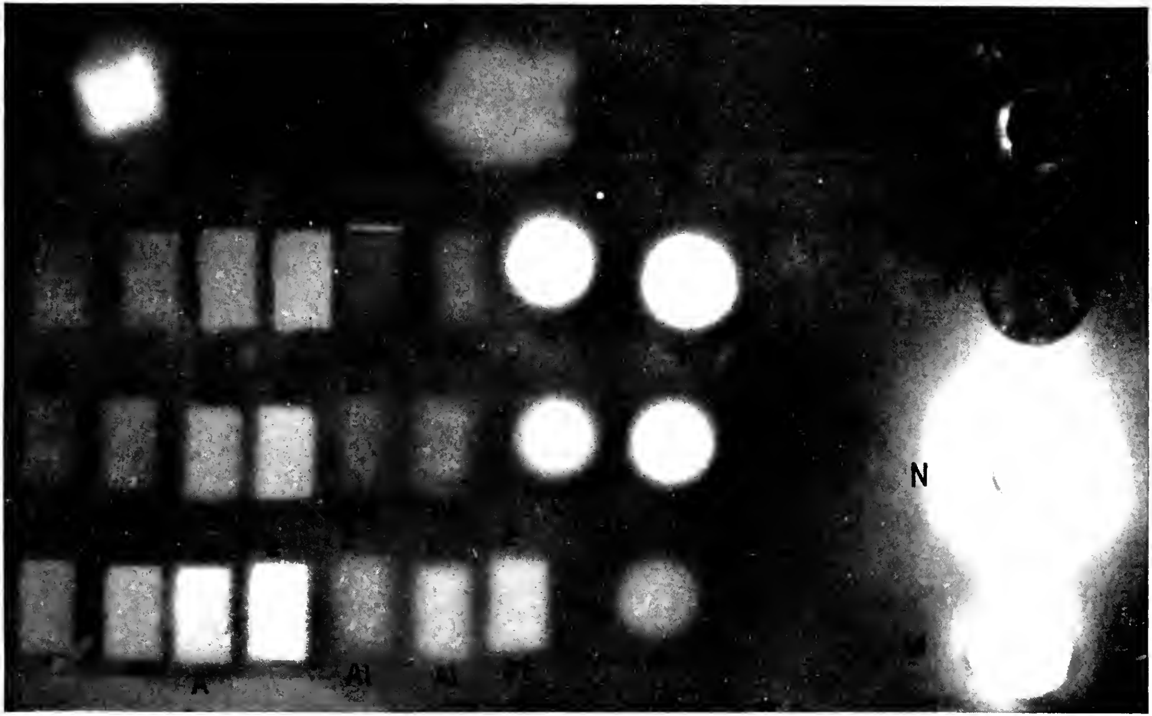
Photographic Method.—A method that is somewhat more troublesome is one that depends upon the photographic effect of these salts, upon the ordinary silver dry plate. Dr. Robert Abbe, of New York, was the first to call attention to this method, and it has since been known by his name. It consists in making graded consecutive exposures upon one plate for the same or different specimens of radio-active salts; for instance, a small window is cut in a piece of sheet lead; above this window, at a given height, possibly 1 or 2 inches, is placed the specimen to be examined. It is then allowed to remain over one spot for five seconds; next for ten, fifteen, twenty, and so on up to sixty seconds; then on a line below, the next specimen to be examined is

Fig. 22



Abbe's method of testing the amount of activity. Dry plate wrapped in paper; over this a plate of lead with a small window; above the window the cell containing the element to be tested.

run through the same cycles. The photographic plate is placed in the ordinary black paper in the same way as when an x-ray exposure is to be made; in other words, it is protected from daylight. After the exposure has been completed, and developed under usual conditions, there will be found upon this plate a gradation of shadows depending entirely upon the length of time of exposure and the strength of the radio-active salt. The longest and strongest produce



Line A.—Radium in glass bottle, 1½ inches from plate, 10 mg. 25 per cent. pure radium. Time, 20, 40, 80 seconds, and 2 minutes. Last part of series 2 minutes each with filters of alumina and thin lead foil.

Line B.—Radium in glass bottle, 1½ inches from plate, 4 mg. 11 per cent. radium.

Line C.—Radium in alumina container, $\frac{9}{10}$ mg. ½ inch from plate.

D.—Container in direct contact with envelope of plate, mica cover in place. Radium, 4 mg. One minute.

E.—Same, 2 minutes.

F.—Same, 2 minutes, without mica cover.

G.—Same, 4 minutes.

H.—Same, 4 minutes without mica cover.

K.—Five grams pitchblende left in place for 12 hours.

L.—Five grams thorite left in place 12 hours.

M.—Container of lead, in which some radium chloride was spilt, washed and all recovered that was possible by a chemist.

N, the lid of the same.

S, the lid of another container, same size, accidentally screwed into *M*, but promptly removed.

R, the container fitting *S*, all exposed for 12 hours, showing the effects of minute quantities of radium.

the deepest shade, and, conversely, the weakest and shortest the palest.

By this method it is also possible to show the effect of filters and the amount of secondary radiation which is set up by them. Certain metals have a very strong secondary radiation, and it is often possible to demonstrate this by a strong precipitation of the silver upon the photographic plate. Lead and aluminium, two metals most used as filters, seem to be leaders in this class.

These crude methods are extremely interesting, but it should be remembered that their variation and the personal equation are such factors that for any serious consideration they must be set aside. At the same time, where measurements are to be made for standards, they must be made by the most careful physicists, and should always be subjected to several crucial tests before they are accepted.

CHAPTER V.

RADIUM.

Methods of Employing Radium—Local—Direct Application—Bandages—Clothing—Protected in an Applicator—Direct Application of the Emanation—Water—Charcoal—Protected Applicators—Apparatus Used to Collect the Emanation—Use of Radium in Internal Medicine—Use of the Emanation—Baths—Injection—Hypodermically — Intravenous — Absorption During Inspiration.

Methods of Employing Radium.—The use of radium as a therapeutic agent must be considered from two standpoints, (1) as a local application and (2) as a general medicine, and under these two headings others must be made on account of the peculiar nature of the radio-active elements. These methods differ to some extent with reference to each element, depending upon the period of life of their disintegration products, and at times considerable modification of the routine must be adopted to circumvent the loss of some valuable cycles in the period where for some reason it is most desirable that they should be retained.

Radium gives an extremely wide range of usefulness, as its emanation has a very active period of about four days, and therefore gives sufficient time to incorporate it in some material where it has a distinct action. For this reason it has taken a place as the type of the different elements of its class, and has gained popularity.

For the therapeutic study of radium it will be divided into the following divisions:

A. Locally:
  1. By direct application of the salt:
    (*a*) Naked or exposed salt.
    (*b*) Protected, or in a capsule of some material, glass, aluminium, platinum, etc.
  2. By direct application of the emanation:
    (*a*) By applying the emanation incorporated in solution of water or other liquids.
    (*b*) By applying the emanation contained in some inert powder, such as charcoal, or made into ointment pastes, etc.
    (*c*) By applying the emanation contained in a small tube of glass or metal.

B. As a general medicine it may be employed:
  1. As radium salts.
  2. As the emanation.

Which may be administered:

A. In solutions, or incorporated with some inert material, and given internally by mouth, rectum, or any of the natural passages, used in the administration of medicine under ordinary circumstances.

B. Injection, in solution and properly prepared to be given hypodermically under the usual conditions, or, where the occasion demands, may be used intravenously.

C. By the inspiration of radio-active air. This method might be said to be unique, but is similar to those where ozone has previously been employed.

Radium in the naked state is rarely used except in a low-grade salt. The liability of losing a small particle of a high-grade salt in an unprotected state, makes this form of treatment practically prohibitory. There is also another reason of greater importance which debars its use; that is, if a small particle of one of these high grade salts becomes imbedded in the skin of the individual handling it, the consequent burn will naturally be serious; for it is impossible to remove the extremely small traces of radium when it once becomes attached to any article.

For the treatment of some chronic diseases of the skin, with a wide-spread distribution, articles of underwear have been treated with a low-grade radium salt, thus making them weakly radio-active. Bandages and pads of various sizes and shapes are also impregnated with these salts; under some circumstances they are dissolved in a very weak varnish which fixes them to the material; while others have recommended that the garment be immersed in a solution of the salts and allowed to dry. Where the varnish is used, the radio-activity of the alpha-ray is somewhat diminished, and as these articles practically derive their therapeutic value from this form of radiation, this point must be considered.

Toiles prepared from radium salts are in practically the same class, except that they are made from a stronger radium preparation and are standardized according to their size,. having enough radium embedded in them to make them of decided value; where they contain a considerable amount of radio-active salt, great care must be taken with them, as in time they become extremely brittle, due to the action of the radiation upon the fabric. The material used is usually silk or wool, and the radium salt is often applied in the form of a varnish, which insures protection to the salt and also to the patient; and their strength is usually rated by the amount of radium salt per square inch, or, as their use has been more or less confined to the European Continent, the rating is usually by the square centimeter.

Their employment has been found useful in certain conditions of the skin, such as chronic eczema, psoriasis; or where the disease is widely disseminated.

Applicators.—The most common method of application of radium is in one of the different forms of containers or radiodes, concave disks of horn, hard rubber or metal, covered with mica, or a small glass bottle or sealed tube, and numerous other designs, suited to the fancy of the operator. The only rule to be observed is, where low rays are to be desired, the thinner the wall of the container the greater the radiation, and where these low rays are not desired the thickness of the container is not to be considered.

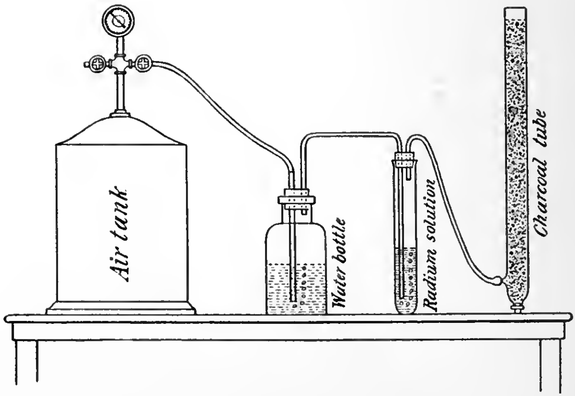
The manner in which the radium is placed in these applicators should be observed, as it greatly affects the position of the salt when in use; if the tube is a large one and the amount of radium small, the bulk of the salt will naturally fall to the bottom; however, if the tube is placed upon its side, and covered with some article that is not transparent, it is quite probable that the activity of the tube will be in the place where least desired. Therefore, these tubes should be just large enough to contain the salt, without allowing it space enough to become scattered, yet leaving sufficient room for the gas formation within the tube; otherwise they are likely to explode and usually this accident takes place while the tube is being handled. This phenomenon may be compared to many other physical crises which take place at the moment of agitation.

The four salts of radium, usually employed in making these applicators, are the sulphate, carbonate, chloride, and bromide; they are rarely found pure in the open market, and their purity, as a rule, is not of vital importance; the by-products found with them are not at all harmful, nor do they in any way interfere with the radiation, the principal factor is the amount of "radium element," they contain. There has been considerable argument over this subject, many contending that pure salts must be obtained for use, and yet, these same pure salts are covered with many thicknesses of lead which obstruct the radiation to the same degree. The advantage in obtaining a salt of high percentage is that it occupies a very small space and can be handled to advantage where it is desired for use in cavities, as for instance 50 mg. of a 50 per cent. radium salt would occupy a small tube 2 mm. wide by 15 mm. long, or $\frac{1}{16}$ inch by $\frac{5}{8}$ inch, while the same specimen of 5 per cent. would require a tube about three times as wide and nearly twice as long. The solubility of these salts makes very little difference in the preparation of the applications; except, where a fine division upon a surface is required, as in making "toiles" or in varnish applications. If a perfectly even surface is desired, it is better to use a soluble salt such as the chloride or bromide; the evenness of these surfaces cannot be obtained by the use of the insoluble salt such as the sulphate or carbonate, which, if applied, must be in the form of an emulsion. Where the radium is placed upon an applicator not protected by a varnish, it is better to employ the insoluble salts; for the soluble salts are slightly deliquescent and therefore take up the moisture of the air, and, if splashed with water suffer considerable injury.

The uniform activity of radium makes it especially desirable, and for this reason it is to be preferred, to the salts of other radio-active elements. When radium gains its equilibrium, which is in about one month after its preparation, it continues to give off α-, β-, and γ-rays in the same proportion with but very little variation for twenty-five hundred years; therefore when a given specimen has been measured, and the actual amount of α-, β-, and γ-radiation determined; further estimations, at stated intervals, are only required to determine loss by accident, otherwise they would be unnecessary and of very little practical value. Aside from these physical properties of the radium salts the only consideration is the amount of "radium element" contained within a given applicator, its size, and the proportion of the different forms of α-, β-, and γ-radiation occasioned by the different substances used to protect or enclose it.

The emanation of radium may be employed under exactly the same condition as the various salts; it has, however, a wider application, and while its preparation requires some skill, it possesses many advantages, with but few disadvantages. The life of the emanation is very short, as one-half the element is lost in four days, and all in about one month; therefore, where it is to be employed constantly, fresh preparations must be frequently made, and for this purpose a large supply of radium is necessary. However, if a tube containing the emanation is injured or lost, its value is not great compared with the amount of radium required to supply the same activity. The supply can always be secured in the place most advantageous for its preservation and the emanation used as a therapeutic agent at any point within a day's travel. The emanation is more commonly used than the radium salts in making direct local applications over large areas and is usually employed in the form of a bath, charged according to the strength desired; but as its use is in conjunction with the internal administration, it will be considered under that section. For local application, the emanation may be applied as an ointment, paste or powder; and for this purpose its preparation may be made by a method, recommended by the late Dr. Shober, which depends upon the absorption of the emanation by cocoanut charcoal. The radium is dissolved in water which has been slightly acidulated with hydrochloric acid. Through this solution a stream of air is slowly passed

Fig. 23



Apparatus designed by Dr. Shober for charging charcoal with the emanation.

which carries with it the emanation; this mixture is then passed through a vessel containing freshly prepared cocoanut charcoal, which, on account of its affinity for the emanation, retains it and allows the air to escape. This method is extremely simple in detail and, where a low-grade activity is desired, fulfils the purpose admirably. It is not to be employed where concentrated activities of high values are desired.

The emanation of radium for use in the treatment of tumors and deep-seated diseased conditions must be prepared with care, and due consideration for the amount of activity is desired. While a number of different forms of apparatus have been used for this purpose, the principles are essentially the same and consist of three separate parts: (1) the apparatus containing the radium, and collecting the emanation; (2) an apparatus for removing the gases; and (3) a pump to place the emanation in the desired apparatus for use in treatment.

The collecting apparatus consists of a flask or series of flasks containing radium in solution that is slightly acidulated with hydrochloric acid. This flask is attached to a pump for removing the air and subsequently to remove the emanation and gases formed by the action of disintegration of radium in water. The pump is a mercury tube about a meter long and acts also as a seal when not in use, keeping the flasks containing the solutions air tight. When sufficient emanation has collected, it is pumped off with the gases, hydrogen and oxygen (which form coincidently with it), and is transferred by a small tube over mercury to a gasometer, where, by decreasing the pressure and lowering the column of mercury, the density is lowered so it can be exploded without danger of bursting the apparatus. This is accomplished by having two electrodes inside the gasometer and passing an electric spark through the mixture. There still remains some residual gas and, while the quantity is not great, it may be removed by placing the container in a vessel holding liquid air: this causes the emanation to condense upon the sides and, while in this cold state, the residual gases may be removed by the third piece of apparatus which is an ordinary mercury pump.

FIG. 24

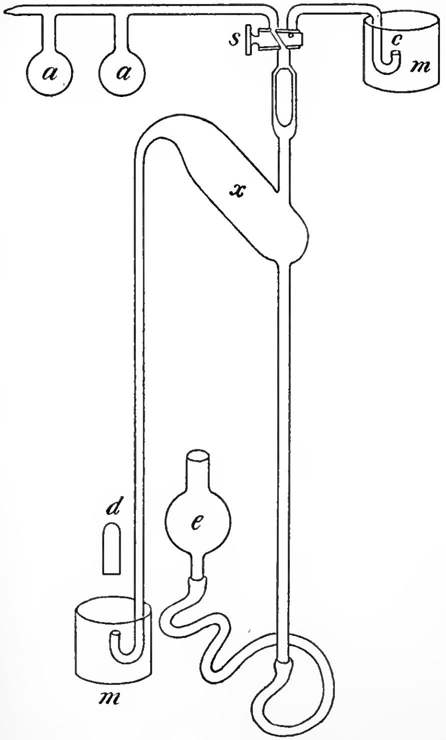


FIG. 25

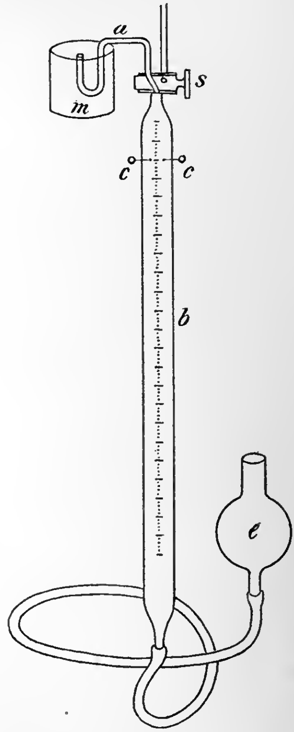


Diagram of apparatus for removal of the emanation.

Radium is dissolved in flasks *a a*. The solution is slightly acidulated; all the air is driven out of bulb *x* through *c* by raising *e* filled with mercury. Upon lowering *e* a vacuum is produced in *x*, the tube at the lower end being longer than 760 mm. height of mercury under ordinary atmospheric conditions. The stop-cock *s* is now turned so as to open *a a* into *x*, when all the gases contained enter *b* in the proportion to their volume. Tube *d* filled with mercury is now placed over the outlet at *m*, the mercury being high enough to cover outlet, The stop-cock *s* is turned so the gas in *b* can be forced out into the tube *d*; this is repeated several times until the gas in the flasks *a a* has been transferred to *d*. Tube *d* is then removed to the gasometer (Fig. 25), mercury bath *m*, and placed over the inlet tube, care being taken not to allow any air to enter tube *d* in the transfer. By lower mercury holder *e* all the gas is drawn into the tube *b*, having first removed the air by adjusting stop-cock *s*. After the gas has entered tube *b* it can be measured, and then by lowering *e* it is rarefied to a high degree; an electric discharge is then sent through the terminals *c c*, which

FIG. 26

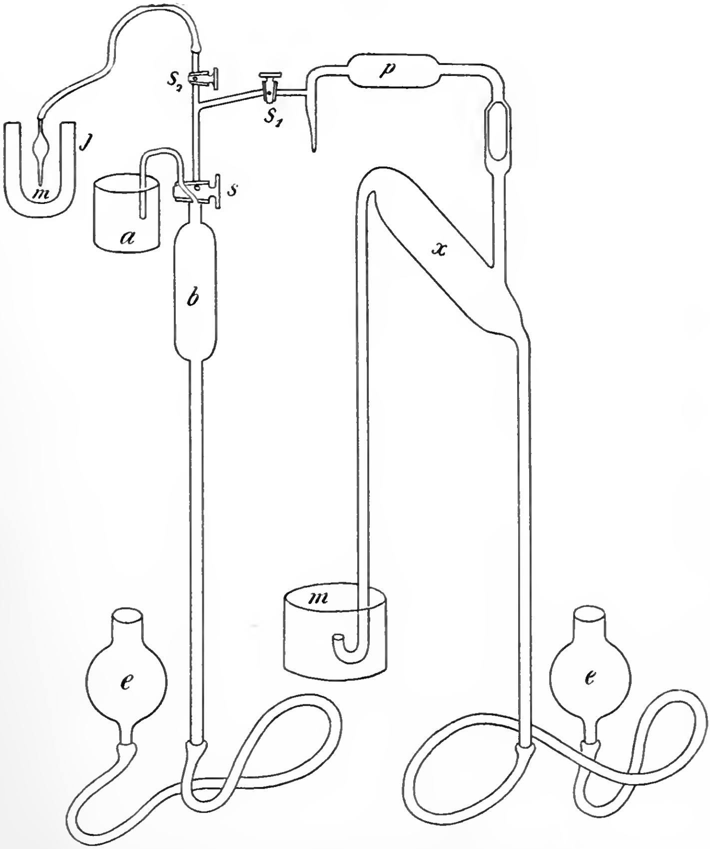


Diagram of apparatus for separating excess of gases from the emanation.

causes the gases to explode. Then if the bulk of gas is not too much it can be placed in a container through the outlet stop-cock *s* and sealed; all must be done without the least air being allowed to enter. If, however, too much gas remains, it may be pumped off by a pump such as Fig. 26. When the tube *d* is again used as a transfer tube and placed over the inlet at *a* and drawn into receiver *b*, it is then forced into the bulb *m* by lowering and raising mercury container *e*. *m* is then placed in vessel *j* containing liquid air, which causes the emanation to be condensed while the residual gases are not; they then are pumped off by the pump, by raising and lowering the mercury. When all the gases have been removed the tube *m* is removed from the liquid air; the emanation again turns the gas, and is forced into the small end of tube *m*, when it can be sealed off by melting the thin glass tube.

After removal of the greater part of the residual gases the emanation, with a very small amount of gas, may be placed in any form of apparatus that is desired (usually a small capillary tube), and this small tube may be employed in exactly the same manner as any of the tubes of radium. For the details of applying this method, a person must be more skilled in the manipulation of the usual laboratory apparatus for gas analysis; otherwise the transfer from one piece of apparatus to the other will be difficult. After the emanation has been removed and sealed in the applicator it must be measured by an electroscope to calculate the activity which is obtained upon the basis of the gamma radiation. This process must be employed for each portion removed and when the amount of activity has once been determined it will conform exactly to the line of decay (see Chart, Fig. 3), usual to the emanation, namely: in four days it will have lost one-half its value, and in fifteen days it will be found to almost approach the zero mark. Therefore the most effective period of the applicator must be in the first four days; after that time it will have lost most of its value and is of use only in superficial cases. The activity given off by one of these emanation tubes depends entirely upon the amount of emanation it contains and may be used in exactly the same manner as though it actually contained the salt of radium; in other words, if it has been determined by the electroscope that one of these tubes equalled 100 mg. of radium element three hours after it was removed from the radium salt, when it gains its equilibrium, from that time on until the fourth day it would then lose about one-half a milligram each hour; after forty-eight hours following its preparation it would equal about 75 mg. of radium.

The same filtration, for deep radiation, is necessary with the use of these emanation applicators, as with any of the other forms; and the same general lines must be adopted for their protection, as the salts of radium depend upon the degeneration products of the emanation for their activity. Removing the activity simply takes away the active portion; therefore in purpose they are exactly the same. If all the active portion of the radium is removed, it requires about one month to regain its activity or equlibrium, and where it is the practice to use the activity in the form of the emanation, it is usual to have a large quantity of radium in the solution, then, instead of pumping off all the emanation, simply remove one-half the accumulated amount. This is determined by practice, and can, in a rough way, be guaged by the amount of hydrogen and oxygen formed from the water by the disintegration of radium. By this method every four days one-half the amount of radio-active value can be obtained, instead of waiting for one month before a new supply can be removed.

The advantages in the use of the emanation are in the many forms of application which can be made. Small, thin tubes, 0.2, 0.3 or 0.4 cm., may be employed, or a shorter one of greater caliber; small, flat, hollow disks of various shapes; practically any form in which it is possible to blow the thin glass container.

INTERNAL ADMINISTRATION OF RADIUM.

For the treatment of certain conditions of disease, radium has been administered internally; the amount given was, of course, extremely small; and the form of salt employed depended upon the requirement of the case with the effect desired. The soluble salts, the chloride or bromide, are used dissolved in water; while the insoluble forms, the carbonate and sulphate, have been used, incorporated in some powder or other inert media. In solution they may be administered by mouth or given as an injection, and under proper precautions, either hypodermically or intravenously. Where a decided reaction is desired, the last two methods seem to be preferred. Its use has been confined to those serious conditions of the blood, such as pernicious anemia, leukemia, and general systemic disorders as Hodgkin's disease.

The emanation, however, has been more widely employed than the salts in the internal administration, and, while its activity is more transient, for the treatment of milder forms of disease, such as gout, it may be preferred, as it causes less reaction. Then it has this advantage, that only the activity of radium is used while the source of supply is always intact and not likely to be lost. Even where it is desired to use this activity in massive doses, there are methods of preparing solutions or mixtures, which, if given internally, would be dangerous to life. Therefore it is possible to use the emanation and meet all the requirements of the actual administration of any one of the salts. The form of emanator preferred for the preparation of these solutions depends somewhat upon their use and the strength of the product desired. One of the commonest forms of administration is water for drinking purposes. This water is prepared in an apparatus having three compartments; the largest reservoir contains the water that is charged, or being charged, while a small auxiliary supplies the amount of water that is withdrawn; the third compartment contains the radium. A certain amount of water can be drawn daily; this same quantity is replenished from a reservoir. The amount taken from the emanation and added to it, must be in

FIG. 27

Emanator for charging drinking water. (Lazarus.)

proportion to the bulk contained in the charging chamber, so that it will remove the supply in proportion to the rate of decay and regeneration of the radium. The calculations are best made upon the four-day basis of half decay; that is, the half charge, rather than waiting from fifteen days to a month for full charge. This is the most economical method and the loss from allowing the activity to disintegrate, which will be passed off if not used, is not so likely to occur. The salt of radium used in the charging chamber must be one of the insoluble forms, such as sulphate, and it must be placed in a vessel not likely to be carried away by the currents occasioned by the entrance or exit flows. For this purpose it is customary to employ one with porous cells, which will allow a slow percolation of the water without the likelihood of washing any of the small grains of salt with it.

By this form of apparatus water, varying from 2500 to 10,000 Mache units per liter, is easily obtained, which is the strength usually employed for administration in drinking, or, where larger quantities are made for baths, these artificially prepared waters are used in exactly the same manner as those from natural sources and have the advantage that, from the apparatus, the supply is liable to be more uniform and not influenced by weather conditions. Testing these waters is done by employing the ordinary gas electroscope, and these tests should be made at stated intervals for any correction due to loss of radio-active material from improper handling. But when the quantity of radio-activity contained in a given amount of water has been once established, there is practically no variation from that standard, provided the apparatus is systematically used. Allowing the water to accumulate or removing a greater amount than should be done under ordinary circumstances, will materially alter the uniformity of the supply.

The dosage depends upon the circumstances and varies from 250 to 20,000 Mache units per day. It should be remembered that as the elimination of the emanation from the system is extremely rapid, these waters should be taken slowly. Baths should be strictly considered under local applications, but as the amount of absorption from the body of these charged waters is sufficient to cause general symptoms and reactions, it therefore becomes a method of internal administration, rather than a purely local application. Water for bathing purposes usually contains about 200 to 300 Mache units per liter.

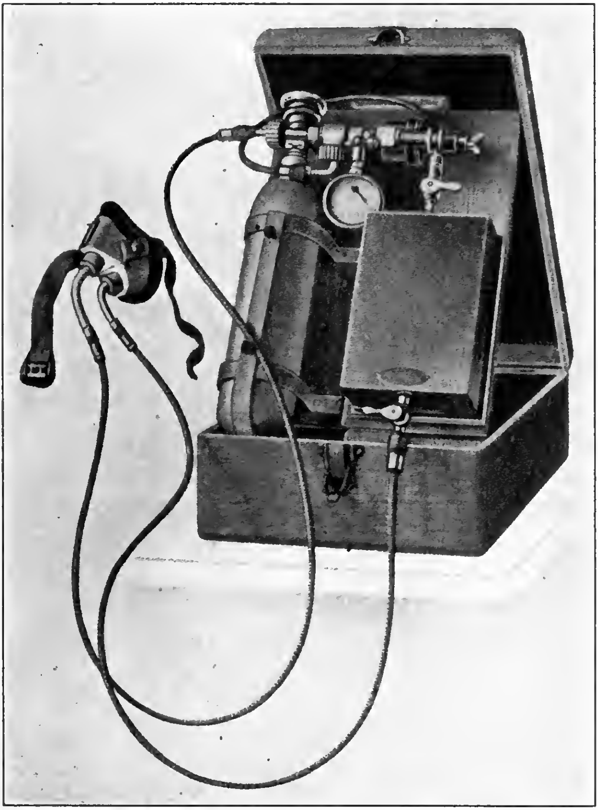
Charging waters with the emanation by having a quantity of uranium ore in it has been practised, but as the amount of energy derived from these ores is extremely feeble, the waters produced from this method have very little therapeutic value. On the other hand, both drinking and bathing waters have been made by the solution of low-grade radium salts, which give the same radio-active qualities to the water as the emanation, and, unlike the water charged with the emanation, have the property of retaining their value for years; the therapeutic difference between the two being that of the elimination from the system of the radium salt, which being a solid, cannot be carried off by the expired air.

Of all the radio-active preparations, the emanation in water solution makes the ideal preparation for either hypodermic or intravenous injections. These procedures are carried out under the usual routine, due care being taken for the local sterilization of the part and the apparatus used in making the injection.

The emanation of radium, being a gas, is frequently employed mixed with air or oxygen and taken into the system by absorption through the lungs. A number of different forms of apparatus have been devised, all having for their purpose a means of diluting the emanation with air, and conserving the waste which is thrown off by the expired air. In large emanatoria the operation is quite complicated; rooms are arranged so that the emanation is pumped into them at a given rate per minute. The air of the room, as it is used, is pumped out and passed through water, lime and other substances for purification, mixed with a fresh supply of oxygen and returned to the room with the emanation. In this way the air is kept in a high state of activity, which, if the amount of emanation were lost by natural ventilation, would be impossible. For the use of a single person a form of apparatus has been devised, which fulfils the purpose of these rooms or cabinets.

It consists essentially of the same parts, but made upon a very small scale, and the use of a motor to propel the air currents is unnecessary. The principal difference is that of the inhaler, which consists of a cone adjusted to the mouth and nose. The intake tube is arranged with suitable valves and attached to the emanator, while the outlet tube is connected with the box for purifying the air. The oxygen is supplied from a tank as the current of air passes in the cycle and helps, with the patient's effort, to propel the currents through the apparatus. With such an apparatus it is possible to use a given amount of emanation for an indefinite length of time. One sitting, as a rule, occupies about three hours. In this way the system is saturated with the emanation for a definite length of time while with the other methods, such as drinking, bathing and packs, the body is charged with this emanation during the process and for only a short time afterward. Therefore by long-continued inhalations of radio-active air it is possible to

Fig. 28



Emanator for charging air, with apparatus for supplying oxygen and removing the carbon dioxide from the expired air. (Lazarus.)

charge and keep charged the blood of the body for a considerable time.

For institutions, where a number of cases are handled daily, special forms of apparatus have been designed, having a number of separate cells, and a device for turning the connection for one of these cells to the air tanks, so that a certain amount of radiation can be used from one cell, and when that supply is exhausted it is changed to another, the time and date being registered, showing the amount of gas that has passed through, and giving a definite idea of the time required for regeneration, which, if totally exhausted, requires from fifteen to thirty days. (See Fig. 69.)

It is possible to construct a form of apparatus which is simple in design and fulfils the purpose almost to the same degree as one of more elaborate dimensions. It is, however, not so economical in conserving the loss of the emanation, and cannot be used the length of time that, under ordinary circumstances, is desirable. This apparatus is easily constructed from a flask with the inlet tube dipping down into it well toward the bottom; the air entering should be passed over fresh calcined lime to remove unnecessary impurities, and again connected with the outlet tube. There should be a drying apparatus to remove the vapor of water and acid that is taken up as the air passes through the water containing the radium. (See Fig. 71.)

The amount of radio-activity from the different forms of apparatus can be measured by the ordinary gas electroscope and where possible to follow the procedure, it should be carefully carried out in detail, as the variation from this source of radiation is somewhat more irregular than the other means used in the introduction of radiation into the body as a therapeutic measure. The estimation of these solutions and gases is usually calculated upon the basis of Mache units. However, different authors make their basis according to the customs adopted in their neighborhood, but where these comparisons are necessary the table of standards will show their relation to each other. Many use the "radium element" as a standard, and adopt the microcurie as a unit. However, speaking of a solution having the activity of 2 microcuries, does not necessarily indicate that radium is present to that amount; the activity may be due to the emanation alone having the value, with absolutely no trace of radium.

CHAPTER VI.

THORIUM.

Practical Use in Medicine—Difficulties of Determining Actual Amount of Radiation—Local Application—Methods—Use in Internal Medicine—Thorium X—Emanation—Radiothorium—Conclusions.

The active portion of the thorium group is usually commercially known as mesothorium; it often contains a list of disintegration products exactly the same as commercial radium. Unlike radium, however, it is by no means as regular in its course, and in fact wide variations exist in its rapid disintegration. A mesothorium product may gain some activity during the first year. It then degenerates until between four and four and one-quarter years, when it has lost about one-half its activity and then gradually declines until between ten and twenty years, it has lost all its activity. There is, however, considerable irregularity in all these thorium products, due to the impurities and the irregular methods of separating the mesothorium I, mesothorium II and radiothorium from the original thorium. So far, the processes of separation are evidently far from being perfect. As most of the products are handled by large manufacturers there has been very little disposition to consider their by-products. The following table gives the contrast between the regularity of the radium group and the very irregular group of thorium elements:

Radium Group.

	Element.	Radiation.	Period of ½ life.	
	Radium	α, β	2000.0 years	Commercial radium as it ages, portion of D, etc.
	Emanation	α	3.85 days	
Active deposit of rapid change.	Radium A	α	3.0 min.	
	Radium B	β	26.7 min.	
	Radium C_1–C_2	$\alpha, \beta, \gamma,$	19.5 min.	
	Radium D	α	15.0 years	
	Radium E_1 / Radium E_2	β, γ	4.8 days	
	Radium F	α	140.0 days	

Thorium Group.

	Element.	Radiation.	Period of ½ life.	
	Thorium	α	Thirty million years	
	Mesothorium I	. . .	5.5 years	Commercial mesothorium, a varying amount of these three, with active product varying accordingly
	Mesothorium II	β, γ	6.2 hours	
	Radiothorium	α	2.0 years	
	Thorium X	α	3.6 days	
	Thorium emanation	α	53.0 sec.	
Active deposit of rapid change.	Thorium A	α	0.14 sec.	
	Thorium B (35% / 65%)	β, γ	55.0 min.	
	Thorium C, Thorium C_1	α	$\frac{1}{1000000000000}$ sec.	
	↓ Thorium C_2			
	Thorium D		3.1 min.	

The variation of the life of these mesothorium products depends upon the proportion of mesothorium I with a half-period of average life of 5.5 years; mesothorium II with a half-period of average life of six hours; and radiothorium with a half-period of average life of two years.

The varying proportions of these elements, with other ordinary impurities common to the radio-active elements, constitute the commercial product. One of the commonest impurities, which, under ordinary circumstances is not objectionable, is radium, and most of these products contain it in proportions of from 12 per cent. to 25 per cent. Reference was made to this fact in the chapter dealing with the chemistry and physics of the elements; from a medical point of view, this cannot be regarded as a serious objection, considering, at the end of the period of disintegration of the thorium, the specimen will contain a small amount of radium.

The thorium preparations are much more active than the radium preparations, due to the more rapid disintegration; but actual comparisons are impossible, due to the irregular mixture of the thorium products. The basis of all measurements is exactly the same as radium, using the "radium element" as the standard, and making comparisons from it in exactly the same manner. However, on account of the activity of these thorium elements, the standards are often exceeded. The radiation of these preparations varies considerably both in regard to the proportion and quality of α, β, and γ and also in the proportion and quality of the different forms of each ray existing in each specimen. The highest range of alpha-rays is given off by thorium C, its penetration being about 8 c.c. of air, and the same is true with the gamma-radiation, which from some of these thorium elements has an extreme power of penetration. Therefore, when the specimen is measured, the quality of each form of radiation should be given.

Local application of mesothorium can be made in exactly the same manner as radium, either in the form of naked salts or protected. Naked specimens of mesothorium may be employed, but if the salts are of high activity due care must be given to the protection of the part to which the application is made, for, should any of the small grains adhere to the surface exposed to radiation serious consequences are likely to follow. Weak specimens may be incorporated in materials such as wool, cloth or silk, and made into underwear or bandages, where a general mild radiation is desired. Small-sized applicators made of silk, wool or other fabric, may be applied in a varnish, but the salt, under these circumstances, must be strong enough to compensate for the loss of the alpha-radiation, lost by the thin covering of the varnish. These applicators are intended for deeper penetration. Local application of mesothorium may be made as a pack or mud cataplasm, or a bath; but as a general rule the thorium salts are more irritating and in large amounts are toxic; therefore, in making these local applications, aside from the radio-activity, caution must be used, otherwise toxic symptoms of general thorium poison may follow.

In the form of protected applicators, the same general principles hold, as in those made for radium. Varnished applicators under the same general principles or placed in capsules of glass or aluminium, or the concaved button with a mica covering; in fact any design suitable to the particular style of work expected from the applicator may be used.

On account of the very high activity of some of these specimens of mesothorium, they must be carefully guarded with filters and protected from the amount of secondary radiation that must necessarily occur where the activity is so intense. Some specimens have been rated as being three or four times as strong as the same amount of radium. This rating is purely relative, from a practical point of view, and on account of its rapid degeneration a year's variation is considerable. However, when these specimens are at their point of highest activity they must be guarded in exactly the same manner as extremely large amounts of high-percentage radium.

On account of this activity many authorities contend that mesothorium, used in well-protected capsules, filtered with several millimeters of lead or platinum, is decidedly more efficient than radium; this depends, to some extent upon the specimen of mesothorium. Should the radiation be of high quality the extreme amount of radiation in the small mass should give an application of a remarkably high degree of efficiency.

The emanation of thorium has a period of life of seventy-six seconds which does not permit its use in any such manner as the corresponding gas from radium; this period of rapid change does not allow sufficient time for the proper handling or manipulation from a practical standpoint. The element in the thorium group corresponding to the radium emanation in usefulness, is thorium X, which has about the same period of life, and while it does not possess the physical properties that favor the easy manipulation of radium emanation, it seems to be of value particularly for internal administration, for which it is employed. Commerically, thorium X has been placed upon the market under several trade names, usually in solution and contained in small sealed ampullas, containing 5 to 30 cm., varying in strength according to the purpose. On account of its nature and the difficulty of manipulation from a chemical stand-point, it does not permit its production except in laboratories especially equipped for this purpose.

From these ampullas containing the thorium X, a solution of varying standards can be made, the rating as usual being in comparison with "radium element." As a general medicine it may be administered three times a day in the equivalent of 1 to 100 electrostatic units or from 1000 to 10,000 Mache units; even in larger doses where the circumstances demand. The concentration of activity is a peculiar feature of thorium X preparations.

The amount of energy from 1 c.c. of solution may run as high as 1,000,000 Mache units which equal about $\frac{1}{100000}$ of a milligram of thorium X element.

Fig. 29

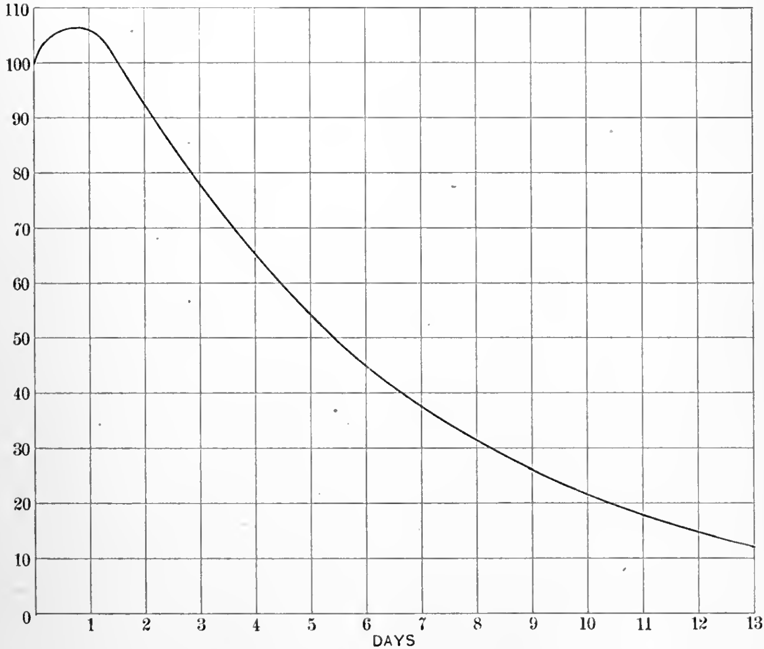


Diagram showing the decay of thorium X.

Where it is desired, the solution of thorium X can be carefully evaporated with some inert substance such as sand, and the radio-active element becomes incorporated in this material. This fine sand may then be applied locally or given internally in exactly the same manner as the solution. Its period of life is not altered in any way except for the time lost in the preparation of the material.

The usual method of employing thorium X is either hypodermically or intravenously and under these circumstances large doses are administered in such diseases as pernicious anemia and leukocythemia, and where enormous doses are employed, the cases must be kept under careful observation, as the changes in the blood elements are apt to be profound. Instances have been reported where death is supposed to have resulted from the effects of these radio-active elements. Injections are made under the ordinary routine measures of sterilizing the parts and the syringes used in the procedure. They may be administered daily, but it is far more common to give one injection and then wait a few days before giving another, noting carefully the effect, and increasing or decreasing the following injection according to the demands of the individual case. The quantity of thorium X contained in a solution holds exactly the same relation to thorium as the emanation of radium does to radium; it has about the same degeneration period or curve decay. Being a solid, it is not eliminated from the body so rapidly as the emanation of radium, and being retained within the system it disintegrates into the emanation, which is possibly to some extent eliminated by the lungs. It therefore has some influence over the respiratory system.

Where it is desired to use the thorium emanation for inhalation, it must be obtained directly from thorium X, by arranging an apparatus to hold a solution of this element and drawing air through it in exactly the same manner as when the radium solution is employed. Under these circumstances the short period of life must be considered and allowance must be made for it. Solutions of thorium X must necessarily be rapidly exhausted of their emanation, which, on the other hand, rapidly recovers. When the radium solution was exhausted of its emanation it was necessary to wait four days for the period of one-half recovery, or if exhausted, fifteen to thirty days for complete recovery; for the thorium product the period is slightly over one minute. But the period of life being such a limited space of time, the amount present is always extremely small (see Fig. 71).

Where these gas emanators are to be used for an extended length of time, they should contain a solution of mesothorium or radiothorium, which, once having gained its equilibrium, keeps the apparatus charged with thorium X which degenerates into the short-lived emanation.

Under some conditions radiothorium has been used alone, but the difficulty of obtaining this element in a fairly pure state does not permit its general adoption. The supply is extremely limited, due to the difficulty of separating it from the elements of the thorium group and also from radium. The time of disintegration stands between the commercial mesothorium products and commercial thorium X. It has the advantage that it does not disintegrate so rapidly as the latter and decidedly faster than the former, and for use as a general medicine under some conditions is desirable.

While the elements of the thorium group are by no means so well defined as those of radium, they serve a purpose which some skilful observers consider superior under some circumstances. For instance, the high activity and the extreme penetrating qualities of the different rays warrant their use locally in the treatment of deep tumors, where a large amount of radiation is desired. Commercially the thorium elements have been placed upon the market under such trade names as mesothorium, radiothorium, and thorium X. The difference in the mixture of mesothorium and radiothorium, mainly affects only the life of the product. While thorium X is of very short duration and can only be obtained in close proximity to the source of supply, its value is principally for internal medication, where it will be found that the thorium products are much more active than those of radium.

This activity can easily be figured by comparing them, mass for mass, with the time of disintegration, the force being the same, but eliminated in a very much shorter space of time. By their activity and the length of time they are incorporated in the tissue, they give rise to violent systemic disturbances, far more noticeable than those under similar conditions with radium. When these thorium products have once been introduced into the system, their elimination is much slower. There may also be the underlying fact that thorium, as used in general medicine, is not free from toxic effect other than might be expected from the point of radioactivity; and beside the general adaptability of the radium emanation, with its regular action and easy manipulation, gives it in many respects a preference over the use of thorium.

CHAPTER VII.

ACTINIUM AND URANIUM.

Practical Use of Actinium in Medicine—Comparison with Radium and Thorium—Methods Used for Local Application—Use in Internal Medicine —Uranium—Local Use—Uranium X—Comparison with Other Radioactive Elements.

Actinium.—The use of actinium in general medicine has been extremely limited, due to the difficulty of procuring a sufficient quantity for practical purposes. It seems to be even more sparsely distributed through the earth's crust than either of its two prototypes, and the difficulty of separation gives little encouragement for future development. Most instances where actinium has been employed were in conjunction with some well-developed scientific laboratory and even there to a limited extent. But where it has been used it seems to be a counterpart of thorium rather than of radium. The rapidity of the disintegration of some of the elements is even greater than thorium, while the radiation from it seems to be less desirable. A comparison may be interesting:

		β-rays; mm. of aluminium for absorption of ½ radiation.	γ-rays; cm. of lead for absorption of ½ radiation.
Radium	B	0.09	
	C	0.5	1.38
	F	0.16	
Mesothorium		0.34	1.1
Thorium	C	0.05	
	D	0.441	1.5
Actinium	C_2	(about) 0.04	
	D	0.24	0.57 to possibly 0.8

This table gives the comparative life of the actinium group:

	Period of ½ life.	Radiation.
Actinium . . .	30 years (?)	No rays
↓		
Radio-actinium .	19.5 days	α to β
↓		
Actinium X . . .	10.2 days	α
↓		
Emanation . . .	3.9 seconds	α
↓		
Actinium A . . .	0.002 seconds	α
Actinium B . . .	36.1 minutes	β
Actinium . . .	2.15 minutes	α
↙ ↓		
C_1 C_2		
Actinium D . . .	5.10 minutes	β and γ

Actinium degenerates 85,000 times faster than radium, therefore the amount of force is enormous, but the quality of the radiation does not seem to compare favorably with the other two elements. It is the rarest of the very active disintegrating series and appears to be of the least value from a medical stand-point.

Where actinium has been employed in the treatment of local disease, it has been applied in applicators in precisely the same manner as was radium and thorium. Since the volume of activity is even greater than thorium, and on account of the predominance of low radiation filtration is absolutely necessary, compresses and other forms of direct local application have been made from actinium X, which has a usefulness of about ten days. Actinium X compares favorably with thorium X, but with a life that is almost three times as long. As the emanation of actinium has a life of only about four seconds, its use for bathing or drinking water must be prepared from actinium X which produces the very rapid changing emanation.

The emanation of actinium is far more soluble in water than the other two, the coefficient being radium emanation, 0.25; thorium emanation, 1; actinium emanation, 2. This may explain some difference in the physiological action manifested by the absorption of it by the tissue juices.

Fig. 30

Radiograph produced by the effect of a solution of actinium X of 200 electrostatic units injected into a mouse, which was killed 30 seconds after the injection, placed upon the plate, and left for 15 hours. The activity seems to be more especially confined to the liver, gastro-intestinal canal, and the osseous system. (Lazarus, Med. Klinik, No. 21, 1913.)

Actinium X, supplied from the actinium with a direct parent of radio-actinium, may be used in charging solutions in exactly the same manner as thorium X, its physiological action and use being more or less similar. The solution may be administered by the mouth or any of the natural passages, as a local injection, or what seems to be most common, either hypodermically or intravenously, and in relatively high doses, from 50,000 Mache units to 150,000 Mache units per day.

On account of the difficulty of dissolving actinium X when it is to be employed in the form of a subcutaneous injection, the solution should be filtered; otherwise solid particles introduced into the system may produce trouble from local areas of undesirable activity. It has been employed hypodermically in the treatment of cases of anemia and leukemia, while baths and drinking water have been used in rheumatism, gout, arteriosclerosis, sciatica, corpulency, and effects of chronic poisoning.

URANIUM.

Uranium and its salts are scarcely to be considered in the same group as these valuable elements, yet they undoubtedly possess some virtue which must not be overlooked. Reports have been made where minerals of uranium were placed over the surface of ulcerations of various kinds, particularly those due to senile keratosis, epithelioma, and lupus vulgaris, and their application was followed by healing. In some of these instances crystals of the native minerals were employed; and here possibly some doubt must be raised as to whether the efficiency was due to uranium alone or, under these circumstances, to the radium and such by-products as are usually contained in these native crystals.

Reports have also been made where the element uranium X was used in the treatment of similar conditions. Uranium X can be prepared from a solution of uranium acetate or better, nitrate, to which a small quantity of ferric chloride has been added; the iron salt is then precipitated by the addition of a small quantity of ammonia hydroxide, causing a precipitation of the iron only as iron hydroxide, to which adheres the uranium X. The solution is then filtered and the radio-activity of the uranium salt is thus carried off by the flakes of the iron precipitate. This precipitate can be applied to the ulcers directly as a paste or mixed with some other inert powder or salve.

Minerals containing uranium have been placed in water with the idea of giving it a degree of radio-activity, which they do only to a very limited extent; the charge which is given is due entirely to the elements radium, thorium, and actinium contained as impurities. Where this method is to be employed under such circumstances, it is important to have the mineral matter in a very finely powdered state and frequent agitation of the water is necessary. The small amount of emanation given off by these minerals is extremely limited, and if it is confined within a mass of mineral matter which does not allow it to come in contact with the water, that proportion of emanation eliminated under the surface of each piece of rock will not be absorbed by the water, but will remain occluded by the mass, and undergo further disintegration passing into other elements.

The water made under these conditions is of very low radio-activity, and from a medical point of view would appear to be absolutely of no value. The therapeutic properties of uranium, as used in general medicine, cannot be ascribed to its radio-activity; while, from the application of different uranium products locally, there is undoubted evidence that its radiation has produced beneficial results in numerous instances.

CHAPTER VIII.

PHYSICAL PROPERTIES OF APPARATUS.

The Basis of Construction—Distribution of the Salts—Toiles—Naked Salts—Applicators—Radiodes—Covers—Maturation—Cashé—Filters or Screens—Applicators—"Cross Fire"—Preparation of Apparatus—Preparation of the Patient—Surface Cases—Deep Cases—Cavities—Implantation—Use of Radio-active Wax—Use of Emanation in Applicators.

THE two principal sources of radiation are from the salts of radium and thorium, while actinium possesses a very high ratio of useful rays; at the present time this element is so difficult to obtain that it is hardly to be considered for practical use. Uranium, on the other hand, is easily obtained, but the amount and quality of radiation derived from it is so small and lacking in penetrability that its scope has been extremely limited and few reports have been made upon it.

Applicators of various forms have been recommended by different operators, most of them having designs of their own, more or less modified to suit the peculiar class of work for which they are employed. However, the following general points must be considered in the mounting of all radio-active salts in the preparation of these applicators.

1. The activity of the radio-active salt.

2. Weight of the salt and the proportion of impurities therein contained.

3. Impurities.

4. Surface and size of the grains of salt.

5. Distribution.

6. Age of salt.

7. The quality and quantity of the fixative substance or wall of a capsule.

The activity of the radio-active salt must be considered in relation to the mount, for if a very feeble salt is mounted in a capsule, very little energy will escape, and such a preparation would be useless; on the other hand, this salt could be mounted upon a flat applicator with a thin varnish, and in this way prove quite useful in surface conditions, deriving its strength mainly from the low rays.

The weight of the radio-active salt and proportion of impurities alter its relative usefulness, in several ways. For instance, if a very strong radiation of the γ (gamma) ray is required for the introduction into cavities, it is desirable to have it in as compact form as is possible, having the radiation emanate from a compact mass. If the γ (gamma) rays alone are desired, and the amount of space not to be considered, then a reasonably large amount of debris, contained in these salts, is not objectionable; in other words, if we desire a small compact mass, a 60 per cent. or a high grade salt must be used, while a 10 per cent. salt containing the same amount of pure radium will give off the same amount of gamma radiation, but the bulk would be many times as great.

If the low rays are to be used, which, as a rule, are not desirable, then the amount of impurities, the kind of impurities, the surface and size of the grains of these radio-active salts are of importance. If all the salt was contained in one spherical mass, that portion of the salt in the centre would lose a fair proportion of its low rays, the mass itself acting as a filter, and in this way the low rays would be occluded within their own generator. If this same mass is spread over a surface larger in proportion than the surface of the sphere, or in fact in an extremely thin layer, then all the rays generating from the thin surface of the salts escape freely, not being obstructed by their own mass or that of impurities. Usually, however, low-grade salts are used for these surface applicators, as the relative proportion of low ray is so much greater than the high rays that the small proportion occluded by impurities is fully compensated by their great preponderance.

Maturation.—The age of these salts is always a vital point. It must be remembered that time is required for these fresh preparations to gain their equilibrium. This varies with the element used and if thorium is the base, its time of degeneration must also be taken into consideration.

The quality and quantity of the fixative agent or the walls of the container give rise to the same obstruction as impurities of the salts and here again the material used must be considered in relation to the quality and quantity of the rays desired.

Radio-active salts mounted upon silk, wool, or other flat material have been given the name of "**Toiles.**" The salt so mounted is usually of low grade, and most of the activity is derived from the low rays; it must be remembered that as a rule they are extremely irritating, therefore stimulating. The soft and yielding nature of these "toiles" allows them to conform to the irregular surface of the body, and the size can be varied accordingly; such articles as bandages and undergarments may also be charged.

These materials may be covered with a thin varnish in which either the soluble salts of radium or thorium have been dissolved or the insoluble salts well emulsified; the latter, however, do not give the even distribution of the soluble salts, but there is less chance of loss should these applicators become accidentally immersed in some fluid.

Great care must be exercised in handling these applicators, as even a small amount of radium or thorium has some peculiar action upon the material that causes them in time to become extremely brittle.

Fig. 31

Fig. 32

Compare these applicators with Fig. 33. Notice the dark color due to age.

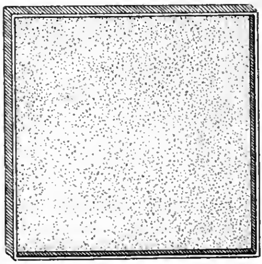
Fig. 33

Round applicators covered with thin mica; each contain about 1 mg. radium element. They have a very limited sphere of usefulness.

Applicators.—A shallow button of metal, hard rubber, horn, ebony, or other material of kindred nature, with a cap of mica that is easily removed, is frequently employed for the application of these salts to surface conditions where the part to be treated is readily accessible. It is rarely necessary to remove the cap and use the naked radium or thorium; the liability to loss from careless manipulation is too great to warrant this procedure. Besides, the chance of a few grains adhering to the skin of the patient might result in a disastrous burn at the site of application.

In some instances celluloid has been used for covering these specimens and where it is employed it should be remembered that the radio-activity of these salts will in time cause it to become extremely brittle. Thin mica has about as little obstructive power to these rays as is consistent with safety; and the action of these salts does not seem to cause any material degeneration, except that like other substances it is colored to some extent by age. This in no way interferes with the penetration of these rays, while it does obstruct vision.

FIG. 34



Square applicator.

A form of applicator that is found to be very serviceable and can be made in many forms, is a disk of metal or hard rubber, to which the radio-active salt is fixed by means of a varnish. The varnish causes it to adhere to the applicator and furnishes ample protection to the radio-active salt. It must be carefully observed from time to time, for like all organic substances, the varnish in time becomes brittle, due to the radio-activity, and is likely to break or fall a way from the surface to which it is attached. In this way some of the salt is likely to be lost, therefore, from time to time, they must be re-coated. The nature of the varnish allows them to be easily cleaned with warm water, bichloride of mercury, or formalin, but not with alcohol or other solvents of varnish. The shape of these applicators is of some importance; formerly they were usually round, and about 2 to 5 cm. in diameter. The round applicator has lately given way to the square one, which, if several are to be applied, may be placed advantageously side by side, in this way covering the surface completely.

Varnish Applicators.—These applicators must be carefully prepared so as to have an even distribution of the radium salt. If there is a greater portion at one place than another, the amount of radiation will be more or less improportionate to the quantity of salt. In the preparation of these disks they must be properly cleansed and a coat of varnish applied, which when dry should be followed by the application of several more coats in which the radium salt has been dissolved; always allowing one coat to dry before applying the next. After the radium varnish has been applied and allowed to dry, several coats of plain varnish are used to protect the radium salts from injury. Drying should be complete, and is best done in a hot water oven; this causes the resins of the varnish to set hard and firm, and if this process has been carefully followed there is very little danger of injury.

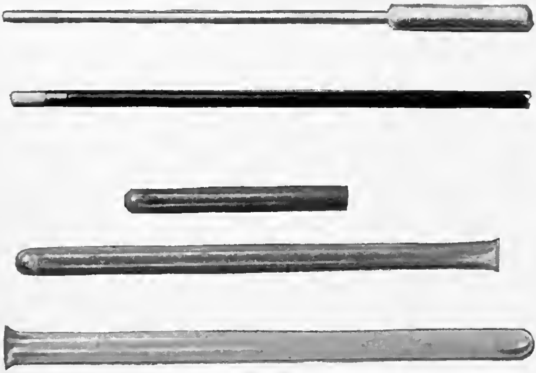
This form of applicator may be used upon the surface, for dermal conditions, or for deep radiation with filters of sufficient material to obstruct the low rays, provided the salts give off a fair proportion of high rays. Where it is desired to increase the amount of surface in one of these applicators for a large proportion of low radiation, a piece of wool or some material having a loose texture may be placed in the bottom of the disk and the varnish then allowed to cover the fabric without loading it down. In this way the uneven surface of the fabric increases the radio-active area. The radiation from these applicators is usually reckoned by the amount of "radium element" for each square centimeter; the proportion of α-, β-, and γ-radiation depending upon the filters.

On account of the difficulty of procuring these radio-active salts, it is desirable to give them the greatest amount of protection from harm or loss through careless handling. The most common forms of applicators are small metal tubes which contain the radio-active salt, or encase a small glass tube or bottle in which this salt is placed. It must be remembered if they are sealed within a glass container as they age, gases are given off and *explosions have resulted;* therefore in handling old sealed tubes, the greatest care must be taken to guard against this accident.

When transferring these small glass containers from one metal case to another, or when opening any applicator containing these radio-active salts, it should be done over and close to a glazed sheet of paper; for should any accident occur the contents would drop upon the glazed paper, which could be promptly folded and the salt collected with little loss.

The metal container may be made of aluminium, silver, platinum, gold, or even lead, depending largely upon the amount of filtration desired; and if some very slight resisting metal is employed, like aluminium, then the β-rays can be used, but where they are not desirable they can be filtered by an additional encasement of sufficient metal to obtain the desired result. These metal containers have been given the name of radiodes by the late Dr. Shober; although the word seems to apply most aptly, there is very little tendency toward its adoption for general use. Radiodes are made so they may be tied together either in the form of a chain or else arranged side by side, forming a square; this adaptation to different forms gives them a wide range of usefulness, for the application to irregular parts.

Fig. 35



Shober's radiode.

For the maturation of the apparatus sufficient time must be allowed for the radio-active salt that is employed to regain the activity lost in the transfer, where it has been found necessary to dissolve it and allow it to recrystallize; the time required for this process, varies with the salt used. Radium salts usually require a month, mesothorium a somewhat longer time to regain their full activity. The cause of this period is the removal of the "active products and the emanation" which require a certain time to re-accumulate. During this time of maturation the color of the crystal changes, becoming darker with age, and if a varnish is used to fix the salt, it changes from its natural yellow to a deep brown color. After the applicator has matured, if radium salts are employed, they remain constant with very little variation.

For the sake of cleanliness, where these applicators are to be used upon a series of cases, covers of various kinds are useful; several layers of sterile gauze will prove sufficient where the surfaces are dry; but where moisture exists or where the applicator is to be placed in a cavity, thin sheet rubber should be used; under some circumstances tubes made of celluloid or glass must be employed.

Filters or Screens.—In the great majority of instances that come under treatment the low rays are not desirable. In order to eliminate them certain metals and other materials are placed about the applicator to cut them off, and these articles have been named filters or screens.

They may consist of air, cotton, rubber tissue, leather, mica, aluminium, copper, silver, tin, lead, gold, or platinum, according to the requirments of the condition to be treated. If air is to be used as a filter, the radio-active salt is placed at a given distance from the surface of the body. The low rays are eliminated in proportion to the distance, but it must not be forgotten that the high rays also lose in value. Under this procedure the further the radio-active salt is from the object the fewer high rays impinge upon it; therefore quite a different effect is obtained by direct filtration. The α-particles are completely eliminated by a thin sheet of metal or even several layers of ordinary paper; they are, therefore, only to be considered in naked specimens of these salts; some few perhaps escape from applicators where the salts are mounted in varnish, but a few inches of air is all that is required to completely annihilate them. With the β-rays it is somewhat different; and while a piece of sheet lead a few millimeters thick will cut off many of the low rays, it is doubtful whether they

FIG. 36

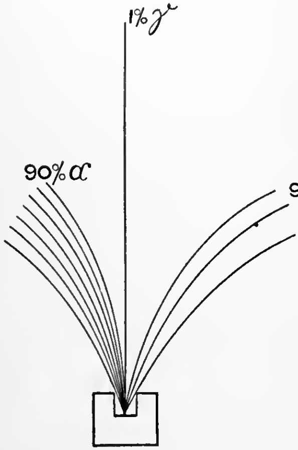
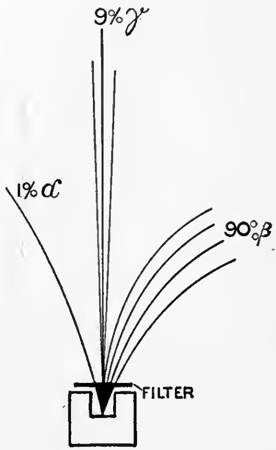


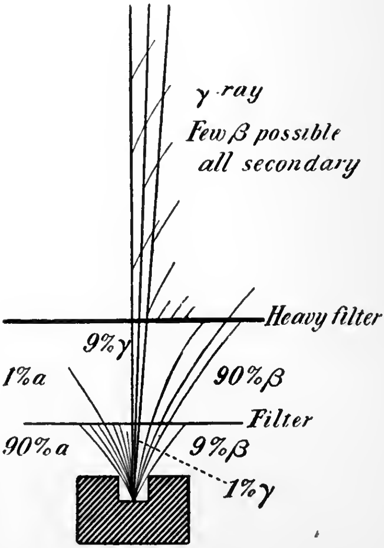
FIG. 37



Showing the difference in proportion of the α-, β-, and γ-rays, with and without filter. By increasing the thickness of the filter the proportion of the gamma-rays becomes greater, the alpha-rays are finally cut off, and the softer beta-rays next, until the filter is increased to 1 cm. of lead, where all the β-rays are practically cut off. There are, however, other secondary β-rays formed along the path of the gamma rays. (Diagrammatic sketch modified from Razet.)

are all eliminated by even a piece of sheet lead 1 cm. thick. There is some confusion upon this point, which results from the formation of secondary β-rays along the path of the gamma-ray. The diagram of Razet, somewhat modified, illustrates this change in the different rays and takes into consideration the formation of these secondary rays along the path of the other rays. The knowledge of the formation of the secondary rays along the path of these high rays, especially when they meet with some obstruction, such as a filter, is of vital importance for the protection of the surrounding tissue from the low

FIG. 38



Showing the different proportions α-, β-, and γ-rays, with and without filters, and the secondary formation of β-rays.

secondary rays formed about the material used especially to occlude them. The formation of these secondary rays differs considerably in different metals; some seem much more irritating than others, but in a general sense the denser the metal filter, the greater the formation of these secondary rays. To eliminate them it is necessary to have these filters in turn filtered by some less dense material, such as paper, cotton, rubber, tissue, or even air. This is demonstrated somewhat diagrammatically in the illustration showing the elimination of some of the low rays but the formation of others above the filter.

FIG. 39

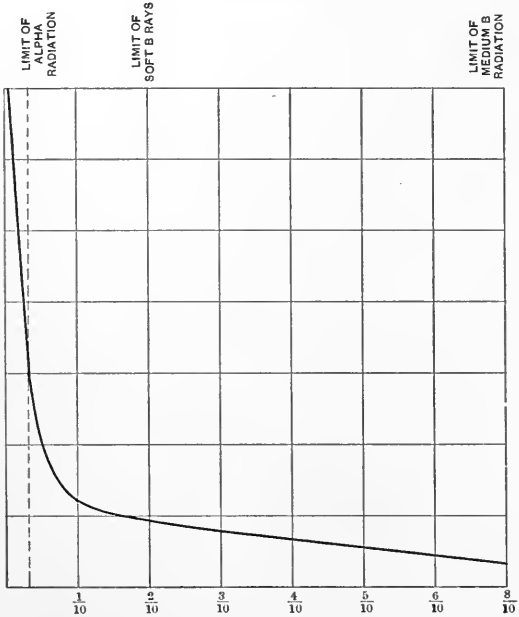


Diagram showing the absorption of the α- and β-ray by aluminium.

The name of "**cashé**" has been given by M. Sagnac to a small lead cone, covered with several layers of paper, then with rubber, and the window at the bottom covered with mica. The radio-active salt can be held in the apex of the cone, filters placed where desired, and then the cashé applied where the radiation is necessary, the lead acting as a filter for the objectionable rays, and the paper, rubber, and mica finally cutting out practically all the secondary radiation, leaving only those rays desirable for the therapeutic effect that may be required.

Radiability of Filters.—The metals usually employed for the filtration of these rays are aluminium, silver, and lead. Gold and platinum are preferred by some, the contention being that the secondary radiation from them is not so irritating as from lead, which corresponds to them in density. The amount of filtration of the different rays is not exactly in proportion to their density, as might be supposed. There is a slight variation for the different varieties of radiation; for the gamma-ray, for instance, in the case of aluminium is 14; silver, 75; and lead, 122. This allows a wide variation of filtration values for the different metals, and likewise this filtration is not directly proportionate to different thicknesses of the same metal; therefore when careful study is to be made of the amount of radiation passing through a given filter, measurements should be calculated directly from it for the different rays.

Aluminium screens are useful when it is desirable to filter out only the very low ray. The lightness of the metal and its ease of manipulation as a thin foil, which does not fall apart and retains its shape without crushing, make it especially desirable. These filters are most useful in dermal conditions, such as acne, capillary nevi, pruritus, lupus, keratosis, and other superficial lesions; the thickness may be varied from 0.01 mm. to 2 mm., the thinnest filters allowing many of the alpha-particles to pass through, while the thickest cut out a large proportion of the β-rays.

Silver filters cut out the softer radiation better than the aluminium, and when used in screens of 0.5 mm. to 1 mm. thickness will be found useful in the treatment of skin affections which require a deeper radiation. It has the advantage over thin lead-foil in that it holds its shape when made in small capsules or tubes, and therefore can be more easily cleansed.

Lead filters are used for deep radiation (Surpénétrant radiation of Wickham) when it is desirable to remove all

Fig. 40

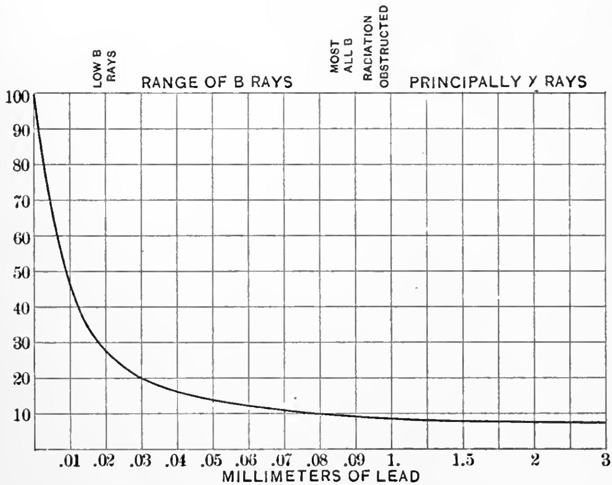


Diagram showing the penetration of the β- and γ-radiation through different thicknesses of lead.

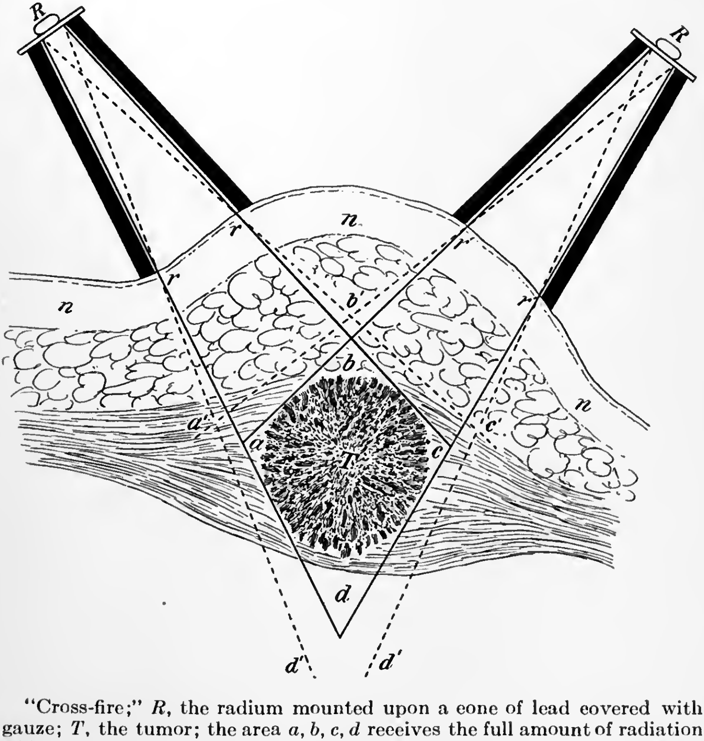
soft rays, in cases of tumors which are deeply embedded in surrounding tissues. These screens vary in thickness from 0.1 mm. to 3 or 4 mm., depending largely upon the strength of the salt. On account of the soft quality of the metal, tubes or capsules of this material must be handled with care, otherwise they are likely to be crushed. They also tarnish rapidly, which under some circumstance might be objectionable. These lead capsules are often covered by a jacket of some other metal, such as silver, which gives them more firmness and therefore less likelihood of injury. Platinum as a substitute for lead is preferred by some, as it lacks these disadvantages; the initial cost, however, must be considered.

The practical application of these radio-active salts may be separated into two divisions: (1) the superficial conditions and (2) deep conditions. In the former a large amount of radiation may be applied for a short time, with practically no filtration. On the other hand, where a deep tumor is to be treated, heavy filtration is needed for the protection of the tissue beneath the applicator. To some extent this can be accomplished by frequently changing the site of application upon the surface, yet keeping in range the object upon which these rays are to be centred.

In making applications to superficial conditions, some authors recommend the direct application of the radiode to the skin, provided the surface is dry, using only some antiseptic, such as formalin, to sterilize the applicators. While a few low rays may be sacrificed by the interposition of some thin rubber tissue or oiled silk, or even thin waxed paper, which may be destroyed after use, it would seem to be a better method and the results in the end would be practically the same. In those instances where the surfaces are moist, these articles are necessary to protect the radiode.

The surface to be treated must be carefully cleansed, all dried crusts should be removed, and after cleansing should be well dried, as moisture, either from secretions or from the application hinders, to some extent, the penetration of the low rays. Ointments and dusting powders, especially those containing a heavy base, must be limited; and applications should not be made previous to the time of radiation which would interfere with the proper cleansing of the part.

FIG. 41



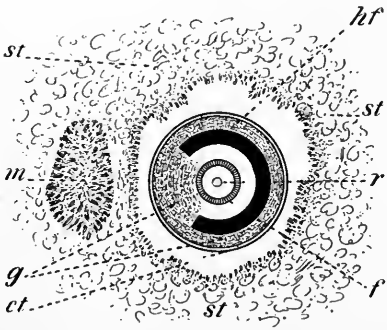
"Cross-fire;" *R*, the radium mounted upon a cone of lead covered with gauze; *T*, the tumor; the area *a*, *b*, *c*, *d* receives the full amount of radiation while *a'*, *b'*, *c'*, *d'*, *d'* and the area between the radium received only a partial radiation . The remaining portions, *n*, are entirely protected.

Cross-fire.—This frequent change of position, or having several applicators at different points at the same time, has been termed "**cross-fire**" by Wickham, of Paris. The word is most significant and the actual bombardment of of these rays is focussed upon one spot, deep within, and yet the surface tissues receive a rather insignificant amount of radiation. The areas over which the applicators have been employed should be marked by a pencil of methylene blue or nitrate of silver, so that at the next application the former site can be easily recognized and avoided. By this method of frequent changing of the site of application and proper filtration it is often practicable to give a large amount of deep radiation without the least disturbance of the superficial or overlying structures.

When *the object of radiation is below the surface,* the preparation of the apparatus is somewhat different and must be modified according to the requirements of the individual case; they are, however, much the same in their general principles. The first consideration is the possible injury of the intervening structures. One method to avoid this accident is by frequently changing the site of application "cross-fire;" and with this, proper filtration of the radioactive salt, eliminating all the low rays. With this in view, the applicator is covered with silver, lead, platinum, or gold, the thickness varying from 0.1 mm. (if the object is directly below the surface) to 2 or 3 mm. if it should be very deep. This metal should be covered with 2 cm. to 5 cm. of gauze or cotton, to eliminate the secondary radiation from the metal; over this, a layer of oiled silk, waxed paper, or rubber tissue, depending somewhat upon the position in which the apparatus is to be placed and the character of the surface, whether it is dry, moist, or discharging freely. After the preparation, the apparatus may then be fixed to the part desired by adhesive plaster, a bandage, or where the application is of short duration it may be held by the hand, providing the proper protection is given, such as a long handle, well shielded.

For the *radiation of ulcers and masses in cavities* the preparation is somewhat similar to the former except that allowance must be made for the better protection of the applicator. For this purpose, celluloid or glass tubes that can be properly sealed may be employed where the radiation of surface conditions alone is desired. Where there is a mass deeply

FIG. 42



A transverse section of an applicator inserted into a cavity: *m*, the tumor; *st*, the surrounding tissue; *r*, the radium surrounded by filter (*f*), which is partly covered to protect the tissue by the heavy filter (*hf*). Over this are placed several layers of gauze to remove the secondary radiation; and a celluloid tube (*ct*) to protect against (*g*) moisture.

embedded in the tissue, lead or platinum capsules that can be sealed may be employed to advantage. A point that must be taken into consideration where the radium is to be used in cavities is the direction and site to be treated. It must be remembered that these radio-active salts give off their rays in all directions equally and in the same ratio; therefore the protection of the surrounding tissues under these circumstances is a matter for serious consideration.

While it is possible to interpose screens which will to some extent hinder the radiation where it is not desired, it cannot be entirely eliminated. For this purpose a screen of lead 3 or 4 mm. thick, with a window cut corresponding in size to the site of radiation, will aid to some extent by allowing a greater amount of these rays to reach the place where they are desired, while the surrounding tissues receive a minimum amount. The preparation of the apparatus for a cavity is as follows: Where the radiation is only desired upon the surface, a radium tube surrounded by a very thin filter (which can be omitted if the cavity is simply ulcerated) is employed. Where a mass exists in the tissue, a filter of heavy metal 1 or 2 mm. thick is used. Over this is placed the "guard," with a window cut out to allow a certain area to receive most of the radiation; this is surrounded by several layers of gauze or paper, and the whole is protected by a celluloid capsule that may be properly sealed.

If the cavity is large enough to permit the use of tampons, the surrounding tissues may be protected to a greater extent by placing the apparatus as described, directly over the site of disease, and back of it as much cotton or wool as the space will permit, in this way bringing the surface where radiation is not desired as far away as possible. The valuable point always to be remembered is that spaces invariably give the best filtration.

Before the apparatus is introduced the cavity should be properly cleansed and rendered as dry as possible. Where tenderness exists, local anesthetics may be employed, but this will be found to be rarely necessary, as it is always more or less possible to accommodate these applicators to any size and position of the cavities, and if they are made so that they can be introduced without stretching or changing the position of the parts, very little pain will result. As most of these cavities discharge freely when irritated, they should be subjected to the least amount of disturbance, since the discharge coming between the applicator and the diseased area interferes with the operation by hindering the radiation with the mass. There is also a likelihood that the position of the apparatus may be disturbed from the same cause.

It is particularly difficult to make proper applications to the cavity of the mouth, due to reflexes exciting muscular contractions which cause the flow of mucus and saliva. If the single treatment is to be extended over one, two, or more hours' duration it may be necessary to remove the applicator at frequent intervals to rest the excited muscles and cleanse the cavity. Under these circumstances anchors or guides must be so placed upon the applicator as to bring it into exactly the same position as before removal.

The other natural cavities, such as the vagina, rectum, external auditory canal, etc., do not, as a rule, show this irritability. Even when the applicators are introduced high into the rectum or into the stomach through the esophagus, when once they are brought into position, they rarely excite reflexes sufficient to cause trouble.

Applicators containing radio-active salts should under no circumstances be placed in cavities without being firmly fixed by a rod or strong cord by which they may be easily removed; without such guide there may be some difficulty in finding them, and disastrous results may follow a too long and undesired radiation.

Implantation.—When the radio-active salt is to be implanted in a tumor, the preparation is somewhat different from the preceding. The applicator must be as small as possible. The capsule which acts as a filter should be made of silver, and have a small ring at one end for the purpose of tying a strong silk cord to it.

The site of operation is prepared as usual, and an opening is made directly into the centre of the mass. After all bleeding has been checked the capsule is wrapped in several layers of gauze and packed firmly into the bottom of the opening. This gauze soon becomes moist from the serum and blood and in this way acts as a filter for the secondary radiation.

While implantation was formerly practised to a greater extent than at present, it usually resulted in failure, from the fact that the activity of the salt was not sufficient to produce the result. However, this operation is rarely necessary, for by the proper filtration and "cross-fire" method it is possible to reach a tumor at any depth, and do far less harm by the rays passing through the tissues, than the irritation and chance of infection caused by an open wound.

There is a most decided contrast between the action of these elements in the two methods. Where it is implanted in the middle of a tumor the action near the applicator is intense, while the vital portion of the tumor, the periphery, receives only a mild degree of radiation; therefore the degeneration in the centre is intense, while the edges are possibly only mildly irritated, and under some conditions may be even stimulated. In contrast to this where the "cross-fire" method is employed, all portions of the tumor receive an equal amount of radiation and consequently the degeneration is equal.

Wax or paraffine has been employed as a means of introducing these radio-active salts into the tissues where degeneration is desired. One of the insoluble salts of radium is incorporated in the wax or paraffine, which is injected into the tumor in a liquid state. It rarely produces any degree of infection and after the tumor has subsided most of the wax can be recovered, with the salts, that are not soluble, but remain like the paraffine, unabsorbed.

Where there is not a sufficient quantity of these radioactive salts, to have a number of assorted applicators, the most practical form for a single one is to have the salts contained within a small glass tube, which is encased within another made of aluminium. In this way the material is protected, with very little of the low radiation being lost. The aluminium container can then be encased in lead, where low radiation is not desired. With proper manipulation and care, practically all the therapeutic values can be obtained, but not with the same ease and comfort as where applicators are made to suit the condition.

The emanation of radium is at times more convenient for practical use than the salts of that element, and where it is employed, the shape of the applicator may be modified according to the requirments of the individual case. The emanation, being a gas, requires the primary containers to be sealed and they therefore must be made of some material that it is possible to seal. After the gas has been introduced, a thin glass tube or one made of lead answers the purpose admirably, as both lead and glass are worked with ease by one having some mechanical skill. It must be remembered that this gas undergoes a rapid degeneration, and where it is used allowance must be made for it. The degeneration is uniform and if the age and strength are known, calculation at any time is not a difficult problem.

These emanation tubes are valuable where, for some reason, it is not desirable to risk the radium, from which it is obtained. They cannot, however, be shipped any great distance, as the loss in strength is extremely rapid, especially in the first few days.

Where the low radiation is desirable it is possible to use the emanation in the form of a compress, mixed with some inert powders, or as an ointment. This method has had very limited use, and care must be taken, when the application is made directly to the surface of the body, that the emanation is not too strong. The same caution should be observed in the employment of these preparations from the emanation as would be used with radium; the activity of radium depends upon the emanation and the emanation upon the "active product." Therefore, should the emanation come in contact with the surface of the body it could not be removed and a burn would result, the severity depending upon the strength and age of the emanation.

Under proper manipulation these applicators for the emanation may be varied in strength, either by first charging them with the required amount and then making use of them, or, if they are overcharged, by waiting a certain length of time, until the decay of the product reaches the strength desired.

While the use of the emanation in some form has many points in its favor, it must be remembered that the preparation requires a large amount of radium with, at the same time, more or less technical skill on the part of the operator in the manipulation of the process, and that every tube must be measured for the amount of radiation it possesses.

PART II.

PHYSIOLOGY AND THERAPEUTICS.

CHAPTER IX.

PHYSIOLOGICAL ACTION.

Effects Observed from Local Radiation—Reaction—Burns—Relief from Pain — Selective Action — Stimulation, its Significance — Effects upon Bacteria — Systemic Disturbances from Local Applications — Internal Administration of Soluble and Insoluble Salts—Effects of Physiological Doses upon the Heart—Alterative, Stimulant and Diuretic Action—Comparison of α-, β-, and γ-rays with x-rays—Influence of these Rays upon x-ray Burns.

THE physiological action of these radio-active elements must be considered from two general sources, the first being when applied locally. This head is then subdivided into the purely local effect and the general constitutional symptoms therefrom produced. Secondly, the action upon the whole system and the local effect upon the different organs when these radio-active elements are administered internally as a general medicine.

Therefore it will be considered under the following heads:

A. Local application:
   1. Local effect.
   2. Systemic disturbance resulting from local application.

B. Internal administration:
   1. General systemic effect.
   2. Local effect upon different organs.

Effects of Local Applications.—When these radio-active elements are used locally, there results a disturbance of the tissue, which is made more manifest the longer they are applied. This effect may be so transient that upon casual observation no change is evident in the tissues, while the subjective symptoms may be only a slight itching. If, however, the application is prolonged it promotes what has been called a reaction, and should it be continued this reaction may become a burn, simulating for the most part the same characteristics produced by the Roentgen ray; with the essential difference that no burns of a severe character have been reported, due no doubt to the fact that radium has been, as a rule, in more skilful hands. At the same time the action from radium is somewhat different; the radiation comparing with the medium x-rays is almost entirely wanting in radium or thorium.

The local action depends upon bombardment of the tissue by the projection of a mixture of the α (alpha), β (beta), and γ (gamma) rays from these radio-active elements. The low rays are, like the low Roentgen rays, most irritating and produce reaction quicker than the high rays; for this reason most of these radio-active salts are applied in some container which filters off these low rays to a very great degree.

Even in applicators made with varnish, the thin layer of resins obstructs all but about 1 or 2 per cent. of these α-rays, and to some degree the low β-rays also. Therefore, while a number of low rays are still present, and will produce a decided reaction, it is as a rule superficial. Where these low rays are filtered to a greater extent and only higher rays are allowed to escape, the reaction will be deeper; and should a burn result, it is decidedly of more serious local consequence, and would possibly produce considerable systemic disturbance.

Reaction.—The word *reaction* has been generally adopted to mean that local effect from these elements which is manifested by some sign or symptom, either objective or subjective. It usually appears at a varying length of time after exposure, from almost the time of application to several weeks; its duration varies and eventually subsides, leaving either no trace at all or a darkly colored pigmented spot which may remain for years and then gradually disappear. The behavior of these local manifestations depends largely upon the idiosyncrasies of the individual. There is some reason for believing that blondes respond or react sooner and with a greater degree than brunettes, and while this is a general rule, it has some exceptions. Usually persons having a skin which reacts quickly to the sun are sensitive also to these radio-active elements.

The individual sensation from a local reaction varies; many complain of a peculiar numbness, while others of burning, itching, and even pain; and, incongruous as it may seem, the burning and itching of a pruritus and the pain of a neuralgia are relieved by treatment.

The *excessive reaction* has been termed a burn; however, the line by which reaction and burns are separated is not sharply drawn, and these borderline instances may be considered from either stand-point. The stage of reddening may be followed by vesication and this by ulceration; either one of the first two stages may be extremely short and pass unnoticed, while in more severe cases redness may be followed by a slough, the depth of which depends upon the dosage. The course of these burns, like those produced by Roentgen rays, is by no means regular; it may begin abruptly and advance to a certain stage, to be followed by rapid recovery; or it may simply remain in a quiescent stage, refusing to yield to any form of treatment. Recurrent ulcerations, developing at times after the healing of such radium burns, have not been reported, but they no doubt follow the same general tendencies as those produced by the Roentgen rays. Upon healing, the skin over the site of an ulceration is usually left puckered and pigmented. The pigmentation usually disappears in a short time, but it leaves the telangiectatic effect that is so noticeable in the burns of the Roentgen rays. While pigmentation following the healing of these burns from radiation is to be expected, this condition usually disappears in the white race, but in the colored race the opposite conditions prevail, the absence of pigment produced by these burns is permanent in the colored. This is not pleasing to the eye in contrast to the dark skin; the spots having a peculiar, blanched, pink-white color of scars. Under ordinary radiation the skin darkens in the colored race in proportion to the amount received, but should ulceration occur in this radiated area, absorption of pigment is very likely to follow.

The cause of this local disturbance in the cells of the affected part is by no means clear, but the ordinary process of inflammation and repair is observed, varying only in degree according to the proportion of radiation. The question is often asked, "Why do new growths disappear from effects of radiation?" and, "Why does it not have an equal effect upon the surrounding tissues?" A very rational answer would be to point out the difference between tissue in normal condition and where some pathological process exists. In sound tissue the blood supply and nerve supply, particularly the combination, the vasomotor supply, are perfect; the giving of sustenance to each cell and carrying off the effete matter is accomplished with clock-like precision; while in the tumor mass we have an erratic lot of cells each striving for its own existence, with general nerve or blood supply to aid resistance; the healthy tissue of the body might be compared to a well-organized city, where approved systems control the supply and demand, while the diseased portion resembles a mob.

Selective Action.—This difference of action upon these tissues, normal and abnormal, has been described by some authors as a peculiar influence possessed by these radioactive substances upon certain tissues and spoken of as a **selective action.** It must be admitted that there is some difference in this local action upon the cellular element of the same individual. However, it can be explained; in most instances, surfaces covered with a moist discharge, natural or unnatural, will endure more radiation than a dry surface; the moisture acting as a filter protects the tissue lying beneath. Parts of the body which have a rapid and free supply of blood withstand radiation to a greater degree than ordinary tissue.

It is a well-known fact that the more highly organized epithelial cells are much more susceptible to radiation than those of the ordinary type, and that all epithelial tissue is far more susceptible than fibrous tissue; but this fact is observed in other forms of degeneration as well as degeneration due to radiation, and while we may agree that the different forms of tissue accept radiation with a widely different result, it can hardly be due to any selective power of these rays upon the cell; on the contrary, it would seem to be the resistance of the individual cell against the power or force of these rays upon them as individuals. The hair-forming cells are quite susceptible to radiation and will often be destroyed temporarily without the slightest sign of reaction upon the surrounding skin. The deep layers of cells forming the finger nails are also among the highly susceptible cells, and persons working about these radio-active elements, handling them, are liable to have pain and tenderness resulting from frequent, short exposures.

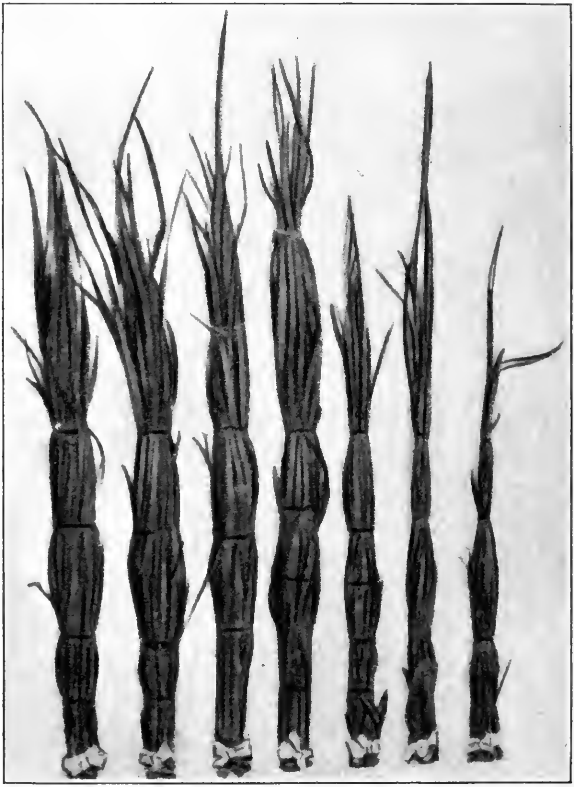
There has been considerable microscopic study made of tissue subjected to the radio-active influence, but there seems to be nothing exceptional that could be ascribed alone to radiation. The form of degeneration in all these cells, whether the radiation be severe or mild, is identical with processes from other causes. This same conclusion has also been brought out by experiments upon animals. In mild degenerations the atrophy of the cells is very slow and the local changes microscopically may be very hard to demonstrate; while in an active process the inflammatory disturbances and the cell degeneration are well shown histologically.

Stimulation.—While the local action of these radio-active elements upon the tissues might be stated to be inhibitory, proved by experiments upon fertile eggs and fish roe, there, no doubt, exists a stage when this local action is purely stimulative. Clinically, under some conditions it might be of value, while in other instances it is to be regarded with some degree of apprehension. This same stage of stimulation has also been noticed when mild and short applications of the Roentgen rays have been made to tissue; but a few mild applications have caused the growth of hair, as in alopecia areata, or where these short applications have given rise to the formation of warts and keratosis. While there seems to be less liability of the stimulation from these radio-active salts producing the same degree of growth as the Roentgen rays there is not the least reason to doubt that under similar conditions the same result might be expected. From an experimental stand-point, at least, the two forms of radiation produce the same results, for where seeds have been exposed to either form of radiation a certain degree seemed to produce stimulation of growth, while if pushed still further it was followed by inhibition. Dr. Abbe has demonstrated these facts in a rather unusual manner, where he has experimented with the effect of radium upon plant life, and alludes to it as follows:

"The stimulation of growth depends on the time exposure, the distance, and the kind of rays used. I believe we may assume the biological acts of living cells to be the same, whether animal or vegetable.

"In these experiments I used oats for the first time, because of their rapid growth. In four weeks an oat may grow about one foot high. One hundred milligrams of pure radium bromide in fine glass tubes was placed in a bottle with two tablespoonfuls of selected oats. To prevent inequality of action the bottle was strapped to the axis of a diminutive water wheel rigged up to run by a faucet at an even revolution, so that every oat was in turn brought in contact with the radium thousands of times during the two days' exposure. At certain intervals I removed twenty-five oats and labelled them. At the end of two days I planted them in rows in special, sifted soil, and raised them first under glass. Beside them, under similar conditions, a row of unradiumized oats. The result at the end of four weeks is shown in this photograph. The plants were cut at the roots, tied in bundles, measured, and weighed. Compared

Fig. 43



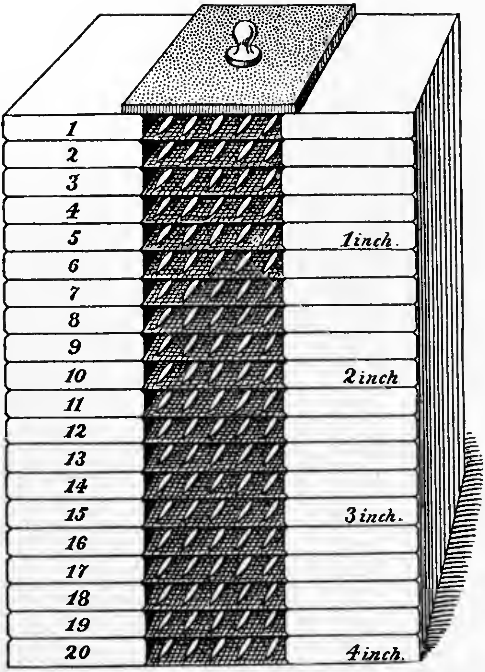
Normal 2 8 16 24 36 40

Results of Exposure to Radium.

Time exposed	No radium	Stimulated. 2 hours radium	8 hours	16 hours	Depressed. 24 hours	36 hours	40 hours
Height . .	100	111	107	111	84	71	53
Weight . .	100	111	120	116	48	44	32

to the normal growth, three bundles were above the normal, and three below, both in height and weight." (See Fig. 43.)

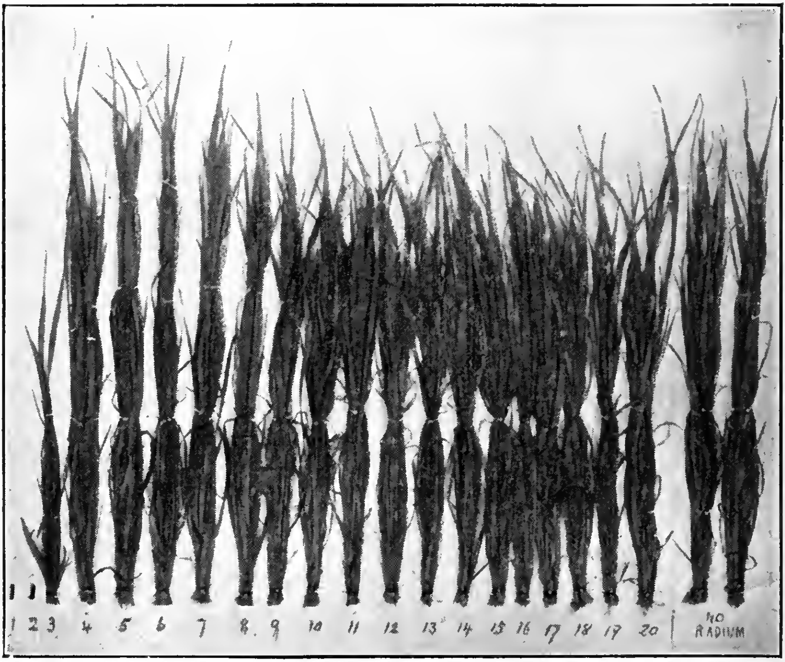
FIG. 44



Twenty shelves of mosquito netting, each holding 25 oats; at the top is a plaque of 5 milligrams of naked radium.

The interpretation of this experiment is this: A deterrent effect on cell growth depends on time exposure, and must be a definite equation for every specimen of radium. The main value lies in the demonstration that, on seeds as well as tumors, the electrons may produce detrimental results, as well as mysteriously beneficial ones, and that probably all the beautiful effects so often seen result, in a measure,

FIG. 45



Growth of oats exposed to naked radium at distances from $\frac{1}{4}$ to 4 inches. Twenty rows. Two rows for comparison, without radium. Exposed six days. Growth after planting, one month. Nearest two rows killed. Fourth, fifth, sixth, seventh, stimulated. Beyond seventh ($1\frac{1}{2}$ inches) all retarded. The nineteenth most stunted of all.

	No radium					1–1½ inch						2 inch						3 inch				
Row	N	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Weight	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Grains	74	95	0	0	14	70	87	77	79	63	61	49	62	58	50	59	63	60	64	62	45	64
			Killed		Stimulated					Stunted												

from accidentally correct time exposure. It is evident that the oats were alternately near and far from the radium tube, as they whirled about, so that twenty-four hours of exposure in the bottle would only represent a part of an hour of close contact, such as takes place when radium tubes are applied on tumors.

A second experiment was, therefore, necessary to show the persistent action of radium at a fixed distance.

This was made as follows (Fig. 44): A series of twenty little shelves of mosquito netting, one-fifth of an inch apart, was arranged by cutting a square hole in the centre of thin boards laid on top of each other with netting sandwiched between. On each shelf were placed twenty-five oats, and a Wickham plaque of naked radium (25 mg.) was bound on top of all, so that each shelfful received a given bombardment of radium at a uniform distance during a similar period. In this experiment I was also able to test the efficiency of all the combined rays emitted from naked radium compared with former work where the alpha-rays were suppressed by the glass container. The exposure of these seeds was continued for six days, with frequent shaking to change the exposure of all the oats on each shelf. The mosquito netting would offer no barrier to the alpha-rays, which even tissue paper would have suppressed. This series was planted in twenty rows an inch apart, with two additional rows of unradiumized oats for comparison.

The results were more interesting than I had anticipated. The two rows nearest the naked radium, but not in contact, were one-fifth and two-fifths of an inch from it. They all germinated and tried to sprout, but died before they were an eighth of an inch high, during the first week.

Those in the third row were up 2 inches; the fourth row, $3\frac{1}{2}$ inches; the seventh to the eleventh rows were outdoing all but the normal ones, which were 5 inches. At the end of four weeks the fourth, fifth, sixth, and seventh rows—which had been $\frac{1}{2}$ to 1 inch from the radium—were now the finest of all, even exceeding the unradiumized rows, notably of a rich growth, darker green in color, and $12\frac{1}{2}$ inches high. All plants were now cut at the roots, tied, photographed, measured, and weighed (Fig. 45).

Let us first remember that the seeds had been continuously played on for six days by a discharge of all the electrons issuing from the naked radium. Let us recall that alpha-rays are known to be of slight penetrating power, of short area of travel, and subject to change into other rays.

The beta-rays have relatively feeble penetrating power, and carry charges of negative electricity. The physics of these rays is credited with soft and hard qualities, the former of feeble penetration, the latter going deeper into the tissues. The gamma-rays, swift, ultrapenetrating, of negative electric charge, are probably the ones more efficient in all use of radium in glass or metal containers.

The interpretation of the experiment on oats at fixed distances from the radium shows that the nearby cells, up to half an inch distant, were all killed. These had the combined rays, but, above all, were exposed to the alpha.

The seeds at distances from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches were greatly stimulated beyond normal growth. These had the combined beta- and gamma-rays, as well as any secondary ones emanating from the decay of the short alpha-rays.

The seeds from $1\frac{1}{2}$ to 4 inches were depressed in their growth, but singularly enough not in inverse ratio to their distance, as would be the case were the energy a losing one as the distance grew greater, or as it might be considered if it had lost by absorption in nearby seeds. On the contrary, the more distant seeds were most affected, so that at from $1\frac{1}{2}$ to 4 inches the growth represented by size, weight, and color of the plant showed most injury at the farthest end; the weakest plants being on the nineteenth row, or about 4 inches away. One may interpret this phenomenon as he wishes, but as I had elaborately thought out the experiment to secure fair play for each seed in choice, planting, soil, moisture, nurture, sunshine, etc., I must attribute the inequality of growth to only one cause—radium.

I am inclined to ascribe an irritating and stimulating quality to the alpha and soft beta-rays, and a destructive force to the deep, penetrating, hard beta- and gamma-rays.

The twenty shelves of oats should represent twenty corresponding sections of a tumor subjected to the same experiment.

Therefore, while this stage is purely transient, it must not be forgotten that a result may be produced quite contrary to the one desired.

The beneficial effects of radiation in certain diseases has been thought to be due to the effect upon bacteria, and from an experimental stand-point this view has some substantiation, for the same effect is noticed with the lower order of plant life, such as the molds and bacteria, as has been so well illustrated by the experiments upon seeds. While many lists have been published showing its influence upon the various fungi, there is, however, considerable difference between experiments due doubtless to surroundings, which to a great extent affect the growth of these different varieties.

From these experiments it would be difficult to make a deduction as to what actually occurs within the tissues of the body, and it is not improbable that, while this effect upon these germs might be fatal, if the tissues receive the same amount of radiation they would suffer likewise; therefore this theory cannot be accepted in its entirety.

ACTION OF RADIUM UPON BACTERIA.

10 mg. $RaBr^1$ 30 to 40 mm.	Prodigiosus.	Staphylococcus.	Streptococcus.	Trichophyton tonsurans.	Achorion. Schoenleinii.
6 hours	living	living	living	living	poor growth
12 hours	living	living	poor growth	poor growth	poor growth
18 hours	living	living	poor growth	dead	poor growth
24 hours	dead	poor growth	dead	dead	poor growth
36 hours	..	poor growth	..	dead	poor growth
48 hours	..	dead	..	..	dead

General Systemic Disturbances Resulting from Local Applications.—The general symptoms resulting from these local disturbances depend to some degree upon the locality that has been radiated, and the extent of radiation. A certain amount of radiation upon the thigh might produce an inflammatory disturbance; if given under the same circumstances upon the head, might cause a meningitis, either from direct inflammation or secondarily from degeneration of surrounding tissue, forming an abscess and possibly sepsis.

Where a large tumor has been radiated it may undergo a gradual dissolution, break down without becoming necrotic, and cause a toxemia. The poisons of the degenerated mass are introduced into the system in a proportionately large, yet regular manner, and are eliminated through the regular channels; while on the other hand, the radiation may be pushed to such an extent as to cause a necrosis of the tumor tissue, since the neighboring cells and vessels are not able to carry off the debris which results in the formation of an abscess. The symptoms in this instance are not those of a toxemia but a septicemia. In either case, where persons are treated for large masses, and the system is debilitated, it must be remembered that it is possible to overload their resistance with these products of decomposition, which must be eliminated. Where the place of reaction is upon the surface of the body, with the formation of an open wound, the same conditions exist as when the mass is buried beneath the surface, but, in addition, infection is much more likely to occur and the absorption of septic products follows. However, if free drainage can be established from the surface, the system is less burdened and possibly the general toxic effect may be less.

The following experiment of the action of radium upon globulins is interesting: If two solutions are prepared from ox serum, one made electro-positive by the addition of acetic acid, and the other electro-negative by the addition of ammonia, drops of the latter solution, when exposed to the rays of radium, turn rapidly to a jelly and become opaque, while the opalescence of the former is rapidly diminished, showing complete solution. This action is due to the α-radiation. While this illustrates the effect only from a very non-penetrating ray, it does explain, to some extent at least, the liability of systemic effects due alone to local radiation.

The pain in these processes, whether the degeneration be upon or below the surface, varies with the individual; in some instances there may be entire absence of the manifestation of suffering, while in others the pain will be excruciating, the general effect upon the person being a matter of individual equation.

In regard to fever, urinary secretion, and other concomitant symptoms, the process of degeneration from radiation does not differ in the least from any other of a similar nature.

There is, however, a train of symptoms which occasionally follow the local application of these radio-active elements which at present cannot be explained and are entirely disproportionate to the amount of radiation. They may be purely psychical, but are probably due to the elimination of certain toxins from the area of local exposure that cause more or less irritation to the general system. These mild symptoms, such as headache accompanied with nausea, vertigo lasting often for several days, after a marked degree of irritability and sleeplessness, are often accompanied with a marked gastro-intestinal disturbance, pain, diarrhea, vomiting and at times the cardiac symptoms may be most alarming. In some few instances the continued use seems to have some influence upon metabolism and causes a progressive emaciation. While the foregoing symptoms from the local application of a reasonable amount of radiation are by no means common, lassitude and a desire to sleep are quite frequent; these conditions are often most desired and possibly may be at times explained by the relief afforded from the local effect of the radio-active salt.

The local effect of all these radio-active elements depends entirely upon the amount of radiation and not upon the element or its form. The radio-activity from the emanation acts in the same way as an equal amount of salt from which it is derived, provided it is balanced in equilibrium in regard to the α, β, and γ variety of radiation. There has been an effort to prove a specific action for the α-, β-, and γ-radiation upon tissue, but it appears that this difference is merely a matter of proportion between volume and penetration. This, however, differs in the administration of these radio-active elements internally. Under these circumstances, not only the element must be considered but also the time it remains within the body and its method of elimination. The action from the soluble and insoluble salts of radium necessarily differs, due to the fact that the soluble salt is rapidly absorbed and rapidly eliminated, while the insoluble salt may stay in the tissue for an indefinite period, giving off by its slow disintegration the emanation that continues in very small quantities to be carried through the system so long as the salt remains.

Internal Administration.—The soluble salts of these radio-active elements, while in the body, give off the same amount of radiation from their products of disintegration, but only continue in that proportion while in the tissue and, necessarily being soluble, they are rapidly eliminated with the secretions. The emanation from both products, being a gas, leaves the body in the same manner as other gases, but only such a proportion of emanation is formed from these products as would be naturally expected under their disintegration process. The insoluble salts supply to the tissues of the body emanation for an indefinite period, while the soluble salts supply the same amount to the body before its complete or partial elimination.

These radio-active elements may be classed as alteratives, and, like drugs of this group, are used in diseases where the pathology is obscure. Their adoption has been purely upon empiricism, in such instances where the action upon the tissues demands a decided reconstruction. The administration of any considerable amount of these radio-active elements may be accompanied by the most profound changes, and there seem to be few organs of the body which escape. Startling changes occur in the blood with a marked alteration in the pressure which in the weak and debilitated are likely to cause death.

The experiments upon animals by Smith[1] illustrate the manner of absorption and elimination of radium salts and emanation, and to some extent act as a guide for their medicinal use. His conclusions are:

1. That after the administration of radium by mouth or by injections a widespread degree of radio-activity is evident throughout the body.

2. That elimination of radium takes place principally and rapidly by the bowels, in a minor and slower degree by the kidneys, while in mice, at all events, there is no evidence that the liver or skin plays any part in excretion. As regards the elimination of the element by the bowels, it is certainly excreted by the small intestines, and there are indications that the large bowel also assists in that function.

3. That the high activity in the lungs is possibly due to the extreme vascularity of these organs, but its constant presence at all times after inoculation and the fact that the emanation is entirely eliminated by the lungs suggest that an accumulation of radium takes place with a view to the more ready excretion of the emanations.

4. That the emanation can be obtained in solution in various media and can be introduced into the body in small doses by inhalation, feeding, or by injection.

5. That after such administration, and however introduced, a general radio-activity of very brief duration is caused throughout the body.

6. The elimination of the emanation takes place principally, and almost entirely, by the lungs, and to a very slight extent by the kidneys.

[1] Quart. Jour. of Med., 1912, p. 249.

7. That the duration of the activity induced in the body or, in other words, the time taken by excretion, differs with regard to the nature of the preparation used. Soluble salts of radium are rapidly eliminated, however administered. The insoluble salts *per os* are excreted directly by the bowel, and there is no evidence of any temporary absorption and circulation. When given by injection, however, an exceedingly slow elimination takes place by the bowel. The time taken, however, is so great that, for all intents and purposes, the salt may be considered to be permanently present at the site of injection.

8. The elimination of the emanation occurs with great rapidity, and is complete after administration in powerful doses in so short a time as four hours.

The same observations have been made in regard to thorium and actinium. The changes are more or less profound, depending entirely upon the salt or preparation and the mode of administration. Necessarily the most profound effects are observed from the uses of these elements, hypodermically or intravenously.

The effect upon the breathing is at first to increase it, both in volume and depth, with a gradual subsidence to a lowering of the rhythm and depth, and from larger amounts an asthmatic condition may be induced. The blood-pressure is usually lowered, and continues for some time afterward, depending much upon the elimination. Under these circumstances the action upon the blood is usually very slight; however, in larger doses or in individuals who are easily influenced by the effects of these elements, a leukocytosis may be produced varying in proportion with the dosage. The normal condition is rapidly restored after the elimination of the offending element.

In physiological doses it seems to have very little effect upon the ferments of the body, such as the saliva, gastric, pancreatic or intestinal juices, all of which show considerable radio-activity under the influences of the different radio-active elements, nor are the ferments of these juices affected when removed from the body and placed beside a tube of high activity. If the gland or glands secreting these juices are influenced locally by radiation, the same changes are noted as would be observed in any other condition of inflammation.

The saturation of all parts of the body is well illustrated by the radio-activity of the child in a pregnant mother given water containing emanation of radium of about 4000 m. u. one-half hour before birth, and a subsequent dose of 4000 m. u. five minutes before birth. Examination of the blood in the navel cord showed the presence of the emanation of 50 m. u. to the liter; placenta 3 to 5 m. u.; meconium, 3 m. u.; and the breast milk, one-half hour after, 21 m. u. per liter.

At the point of exit from the body, as the lungs, the kidneys, and under some circumstances where insoluble forms of these radio-active elements given by the mouth and eliminated by the bowel, are noticed the greatest changes; particularly in the kidneys where the emanation is employed, the urea is increased 100 per cent., therefore the emanation may be regarded as a powerful diuretic. In some individuals there is a decided change in the elimination of all purin products while in others this disturbance is scarcely noticeable.

The effect upon the genito-urinary system is that of stimulation, if given in moderate doses, internally or locally as baths. This is in direct contrast to the effect of radiation from the x-ray, and no doubt γ-radiation from these elements, if locally applied, would not have the same effect. However, the systemic use of these radio-active elements cannot be expected to agree with the effects of local applications.

As a glandular stimulant, the interest manifested in trying to connect the endemic developments of goitre with the surrounding water supply is another fact pointing to the stimulating properties of small quantities of these radio-active elements.

Comparison with the Roentgen Rays.—Comparisons are often made between the Roentgen radiation and the radiation from these radio-active elements; and while rays of equal penetration seem to exist in both forms of radiation, from a physical point of view they do differ, and reference to this has been made in the physical section. The rays that penetrate a given amount of tissue to a certain depth differ widely in their character. For instance, a middle β-ray might be compared with a fairly low x-ray, while a middle x-ray compares with the high β-ray, and if there is such a wide difference between these two rays of equal penetration from a physical stand-point, it would certainly seem that there should be a difference between their action upon the tissue. Generally considered, the action of these rays upon tissue might be said to be similar, excepting their power of penetration. Taking the α-, β-, and γ-rays as a group, comparison can easily be made to the energy given off from an x-ray tube. Two facts must be taken as a basis. Low rays do not penetrate, are irritating, and carry with them an amount of force that does not seem to exist in the high rays, which are penetrating and do not seem to produce so much irritation. The γ-rays of radium and mesothorium are decidedly more penetrating than the x-rays, consequently it can be expected that they are decidedly less irritating, which does seem to be the fact from observation.

Therefore the γ-ray penetrates each individual cell, produces a general reaction of all the cellular elements, and all parts degenerate simultaneously; the force of the low ray is expended upon the cell wall and the nucleus escapes, thereby allowing the cell to regenerate.

The radiation from these radio-active salts is uniform in regard to the amount and the constancy of penetration, while under the best management possible there will be some variation in the degree of penetration of the radiation given from the x-ray tube. The value of the radiation from the radio-active salts can be measured and the definite amount of dosage can be determined; while on the other hand the dosage of radiation from the x-ray tube is a variable quantity.

In either event there are certain tissues that seem to yield better results from the effects of these radio-active salts, which seem less prone to be irritating, provided the low rays have been eliminated; while contrariwise there are conditions where the Roentgen radiation seems to be more efficient. It is not unlikely that in the future they will divide into two classes, those best suited for radiation from these radio-active elements, and those for the Roentgen rays. The study of the tissues from a histological stand-point fails to reveal any degeneration that would be distinctive of either form of radiation.

One noticeable point is that the laboratory workers in and about radio-active elements have not suffered in the proportion that workers of the same class have in the making and handling of x-ray apparatus. Furthermore, a number of instances have been reported where the effects of x-rays, such as the keratosis and small trophic-like ulcers, have been successfully treated by the application of these radio-active salts; yet while physically the action of these forces are so much alike, they evidently must differ to a very wide degree. Burns and the other untoward effects noticed upon the laboratory worker in the radio-active elements heal promptly and do not leave the long, indolent, ulcerative condition so common in the analogous condition from the Roentgen rays. These facts more than any of the others show the relative difference between the two forms of radiation.

CHAPTER X.

THERAPEUTIC VALUE OF NATURAL WATERS AND MINERALS.

Springs—Wells—Spas—Emanatoria—Baths—Drinking-water—Local Application—Mud—Their Application—Uranium Minerals.

The infinitesimal amount of radium occurring in these waters is well illustrated by the analysis of the King's Well in Bath, England, where Sir William Ramsey estimated that 1,000,000 liters contain 1.73 mg. of radium. This spring may be regarded as a representative of its class, and explains why these springs have been of such value as health resorts for centuries.

The difference in effect of these waters when transported to any great distance and used as they come from the spring is explained by the radio-activity derived from the emanation of radium, which degenerates rapidly. Other waters having exactly the same chemical composition without this activity fail to have the same therapeutic properties.

Wells in the neighborhood of Joachimsthal, Austria, and the surrounding countries of Bohemia, Saxony, and Bavaria, all show a relatively high activity, being rated as giving between 33 to 49.5 Mache units per liter. It has been said that some of them give as high as 1200 Mache units; but as this unit has been rather loosely used, this high assignment of activity is undoubtedly a miscalculation. It may be possible to concentrate the activity, but manipulation of these waters usually drives off the radio-activity which they naturally possess.

Some of the resorts and spas in Central Europe have been equipped with well-developed emanatoriums, where, if the natural waters are not of sufficient strength, they are artificially increased in their radio-activity by suitable apparatus used to collect it from the waters and recharge them directly from solutions of radium. Japan, South America, and the United States have followed the example set by Germany and France, and are developing their natural waters where it is possible to obtain springs of sufficient strength.

These waters may be employed locally in the form of a bath, or where the occasion demands, some material may be moistened and formed into compresses or packs. Internally they might be used as drinking-water, and under some circumstances the local and internal use may be combined, as in douches and rectal injections. With suitable equipment, where radium is the source of activity, rooms or small cabinets may be arranged with mechanical devices to blow air through these waters and cause a certain amount of the emanation of radium to be taken up with the air and be distributed in these rooms or cabinets where patients can breath a radio-active air. This gives an additional source from which a patient can derive the benefit of these waters.

Under natural conditions springs with the highest radio-active values are found in the neighborhood of uranium- or thorium-bearing minerals; there are, however, exceptions to this; but as the natural resources of the surrounding country are not always definitely known, the failure to detect any of these radio-active minerals in the soil of that locality must be due rather to the lack of sufficient analysis.

Radio-activity of Some of the Natural Waters of Europe.

Joachimsthal (iron spring)		600.0	m. u.
Gastein, Grabenbäckes well		155.0	"
Gastein, Elizabeth's well		133.0	"
Gastein, Chorinsky		121.0	"
Baden-Baden (salt) (Bütt)		126.0	"
Baden-Baden (salt), Murquelle		24.0	"
Landeck, Georgenquelle (sulphur)		206.0	"
Landeck, Freduchquelle (sulphur)		119.8	"
Landeck, other springs	1.7 to	53.8	"
Karlsbad	0.4 to	31.5[1]	"
Karlsbad, Muhlbrannem (alkaline)		31.5	"
Karlsbad, Vordere Schlaskbrunnen (alkaline)		17.4	"
Mergentheim (alkaline)		7.1	"
Marienbad (alkaline)[1]	0.66 to	4.57	"
Wiesbaden[1]	0.8 to	11.95	"
Homburg[1]	2.3 to	8.0	"
Kissingen[1]	2.85 to	4.3	"
Nauheim[1]	0.29 to	28.6	"
Johannisbad (temperature, 29° C.)[1]	0.24 to	4.04	"
Leplitz (temperature, 21.9 to 32.5° C.)[1]	3.13 to	6.56	"
Villach (temperature, 29° C.)[1]	0.8 to	2.0	"
Kudowa (iron)	2.0 to	22.5	"
Leukerbad (arsenic, calcium, hot)		0.26	"
Talheim (sulphur)		16.3	"
Neundorf		20.0	"
Franzensbad (mud)	2.8 to	16.0	"
Wiesbaden	0.8 to	11.95	"
Pistyan Hungary (hot, temperature, 58° C.)	1.32 to	203.0	"
Porto d'Ischia (temperature, 65° C.)		4.7	"
Ragaz-Pfäffers, Switzerland (temperature, 41° C.)		0.33	"
Naples	0.2 to	2.7	"
Lacco Ameno (Ischia) (temperature, 57° C.)	36.9 to	372.0	"
Castellamare		22.6	"
Battaglia, near Padua (temperature 72° C.)	2.5 to	4.6	"
Griesbach	3.3 to	26.0	"

When these waters are used for baths, the person must be fully immersed, having as little of the body above the level of the water as is possible for breathing; then the

[1] Several springs.

whole tub is covered with a rubber blanket and the water slightly agitated; the patient breathes the air from this water charged with radio-active gases, thus conveying some of the activity into the lungs. These radio-active substances are absorbed by the lungs, which play a very active part in the absorption and elimination. The time given for each bath varies, as a rule, from fifteen to forty-five minutes, while the temperature is governed to suit the comfort of the patient.

The water employed for local medication, such as packs, compresses, etc., is usually somewhat stronger, and may contain from 60,000 to even 90,000 Mache units per liter. These strong solutions must be made artificially, as the natural waters do not contain this high activity.

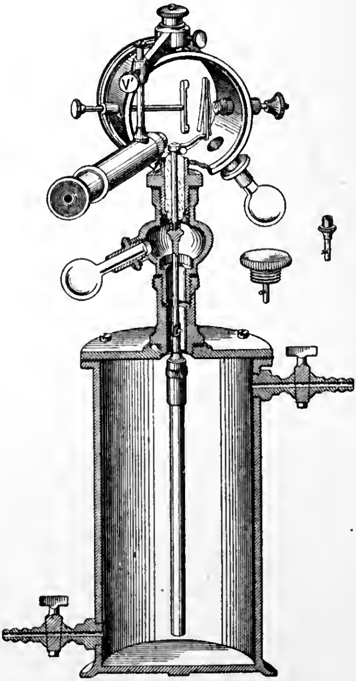
Radio-active earth and *mud* have been employed in the same manner. They have the advantage over the compresses as they retain the moisture longer, and possibly bring the radio-active material into direct contact with the tissues, which might be desirable in cases of rheumatism. In those instances where dermal irritation exists, moisture is usually to be avoided.

These preparations may be made directly from the ground powders mixed with water, and a small quantity of glycerin may be added if thought desirable. On account of the expense, where these earth compresses contain sufficient radio-active material, they may be sterilized by heat, and re-applied, provided the radio-active material is in an insoluble form.

Drinking-waters, from these natural sources, are usually of about the same activity as the water used for bathing purposes; where a higher activity is desired it is necessary to prepare them artificially to bring their strength to a sufficient standard to be of medicinal value.

Medicinal Uses.—The class of diseases in which these waters have been employed and recommended are those which have always defied the best efforts of the medical profession; their pathology is not understood and the recommendation of radio-activity is from a purely empiric standpoint.

Fig. 46



Fontactoscope. Electroscope for estimating the radio-activity of water and gases.

According to Prof. Ernst Sommer, of Zurich, these waters have been found of value in the following diseases:

1. Anemia, chlorosis, and allied blood diseases. Those waters having iron in solution will be of value, and should be taken internally, as drinking-water.

2. Arteriosclerosis. Water having sufficient quantity of emanation to lower blood-pressure should be used.

3. Bacterial infections. The water used here must be of sufficient strength to have a bactericidal action.

4. Arthritis; subacute chronic and deformans.

5. Infections of the nose and adjoining sinuses. Water is used in these infections as a douche.

6. Heart affections; myocarditis; under same conditions as No. 2.

7. Joint disease of rheumatic origin, subacute or chronic.

8. Gout, uric acid diathesis.

9. Skin diseases (eczema, psoriasis). Here the waters may be used in combination with stronger radium preparations.

10. Chronic exudative conditions, such as empyema, plastic pleurisy, perimetritis.

11. Sciatica.

12. Catarrhal conditions of the air passages.

13. Diseases of the lymphatic system; spleen; enlarged glands due to scrofula.

14. Chronic diseases of the bone.

15. Cancer of the stomach. Drinking the waters gives considerable relief and will cause patient to gain weight.

16. Chronic myocarditis.

17. Tumor.

18. Chronic neuritis.

19. To absorb the exudates of apoplexy and vicious bone unions and operative scars.

20. To aid in building up the tissues in convalescence.

21. To encourage tissue change in corpulency or diabetes.

22. Tabes dorsalis; will relieve the condition to some extent.

23. Malignant tumors will assist other means in restoring the natural condition.

24. Uterine disease; dysmenorrhea; para- and perimetritis.

A method that has been recommended in the use of these waters is peculiar and apt to be somewhat tedious. The patient is directed to sip the water every five minutes for two hours; then a rest is given, and another sipping séance. The idea seems to be to saturate the body with these charged waters slowly and evenly—in other words, saturating the body and keeping it in that condition, which can only be done by this method. The emanation which is the active portion of these waters is rapidly eliminated by the lungs. If, therefore, the same amount of water is taken at one time, in a very short time after drinking most of the activity has passed out in the expired air, and it is to overcome this rapid elimination that this sipping method of taking these waters has been recommended.

Under some conditions the use of these radio-active waters and muds seems to be contra-indicated, such as acute rheumatism complicated with erythema purpura; or acute myo- or endocarditis; gout in the acute inflammatory stage; in tuberculous disease where processes are active; certain active forms of acute specific arthritis, and conditions where there is an active suppurative process.

A factor which should be taken into consideration in the treatment of these conditions is the surroundings. It is well known that the results obtained in sanatoria and spas are most satisfactory, due undoubtedly to the rigid routine adopted in these institutions. The regularity of diet, exercise, and medical treatment, will often give relief to conditions which is quite impossible to obtain at home; therefore, when results are reported from these institutions, this point must be taken into consideration.

Where these waters and muds are to be employed in private practice, their strength should from time to time be tested. In fact, some preparations upon the market degenerate in a very short time, and only show the faintest signs of activity by the most delicate tests. Far more active preparations or radio-active muds can be easily made by simply mixing small quantities of commercial uranium oxide or the various thorium salts with a sufficient amount of kaolin and water to dilute the activity.

Reports of small epitheliomas and of lupus vulgaris successfully treated by the local application of the natural crystals of autunite have been made. It is chemically composed of uranium calcium phosphate. Applications of several hours' duration were made on several successive days and did not provoke any great amount of reaction. Considering that under these circumstances a native mineral was used, it would be difficult to state that the beneficial action was due alone to the uranium; it is possible that it contained the usual amount of radium, thorium, and allied elements, which, as a rule, are associated in nature. Reports, however, have been made where uranium salts, artificially prepared, have been used under similar circumstances.

Conclusions.—Accounts of good results from the use of these radio-active waters, muds, and earths have come from many sources, and seem to be quite satisfactory, but it must be remembered that the diseases for which we find them so highly recommended belong to a class, which, under certain peculiar conditions, often seem to undergo a most beneficial change and at the same time are particularly prone to relapse quite as unexpectedly. It might be well to suspend judgment upon the real value of these radio-active substances until their apparent value could be tested under ordinary circumstances.

CHAPTER XI.

APPLICATION IN DERMATOLOGY.

Principles Involved in Treatment—Diseases of the Hair—Keratosis—Eczema — Pruritus — Herpes Zoster — Ichthyosis — Lichen — Psoriasis — Xeroderma—Acne—Syphilis—Lupus.

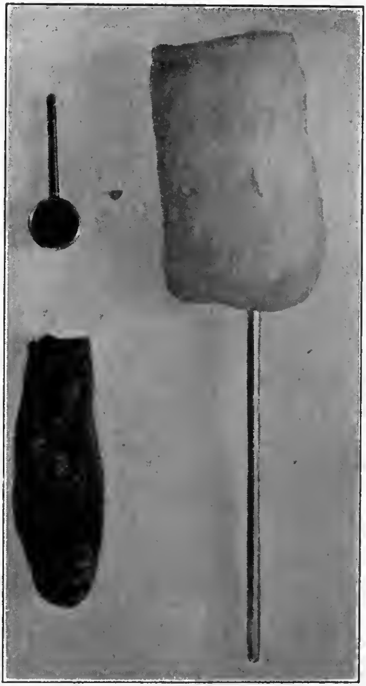
Radium has been employed as a local therapeutic agent in dermatology by such authorities as Wickham and Degras of Paris, Freund of Vienna, Bayet, Schiff, and many others, who have reported favorable results. The indications for its use are particularly those instances where other agents have absolutely failed, or where, for cosmetic reasons, other agents are liable to produce scarring and disfigurement of the surface of the skin, either from the application of the medicant, or from contracture of the scars subsequent to or in consequence of the healing of the lesion. Under such conditions, where the disease process is apt to produce an amount of fibrous tissue giving to the part an overgrowth or tumor-like formation, the absorption caused by the application of radium or thorium products causes this excess of fibrous tissue to be absorbed, leaving the tissues in a condition more or less resembling the normal structures. Under certain circumstances it may be like many other therapeutic agents, merely a matter of election, being desired only on account of its ease of employment, relieving the person affected from months of application of washes and ointments that are not desirable from the point of personal comfort, debarring the unsightliness and the actual discomfort such applications usually produce.

These radio-active salts must be used with the greatest care in all these dermal conditions, and should only be applied by one familiar with the various diseases of the skin, and having a complete knowledge of the condition and phases of the various eruptions; likewise, if conversant with dermatology before making these applications, that person must have a thorough knowledge of the activity of the individual form of application, the amount of radiation, and the length of time to be applied; otherwise the dosage will not be in conformity with the process, and failure will result in consequence.

These radio-active salts are applied in these conditions under two distinct heads, diametrically opposed to each other, yet blending so closely that it is impossible to draw the line of distinction.

First, they are applied where *stimulation* is desired. Here the dosage is extremely small, depending upon the depth and quality of the tissue. In superficial cases the radio-active salts need only a slight filter. If the varnish applicator is to be employed, a thin sheet of mica, aluminium, or waxed paper may be used, which in reality is more for the protection of the radio-active salts than a filter. Here the α-, β-, and γ-rays act together, and the exposure should be extremely short, as nearly all the energy of the radio-active salt is employed. If this stimulation is desired at any given depth, thin lead filters must be interposed between the applicator and affected part, the time of application made proportionately longer, also calculation for the loss of energy from the filter and the penetration of the tissues. Under these circumstances the β- and γ-rays are employed, the α-rays, which are the most dominant source of energy, being eliminated.

FIG. 47



Small applicator with rubber cover for protection. Large applicator surrounded by an inch and a half of gauze to cut off low radiation.

Where it is desired to absorb tissue products, the application should be more prolonged, giving rise to some reaction which secondarily causes absorption. Again, the depth of tissue must be considered, and the application and applicator arranged accordingly. As a general rule, a severe reaction is never desirable, and should always be avoided. This, however, is not always possible, due mainly to the idiosyncrasies of the individual under treatment. Where these violent forms of reaction have been induced considerable pigmentation is likely to follow, which often lasts for some time after the process has healed; if not too severe, it eventually disappears.

The action of these rays under this *second head* may be termed *astringent*, and if carried still further, pass into the *atrophic*. This gives rise to a *decongestive stage* that is desired in conditions of inflammation. The stage between, which might be termed the astringent stage, which gives rise to the decongestive stage, is only slightly past that of stimulation; while the atrophic stage is a large one and may range from such a slight degree, which really might be termed astringent, to where the atrophic condition gives rise to an actual necrosis. Just how much radiation is required from a given specimen to produce these results is a matter of experience, and still more actual experience with an individual application; and it is just in such instances that the difference between radium and mesothorium is so manifest. As pointed out before, the constant changing of the proportion of rays in mesothorium must give a different result if applied in the same manner over a series of several years, while, on the other hand, radium remains constant, and its degree does not change; therefore, when one becomes accustomed to handling an applicator made with a radium base, it would seem that its constancy would be an asset that is worth considering. This fact of evenness of radiation is more important in dermatology than in any other field, for the influences desired from these elements require the most refined technique that it is possible to develop.

Diseases of the Hair.—In most instances diseases of the hair reported in literature and those that have come under observation have been treated by the Roentgen rays. This method has, as a rule, been found most satisfactory, and no doubt the reports made of the use of radio-active salts

Fig. 48

Showing the depilatory effects of radium. Case treated for a glioma.

in the treatment of these diseases have been so satisfactory that a change in the form of treatment is not desired. This is especially marked in conditions of alopecia areata, where the use of the Roentgen rays has, in many instances, produced the desired result in a very short time.

In the treatment of alopecia areata only very mild stimulating doses should be used, the exposures short and not too frequent; but where the opposite effect is desired, radiation must be pushed either during one sitting or several; where the one-sitting method is adopted, a most rigid technique is required.

Hypertrochosis.—Hypertrochosis has been mentioned as a disease that could be benefited by radiation, and good results have been reported; but as the depilatory action of the milder form of radiation is so transient it is hardly worth the risk of the severe reaction, which may result in a scar, or in a local condition which is far worse; coarse, bristly hairs often grow and become extremely troublesome from their irregular growth, therefore radiation in any form is not to be recommended. Hypertrichosis may be treated by the electric needle, and where it is skilfully employed the result is all that could be desired.

Sycosis, favus, and the various forms of tenia trichophytin have been treated by radiation. The relief in these diseases depends upon the depilatory effect of these rays; the usual form of radiation employed for these infections of the roots of the hair was the Roentgen rays; it appears to have been most satisfactory. Many reports from all countries show its universal use, and a few have been made where the salts of radium or thorium have been used; and there is not the least reason to infer that they would not have been equally efficient. Wickham and Degras refer to its use in sycosis.

Senile keratosis and **keratosis** occur upon the face or back of the hands, often in such size and character as to be disfiguring, at times producing some discomfort; and if the irritation that has caused them continues, they often degenerate and become epitheliomatous. These local areas usually yield easily to radiation, and under these circumstances radium or mesothorium is to be desired.

Symmetrical palmar keratosis and congenital trophoneurotic dyskeratosis, allied to the former condition, have been treated by Wickham with radium filtered by 0.1 mm. of aluminium.

Angiokeratoma in a female, aged twenty-one years, was treated by the same author, and was successfully removed, leaving only a very slight scar that was scarcely visible.

Eczema.—Eczema in its various forms has been treated by these radio-active elements, and many reports have been made of its successful use. The Bayet series of 99 cases shows a complete healing in 86 and improvement in 3. The different forms reported included nearly all varieties. The chronic eczema of children occurring upon the face and about the mouth has yielded to radiation when other forms of treatment failed. In a child, aged two and a half years, the radium was applied in the form of a flat applicator 4 cm. square, which contained 160 mg. of radium-barium bromide, filtered through rubber. Two series of three treatments of five minutes each accomplished the result. Most of the cases of this class were treated by this technique. Eczema occurring upon the palms of the hands and soles of the feet, with deep cracks and fissures, causing considerable discomfort from burning, have yielded to the applications of radium, which must be powerful, and the sittings very short.

Seborrheic eczema of a refractory nature that has not responded to milder forms of treatment and other cases as non-pruriginous eczema, eczema varicosum, and eczema lichenoïdes have been treated with radium.

Acute eczema has been successfully treated, and under these circumstances these radio-active elements must be very weak, otherwise the irritation caused is likely to produce considerable discomfort. The applicators used for treatment in these cases should be large and flat, so as to cover considerable surface; usually varnished applicators without screening may be employed. Wickham mentions a case of eczema that had recurred during the summer for a number of years; numerous applications were tried without avail until treated with radium, which resulted in complete cessation of the yearly attack. The same author calls attention to the following points in the treatment of these eczematous conditions: (1) The apparatus used should be large, with powerful radio-activity; (2) make short exposures with intervals between them; (3) use weak and medium rays, without filter, or only a very thin one, except in those instances where deep infiltration exists; and (4) avoid all superadded inflammation. Attention must be given to care of the affected parts, and the general systemic condition in the same manner, as is usual in other forms of treatment where the rays have been employed. After relief of this local condition, it is important to protect the patient from future outbreaks, as, for instance, if the eczema is due to some irritant from occupation; indigestion, or similar cause, it must be corrected. The success in the treatment of these cases depends to some extent upon the care that is given to these details which are so often disregarded. It must be remembered also that the effect of radiation is purely local and will not remove the exciting cause. Neurodermatitis, a condition often associated with some of the different forms of eczema, which is extremely annoying, causing a great degree of discomfort, is likewise easily relieved, when treated with these radio-active elements.

Pruritus.—Pruritus about the anus and scrotum in the male and vulva in the female is at times intensely annoying on account of the intolerable itching, and is usually coexisting with some systemic derangement. Where the cause cannot be corrected by internal medication, and is dependent upon some neurosis, the use of radiation will be of value for local relief, and this in time will act advantageously upon the whole system. Either the radiation of the *x*-rays or one of the radio-active elements may be used. The results that follow cannot be accomplished by any other method; however, if the local condition is due to some direct cause, such as diabetes, this must be corrected, otherwise radiation will not be found practical.

Treatment in these cases should be given with a fair amount of filtration ($\frac{1}{2}$ mm. lead screen), as penetration of the tissue to some depth is desired. The result, when accomplished, seems to be fairly permanent.

Wickham and Bayet report numerous cases. The latter author concludes that in all these diseases, depending upon a localized dermal neurosis: (1) Good results from radium have been frequent; (2) they heal rapidly; (3) under some conditions where recurrence has been observed the attacks are usually milder and yield easily to a second period of radiation; (4) the rapidity and thoroughness with which these results occur is remarkable, especially in such cases as pruritus of the arms, vulva or scrotum, conditions which have always been rebellious under the best treatment.

Herpes Zoster.—While it is doubtful if the course of the disease is to any extent influenced by radiation, the local symptoms can be relieved, especially in those cases which run a protracted course; the influence aiding the restoration of the local parts relieving the burning pain which causes such distress. The subsidence of these symptoms gives a great degree of comfort, and allows the withdrawal of narcotics, in this way giving rise to a gain in strength and general systemic improvement. Good results have been reported from both forms of radiation, and at the present time it would be difficult to tell exactly which is most desirable.

In other painful conditions of the skin dependent upon some local neurosis, radiation will be found to be of value; it must be carefully applied, and fairly well filtered, deep radiation being needed to reach the nerves well below the superficial layer of the skin. If these radio-active salts are to be used, the applicators should have a large surface and be covered with high-test salts. Exposures should not be long, a few minutes on succeeding days for a series of four to ten days, when an intermission should be given of a few days to several weeks. Usually the patient feels a decided benefit after the first series of treatments, improving with each successive séance.

Zosteriform ichthyosis has been successfully treated with radium and the resultant scar was scarcely perceptible. This, as in other forms of diseases of the same character, needs applications with a fair degree of penetration.

Lichen Ruber Planus. — Lichen ruber planus is another disease resulting to some extent from a debilitated system, and while the ultimate relief depends to some extent upon the correction of the existing causes, the local condition is often materially benefited by the healing of patches and relief from the concomitant symptoms.

Psoriasis.—In this condition radium has been employed upon some of the local areas with success; application is made through thin screens of aluminium, or in some instances the bare varnished applicator has been applied to the affected area. Short, frequent applications have usually caused rebellious localized areas to yield. Where the disease is extensive and spreads over a large area, the application of the Roentgen rays may be more desirable, and equally good results have been reported by this method.

Xeroderma Pigmentosa.—Xeroderma pigmentosa, a rare disease of obscure origin, begins early in life, and is progressive, attended by pigmentation, telangiectasis, cutaneous atrophy, and tends toward malignancy, usually ending fatally. This condition has been treated but not successfully.

Acne, under ordinary circumstances does not call for radiation, and only those cases that have been refractory to other forms of treatment should be accepted. The correction of general systemic disturbance is as important where radiation is to be employed as it would be where the ordinary procedure is adopted. Therefore, if the causes of these cutaneous eruptions are corrected, there is very little likelihood of recurrence. The beneficial effect of radiation has been thought to be due to the effect of these rays upon the bacterial infection of the disease; it would seem, however, that if the rays were powerful enough to kill these germs, the cells of the affected parts would suffer also; at the same time the radiation given is usually mild and is not pushed to a degree that would likely produce such reaction. Therefore it is apparent that the benefit to the condition is due merely to the increased cellular activity, caused by the stimulation of these rays.

Acne vulgaris has been successfully treated both by the Roentgen rays and the application of these radio-active salts. Where either form of radiation is used the dosage must be mild and penetration moderate; usually heavy aluminium, or $\frac{1}{4}$ to $\frac{1}{2}$ mm. of lead foil. A number of successive treatments should be given at stated intervals. Where the Roentgen rays are employed, the greatest care must be observed to prevent burns; the scarring in this event is often worse than the previous existing condition.

Where deep pits with numerous small keloids exist as the result of large pustules, treatment adopted for their relief must be considered individually. Under such circumstances radium is best employed, as it can more easily be placed over these small areas and the amount of radiation governed entirely by the amount of redundant tissue. Rhinophyma, hypertrophic acne, and acne rosacea, the effects of the later stages of this disease, may be generally benefited by the action of either the Roentgen rays or these radio-active salts. The treatment in this condition is somewhat different from that of the preceding. In administering the radiation it must be given with the intent of producing contraction of the tissue; thereby causing an absorption of the excess of fibrous tissue and a lessening of the vascular supply. The dosage must not be pushed to the extent of causing intense reaction, otherwise ulceration and scarring will result. A reaction of mild degree is, however, necessary, and when once established, should be allowed to subside before further treatment is instigated. By several successive series of applications, contraction of the tissues can be established.

Syphilis.—The conditions of this disease usually placed under treatment have in most instances been mistakes of diagnosis; large gummatous conditions will, in the great majority of cases, yield to the influence of radiation; and not until they have recurred, either at the local site or distant parts, is the true character of the disease recognized. Treatment has usually been established upon the theory that the disease was of a malignant nature, or possibly that of lupus. The instigation of the proper form of treatment will usually prove the error. There are, however, conditions of syphilis which will be materially benefited by radiation; and these conditions are where the ulceration has taken a very low, indolent form, with no tendency to regeneration; or where this ulceration has been of years' standing and has taken the form of a malignant degeneration. Under these circumstances the amount of radiation must be in proportion to the depth of tissue involved, which is, as a rule, considerable; therefore, fairly penetrating rays are to be desired. Screens of about ½ mm. of lead will be found necessary. Radium of fairly high activity should be employed. In conjunction the usual antisyphilitic treatment should be given and continued, as it would be under ordinary circumstances. The effect of radiation is purely local.

Lupus Vulgaris.—Lupus vulgaris is a tuberculous affection of the skin, characterized as a cellular overgrowth and infiltrations terminating in ulceration. The degree of infection and the amount of invasion to a great extent determine the form of treatment to be employed. Recurrence under any form of treatment is to be expected, but careful guarding against extension of the process will, to a great extent, prevent the extensive tissue destruction that is so usual in these cases. In the milder forms of this disease treatment by the Finsen light may be employed where it is desirable, but the length of time and the trouble in making the application deter many from making use of this method; at the same time the results from the Roentgen or radium rays, with shorter periods of application, are just as efficient and are cosmetically equal. In the later stages of this disease the Finsen light is of no value, and therefore the other methods of radiation must be employed. The ultraviolet ray given off by the Finsen light has very little power of tissue penetration and, in those cases where it is employed, pressure must be made over the site of disease to press out the unnecessary blood supply; a quartz lens being employed for this purpose. These rays will penetrate quartz and are blocked by ordinary glass. The comparison of other low rays is rather interesting, as the degree of penetration existing between them is not to be regarded in proportion to the thickness of the article that is supposed to block them.

In the treatment of lupus vulgaris, where the ulceration has caused extensive destruction of the skin with infiltration of fibrous tissue, several conditions must be carefully avoided. The scar tissue which has formed where the ulceration has previously existed is of low grade and lacks vitality. If radiation is pushed with much vigor it is apt to break down, whereas in other portions, where the overgrowth has been excessive, giving rise to considerable thickening, absorption is desired. In those cases where the skin naturally possesses a high degree of pigmentation, as in the colored race, radiation must be employed carefully; otherwise the pigment will be removed, giving an unsightly appearance should the disease exist upon exposed parts. At times the accident is unavoidable. Warning should always be given upon this point before adopting measures for treatment. Wichman, of Hamburg, has devoted considerable study to the treatment of lupus with radium, and reports a series of 30 cases to show the liability to recurrence. Of the 23 that have been treated:

4 patients remained free from recurrence for four years.
8 patients remained free from recurrence for three years.
6 patients remained free from recurrence for two years.
4 patients remained free from recurrence for 1 year.

The majority of these cases had been previously treated by other methods, and represented all stages of the disease.

Localized tuberculous ulcerations, usually caused by direct infection, have been treated with radium and Roentgen rays. The methods adopted are exactly the same as in deep infections of the skin from other diseases. As these local tuberculous ulcerations are likely to cause infection of the deeper structures of the body, care must be exercised after healing the local condition lest the patient develop a general tuberculous infection.

Lupus Verrucosus.—Wickham (*Radium Therapy*) advises that where this condition exists the wart-like growth be removed by electrocautery and followed by applications of radium to the base of the ulcers caused by the removal of the growth.

Lupus erythematosus has been most refractory to all forms of treatment previously recommended, and where radium has been properly employed good results followed. The applications must be made with fairly strong radium; the area of radiation must extend well beyond the defined line of disease.

CHAPTER XII.

APPLICATION IN OPHTHALMOLOGY.

Action upon Inflammatory Conditions—Tuberculous Infections—Trachoma—Spring Catarrh—Glaucoma—Keloids—Scars upon the Lids, and Other Local Conditions.

Inflammatory Reaction.—Radium has been employed in the treatment of small epitheliomas upon the skin or mucous membrane occurring about the orbit, and if properly applied there is practically no danger of injuring the contents of the eyeball. The slight erythema produced as reaction often causes the soft tissue in and about the orbit to swell to an alarming degree; this, however, subsides rapidly, leaving the structure in a perfectly normal condition. This amount of reaction is rarely observed in other portions of the face from the same dosage; and while these ulcerations often heal with very little reaction, they are more likely to recur. The treatment of tumors such as small warts and papillomata in this region does not differ from that in other portions of the body; only where it is possible the sensitive portions of the eye should be carefully guarded against all unnecessary reaction.

The treatment of tuberculous infections of the eye has been studied from an experimental stand-point, but so far no practical deductions have been made that would be of clinical value; the fact that radiation retards the growth of bacteria would suggest that it might prove useful in these tuberculous infections. Lupus vulgaris about the eyelids has been successfully treated.

Trachoma.—Trachoma has been treated by the application of both radium and mesothorium with varying results by a number of authorities. In some instances it has been of the greatest value in causing a subsidence of the inflammation, absorption of the granulations, and even the clearing of a pannus where it existed. From other sources, the reports have not been so enthusiastic; some even stating that very little improvement could be noticed after the applications, and that where pannus existed, no improvement could be expected.

The applications were made by everting the eyelids and holding them in position with the fingers or some instrument, keeping them moist, when necessary, with a little salt solution, then placing the applicator in position and allowing it to remain for five or ten minutes at each sitting. The amount of radium or mesothorium employed was from 1 to 10 mg., and usually about a dozen applications were made. These applicators were not filtered; the salts were simply encased in thin glass tubes, therefore the β- and γ-radiations were employed. Care was taken not to expose the eyeball too long at any one angle. Some remarkable results have been seen in the treatment of this disease with the Roentgen rays; they are, however, by no means constant.

Spring Catarrh.—Spring catarrh has been treated by radium and results have been reported to the effect that it did not recur; however, the disease has naturally an irregular course, and in many instances, where this form of treatment has been most skilfully employed, it seemed to have very little influence upon it. A case reported by Turner, of Edinburgh (*Radium Therapy*, London), is of interest. The illustrations of the article show marked improvement in the condition of the healed eye. A capsule of 10 mg. radium bromide was employed over the eyelid for ten minutes every day. Later one containing 1 mg. was substituted on account of the first applicator being in use and the irregular attendance of the boy. The improvement occurred in about six weeks, during which time he received 32.5 mg. hours.

Vicious Scars or Keloids.—Vicious scars or keloids occurring in or near the eye should be treated exactly the same as when occurring in other parts of the body and likewise the same results are to be expected. It is not uncommon to find a hard, unyielding mass of fibrous tissue distorting the softer structure shrink and leave the surface soft and pliable.

Glaucoma.—Glaucoma has been treated by Wickham (*Radium Therapy*), and in the case mentioned the result was only temporary. The technique used was interesting: He applied the radium over the temporal and superciliary regions only, and interposed between the radium and the skin a rubber sheet of 1½ mm. thickness to avoid secondary radiation.

Keratitis, ulcers of the cornea, episclerosis, chalazions, hypopyon have been included in the list of the diseases treated, and very good results have been reported of the relief obtained from radiation in bad cases of pterygium. Many experimental studies have been made upon the eyes of living animals, causing ulcers, inflammatory reaction in in the cornea, iris and changes subsequent thereto, but from a practical stand-point very little has been gained.

Radio-active salts cause a peculiar luminescence of the eyeball, which is perceived to some extent in persons who are blind from opacities of the cornea or vitreous, but free from diseases of the nerve. The cause of this is unknown, but for some time it was thought possibly it would give a method to the blind whereby they could see under these conditions, and while it remains of physiological interest, nothing of practical value can be developed from this rather curious phenomenon.

CHAPTER XIII.

APPLICATION IN DISEASES OF THE EAR, NOSE, AND MOUTH.

Inflammatory Diseases—Deafness—Tinnitus Aurium—Nasal Polypi—Diseases of the Mucous Membrane — Caries — Pyorrhea — Malignant Diseases.

At times the application of either radium or mesothorium will be found to be valuable in certain inflammatory diseases of the ear; and the relief from tinnitus aurium, with improvement in the hearing, has been reported; instances depending upon some sclerotic change or where a suppurative process exists may be altered and benefited to a marked degree. Hagel[1] reports a series of 16 cases with decided improvement in about one-half; all but 2 cases were benefited; their ages ranged from six to sixty-nine years. Applications were usually made back of the ear in several very short treatments, from one-half minute to ten minutes, every few days, with an intermission of several weeks or months; the amount of radium or mesothorium employed being about 5 mg. without filter. At other times the emanation of radium was used by inhalation and baths.

Polypi of the nasal tract or those that occur in the external auditory meatus may be treated with radium, and a number of interesting cases have been reported where they have been successfully removed from the larynx and trachea.

[1] Münch. med. Woch., September, 1913.

Different forms of applicators have been devised to carry the capsule containing the radio-active element directly to the part, and where this is possible the effects are rendered more certain and there is less likelihood of disturbing the surrounding tissue. Where, however, this is not possible a series of exposures by the "cross-fire" method will doubtless accomplish the result.

The absorption of fibrous tissue is one of the most marked features of these radio-active elements and Kantas[1] reports a case of tracheal stenosis that was completely absorbed by the use of radium.

Psoriasis occurring upon the mucous membrane of the mouth has been treated by Wameknos[2] with success, and he has also found it to be of value in pyorrhea alveolaris. In the treatment of most of these cases he employed a strong solution of the emanation which was held in the mouth or sprayed upon the diseased parts. At times, where it was possible, he employed an apparatus that would carry the emanation in air into the buccal cavity. The principal object is to allow the emanation to be in contact with the part as long as possible for its action upon the pus-forming organism.

In some cases of dental caries the employment of cocoa butter charged with the emanation will be found useful.

Malignant diseases of these cavities often gain headway to such an extent before being recognized that an operative procedure, from a surgical stand-point, would not insure any permanent relief. These cases are strictly to be included in the field of radiation. Under some circumstances the Roentgen rays may be selected, but in those

[1] Wiener. med. Woch., 1912, p. 1190.
[2] Berl. klin. Woch., June, 1913.

instances where it cannot be brought in direct contact with the disease, it will be found to yield sooner and with more certainty to the effects of these radio-active salts. The technique employed in the treatment of these tumors will be considered under their respective classes. Tuberculous ulcerations of the mucus of the mouth and nasal cavities yield to radiation from the Roentgen rays as readily as they do to these radio-active elements; therefore the choice is merely a matter of convenience. The proper diagnosis of this condition is, however, at times most difficult as it so closely resembles syphilis and malignancy. The error often leads to considerable embarrassment and disappointment in the ultimate results.

CHAPTER XIV.

APPLICATION IN DISEASES OF THE GENITO-URINARY SYSTEM.

Cystitis—Sexual Neurasthenia—Inflamed Prostates—Enlarged Prostates—Chronic Urethritis—Venereal Warts—Tumors—Malignant Diseases.

In diseases of the genito-urinary system radio-activity has been employed locally for its effect upon inflammatory conditions and their products, tumors, malignant disease, and in the aged for enlarged prostates. The local application in sexual neurasthenia seems to have afforded some relief, doubtless due to the action upon the often inflamed prostate and neck of the bladder. Usually in these cases the local treatment is accompanied by the use of radio-active waters taken internally and also as baths. The internal administration may prove useful in cystitis and allied conditions of inflammation. Even when it is accompanied with a mild albuminuria, it will clear the urine of both mucus and pus by the action of the emanation, which under these circumstances acts as a urinary antiseptic.

The usual method adopted in these cases is the drinking of large quantities of water containing the emanation of radium (best taken by continued sipping), as by this method the system is continually saturated with the emanation, while if taken rapidly in three-, four-, or five-glassful doses daily, shortly after the water has reached the stomach the greater part of the emanation will be eliminated by the lungs.

Under the same form of treatment cases of pyelitis, pyelonephritis, and interstitial nephritis will also be decidedly benefited. In gout, where radio-active waters are employed they should not contain as high a percentage of emanations as those in the inflammatory disease. It should be understood that large amounts of water must be taken into the system to act as a flush, and by its diuretic action upon the kidneys give rise to free elimination which will relieve these conditions.

In conditions of sexual neurasthenia these waters are usually employed as local injections into the rectum and bladder; this should be accompanied by sitz-baths, and certain amounts should be taken internally by the mouth. Waters containing a high charge of emanation should be used. A number of reports have been made of great improvement in these cases, although it must be realized that in a condition such as this the psychical element no doubt plays an important role. Possibly the routine adopted in the treatment of these cases accounts to some extent for their improvement. Where inflammation of the prostate or neck of the bladder actually exists, the application of radium locally, in strength enough to produce a slight reaction, will be found helpful in aiding the parts to regain their natural tone.

Enlargement of the prostate in old men, with the condition attending upon it, can often be relieved by the local application of radium. Desnos[1] reports a series of 46 cases in which 13 were absolutely relieved of all their distressing symptoms of painful and frequent micturition, with improvement in the urine and considerable shrinking of the prostate gland. The applications were made through

[1] Bull. Med., No. 95.

the urethra, also through the rectum; but no mention was made of application through the perineum. The amount of radium power employed was from 10 to 50 mg.; the time of application varying from twenty minutes to two hours. The applicators were protected by filters so as to eliminate the low β- and γ-rays and no untoward symptoms followed the applications.

In obstinate cases where the applications to the prostate through the urethra and the rectum cause disturbing symptoms, there is no reason why applications over the pubis and perineum should not be made, as it gives another line of cross-fire which under conditions such as chronic prostatitis should be employed, as further local inflammation will certainly add to the distress and discomfort of the individual; therefore, all means should be taken to strictly guard against it. Some reports have been made where benefit was derived from the application of the bath and the drinking of emanation waters.

Chronic Urethritis.—Chronic urethritis due to vegetations along the urinary tract have been treated with fair results from the local application of radium, not necessarily placed upon the spot, but by cross-fire methods from without. Here, as in other places, the low rays of radium are not desirable on account of their irritation, which should be avoided.

Warts and external vegetations, especially in women, from old gonorrheal discharges that show a tendency to recur after other forms of treatment, may be benefited and permanently healed by radiation.

Benign tumors of the bladder have been treated with radioactive salts either from within through a cystoscope, making the applications direct, or, in those cases where operations have been performed, through the opening of the wound, which, while it aids in being able to follow the process, is by no means necessary. Many tumors of the bladder have been treated from without by applying the radio-active element upon different places near the bladder, always directing the rays by cutting off the lines of radiation that are not desired, filtering with heavy lead, frequently changing the position of the element; and by always keeping the line directly upon the tumors it is possible to completely absorb the undesirable tissue without harm to the surrounding structures. Papillomas are the most usual benign growth occurring in the bladder near the neck.

Carcinoma of the prostate occurring in 15 cases was treated by Pasteau and Degrais.[1] The relief was a subsidence of hematuria in some, while in others the disease was to a considerable extent improved; even the surrounding lymphatic glands became smaller from the effects of the treatment. The capsule containing the radium was introduced into the bladder, the rectum, and in some cases through a perineal wound. Treatment occupied from three to four hours, a few days apart; five or six sittings were given, followed by one month of intermission. They particularly mention that radium should never be introduced into an empty bladder. As the results from the regular operative procedure have been so poor in this disease, this method is believed by these authors to be a decided advance.

Carcinoma of the bladder that has reached the stage where operative interference can no longer be regarded as a proper procedure may often be relieved by the use of radio-active waters applied locally. It will be found that the pain will

[1] Jour. d'Urol., Paris, September, 1913.

be decidedly lessened as will the bleeding. This also allows to some extent a recuperation of vitality.[1]

Fibrous scars of penis and stricture of the urethra have been treated and benefited by softening of the fibrous tissues. The condition existing here resembles to some extent keloids existing in other parts of the body and should be treated in exactly the same manner.

Fibroma of the Penis.—A rather unusual condition was treated by Pinch.[2] The patient, fifty-six years of age, developed a small tumor 1 by 0.5 cm. on the dorsum of the penis behind the corona. It was painful at times and caused him considerable annoyance. Radium treatment reduced it to the size of a small shot and since that time it has not troubled him.

The second case, fifty-one years of age, developed a tumor about the size of a walnut at the root of the penis, situated in the corpus spongiosum; it was of about nine months' duration and was not painful, but caused a slight retraction of the organ. Four treatments of six hours for three consecutive days were given at intervals of six weeks, of 30 mg. of radium bromide screened by 2 mm. of lead, fixed at right angles over the tumor. This, like the first, diminished until it became the size of a pea, when it gave no further trouble. Both cases were impotent while the tumor existed.

Carcinoma of the testicle and carcinoma of the penis have been reported treated by radiation, but results have not been encouraging; the disease in this locality seems to possess a marked tendency toward rapid metastasis with rapid extension.

[1] Löwenthal, Grundriss der Rad. und Thor., Wiesbaden.
[2] London Radium Institute Report, 1913.

CHAPTER XV.

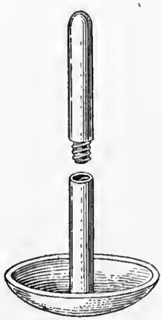
APPLICATION IN GYNECOLOGY

Method of Application—External Vegetations—Urethritis—Vaginitis—Metritis—Fibroid Tumors—Malignant Diseases.

The application of radio-activity in diseases of women must be considered from two stand-points: those where radiation can be administered from without and the others where internal applications are necessary. Conditions requiring applications upon the external surfaces do not differ from those of other parts of the body, but where internal applications are to be made, a variety of instruments have been devised to carry and hold the radio-active capsule in the bladder, uterus, vagina or rectum; and when such instruments are employed, aside from observing the natural surgical precautions adopted for their introduction and retention, the activity of the element must likewise be considered, lest processes of an undesirable nature result.

Radium or any other radio-active salt need rarely be introduced into the body of the uterus; usually as much can be accomplished by other means, from without, by applying the radio-active salt in different positions, so that the rays cross at the exact spot where radiation is desired, thus avoiding internal applications and the complications that are likely to arise from accidents subsequent to its use. Under certain conditions internal applications are necessary and for this purpose small capsules may be introduced, having a string attached for their removal. After placing the capsule in the desired position it can be held in plaee by packing with gauze or cotton wool. Certain forms of stem pessaries have been made to hold these capsules in position, but they are rarely neeessary; and in eases that tend to bleed easily they are apt to provoke alarming hemorrhages. The same eondition pertains to the use of a uterine sound so adjusted as to earry upon the distal end the eapsule of radium. If retained within the body of the uterus for any length of time the movement of the body in eoughing and breathing, as well as the voluntary movements where extensive diseases exist, are liable to produce not only severe hemorrhage but perforation.

Fig. 49



Uterine pessary, opens so the small tube of radium ean be plaeed in the upper end.

External vegetations, obstinate to other methods, may be treated by the application of radium. The wart-like exeresеence may be removed by the knife, eautery or caustics, and the applieation of radiation made to the base of the ulcer left after one of these procedures. This saves to some extent the amount of time used in radiating the surfaces enough to cause absorption; where it is desirable, however, the masses can be treated by radium alone and depend entirely upon the radio-activity for their removal. Radium should be applied with a filter of about $\frac{1}{4}$ mm. lead and the part radiated enough to cause some reaction.

Chronic urethritis is usually due to deep infection of the urethral gland or small wart-like growths along this passage. Application of radium in sufficient strength and time to produce a rather severe reaction has greatly benefited some of these cases. Wickham recommends a number of short applications made the same day, with intervals of one day. Reports have not been published upon this subject and therefore the proper technique cannot be considered.

Metritis.—Metritis of the catarrhal type has been successfully treated by the internal application of radium. Wickham uses a stem pessary where the distal end, for a distance of two inches, is covered with a radium varnish; the strength of the varnish differs and they are used to suit the requirements of the individual case. A series of cases was treated with varying degree of inflammatory disturbance and all were more or less benefited; some were markedly improved. As the inflammation subsided the uterus became smaller, discharged less, and where a tendency to bleeding existed it was also relieved. In some severe types a pessary was used where the stem contained 90 mg. of radium salt protected by 0.03 mm. aluminium foil and several sheets of rubber. The lower end was protected by 0.1 mm. of lead foil. Applications made with this strength of radium were of five to twenty minutes duration every other day. Where it was left for a longer time lead or silver filters, from 0.1 to 0.5 mm., were used, and the interval between treatments was increased at the same time.

Fibroma.—Radium in the treatment of these tumors may either control the bleeding, with only a slight reduction in the size of the tumor, or cause the tumor with its concomitant symptoms to disappear entirely. A few cases fail to react at all. It must also be remembered that radiation from the *x*-ray has also produced these results; therefore too much credit must not be given to these radio-active elements. In fact many authors believe that the former mode of radiation is superior and that an extremely high degree of Roentgen technique has been attained in this field. Where radium is to be employed it may be used internally, externally, and combined; the advantage seems to be with the last method. In some instances the application of the Roentgen rays has been combined with radium, thereby giving the advantage of both forms of radiation.

In selecting these cases for treatment a correct diagnosis is most important; ovarian cysts and tumors of a malignant nature must be excluded. The cases responding best to radiation are those that grow slowly; the rapid type rarely respond; those in later life yield better than those appearing early; Pinch[1] reports a young woman of twenty-six years with a fibroid the size of a three-months pregnant uterus; the cervix was hypertrophied, elongated, and edematous. For three years she had suffered from dysmenorrhea and menorrhagia, which had steadily increased in severity; curettement had been performed about one year previous with some relief, but the symptoms gradually increased and hysterectomy was advised. Two series of five treatments, about six weeks apart, were given with 100 mg. of radium screened with 2 mm. of lead; the effects of which caused the next menstrual flow to be decidedly less.

[1] Rep. Radium Inst., London.

Oudin and Verchère[1] treated cases of fibroma by placing in the uterus a capsule of 27 mg. of radium bromide in a glass tube surrounded by an aluminium capsule; decided benefit resulted from these applications.

Malignant disease of the female genital organs may be regarded as one field where radium and thorium have been more efficient than any other form of treatment. While the results have by no means been ideal, a certain number of hopeless cases have been restored to health for at least a temporary period. These results have been for the most part cases that had passed the operative stage. At present early and thorough surgical operation should be advised for all these malignant conditions occurring in this region as would be customary in other fields of disease. The idiosyncrasies toward radiation are too numerous to risk valuable time. Postoperative radiation certainly can do no harm, and here, as in other fields, it is only a matter of time before it is universally adopted. When the case has passed beyond the stage of operation, the earlier radiation is employed the better the chances for recovery.

Carcinoma of the Uterus.—Cases of uterine cancer occurring about the cervix, as a rule, do better than those occurring in the body. Pinch has summed up the situation as follows:

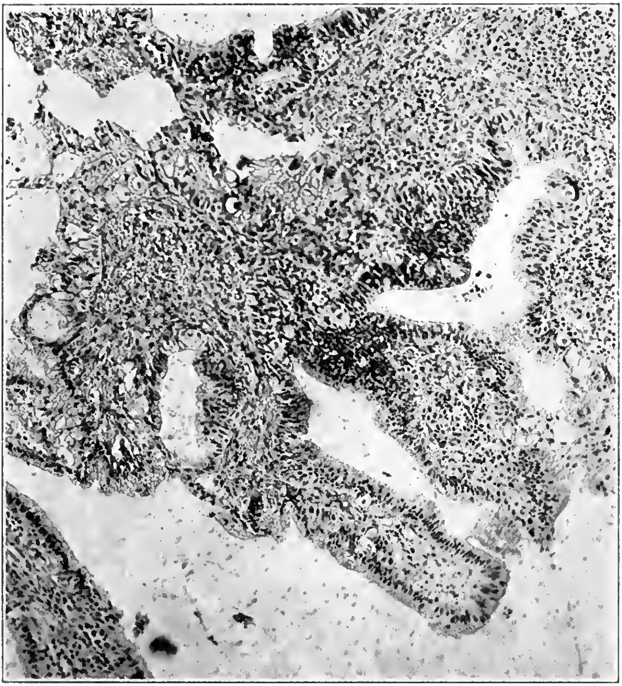
"In cases of inoperable malignant disease in this situation radium will often bring about results which cannot be obtained by any other known method of treatment. Hemorrhage is arrested, the discharge is diminished in amount and rendered inoffensive in character; the ulceration is healed, and the pain is greatly relieved.

"The rate of growth is checked, sometimes completely arrested, and the surrounding infiltration and induration are

[1] Bull. Méd., 1906.

so much lessened that in but few instances cases previously declared to be inoperable have failed to become operable.

Fig. 50



Section of scar tissue from a case of adenocarcinoma of uterus. One year after beginning treatment. Notice the evidence of carcinoma, although the woman appears to be in perfect health. (Records of the American Oncologic Hospital.)

"The action of radium is, however, only local and though it may and often does check the rate of growth, yet in most cases dissemination will sooner or later occur and the disease spread to parts beyond the effective range of radium."

The amount of radium used in the treatment of these cases is from 50 to 100 mg., screened with 2 mm. of lead and 3 mm. of rubber. Exposures should be prolonged, lasting from thirty to sixty hours, spread over a period of from five to ten days, and repeated at intervals of about six weeks. However, some cases will respond to extremely small amounts of radium. The following case was treated with only 1 mg. radium, used in an aluminium applicator covered by a glass tube:

Mrs. M. S., aged fifty-four years; school matron by occupation; came under observation April 28, 1908. Family history was negative. She was the mother of four children; the first was stillborn; second labor was twins; she then had a miscarriage, and last a normal birth. Menses were always profuse, but never menstruated after her last labor, which occurred when she was thirty-four years of age. She suffered from an abscess of her left breast with every child, although her children could always depend upon the right breast for nourishment. Her general health was good until about a year previous, when a sero-bloody discharge from the vulva was noticed. She consulted her physician and operation was advised. A few months later she consulted another physician, who took her to one of our hospitals and at this time operation was not deemed advisable on account of the extensive pelvic involvement. Local treatments were then given for some months, but as conditions did not improve radium was advised. Local examination at the time showed an old laceration of the perineum with a rectocele; the anterior vaginal wall did not descend; the uterus was small and in good position; the lower part was fixed, with thickening toward the bladder; cervix thin, with a large cup-shaped ulcer; the right broad ligament was negative, while the left was much thickened and there was a general induration of the upper vaginal walls. Bleeding was quite free after the examination and the inguinal glands on both sides were large and tender. Histological examination made by Dr. John M. Swan of a specimen removed from the ulcerated area showed it to be an epithelioma of a squamous type of cell.

Applications of radium were given three times a week, each treatment lasting for one hour.

In a few weeks there was a general improvement in all symptoms; there was less pain, the discharge was not so offensive and contained less blood. It might be stated here that the douching was continued. Local examinations were made at stated intervals and very little improvement was noted, although her general health was much improved; this woman continued uninterruptedly her work.

By the end of July both general and local symptoms had improved to such an extent that the patient decided to leave the city for her vacation. In six weeks she returned, complaining of pain as well as hemorrhages. Local examination showed about the same conditions as before, except there seemed to be more encroachment upon the posterior vaginal wall. Routine treatment was again adopted with the same general and local improvement, which continued until the following summer, when the patient decided to visit riends in a neighboring city. Her vacation was limited, for at the end of two weeks a recurrence of hemorrhage caused her to return home for further treatment. The following summer no vacation was taken, nor did she return to her position in the fall. About this time she developed a markedgeneral cachexia, while the local condition remained stationary.

Early in October the patient's stomach became rebellious and could not be controlled; the urine was choked with albumin, possibly due to a nephritis; delirium followed and within ten days she died.

This case seemed more or less remarkable because of her arduous labors for two years and six months from the time she was known to have an inoperable cancer of the cervix. At the same time she was spared all the miseries that usually accompany this disease, the cause of death being a toxemia, the same as observed in cases of similar disease when treated by the *x*-ray, where the local conditions are greatly improved but where there is a general sapping of the system from some unknown cause.

The local condition at the time of her death showed very little malignant disease; unfortunately postmortem examination was refused.

Carcinoma of the vagina responds to the use of radium in a large proportion of cases, possibly for the reason that the radio-active salts can be brought in closer proximity with the disease, or the condition can be followed with a greater degree of accuracy. A number of instances of great improvement have been reported. The following is an example:

Miss B., aged fifty-one years; factory worker. Previous history contains nothing of interest. About three months before coming under observation she experienced considerable uneasiness in the pelvis accompanied with some distress when passing urine, and some vaginal discharge, these symptoms gradually increasing until about a month ago. She visited another hospital, where vaginal examination disclosed a mass about the size of a hen's egg in the left vesico-uterine space. The mass seemed to be slightly movable with the surrounding structures, but otherwise was fixed and tender, but not painful. Cystoscopic examination disclosed an excavated ulceration, about the size of a silver quarter, in the left side of the bladder, corresponding in location with the mass. At the time of her admission to the Oncologic Hospital the growth had extended considerably and ulcerated into the vagina as well as the bladder. The patient was extremely weak and practically bedridden, with a temperature ranging from subnormal to 101° F.; most of the time from 99° to 100° F. She had a very foul vaginal discharge and painful micturition, and was taking about ½ gr. of morphia several times a day for relief. She was then treated with radium (11 mg.), filtered only by about ½ mm. of aluminium and a glass tube; treatments were given every other day for an hour until she had received 18; this was followed by 8 two-hour treatments under the same conditions. Fourteen weeks after her admission to the institution she was able to leave and return to her home. Ulceration had healed and there only remained a small nodule about the size of a hickory nut; all symptoms had disappeared.

Carcinoma developing from the ovary or in the ligaments has been treated by radiation; the results are about the same as malignant disease occurring in other portions of the abdomen. Carcinoma involving the bladder in the female is usually from extension of disease from the neighboring parts, and is rarely primary.

Epithelioma of the vulva responds to the use of radium, with a fair chance of ultimate cure, if the disease has not been allowed to progress too far. Involvement of the inguinal glands lessens the chances, as it is probable that the pelvic glands are also involved. The disease usually begins near the mucocutaneous junction and simulates the condition when it develops upon the lip in its tendency toward metastasis. If some operative procedure has been performed, postoperative radiation to lessen the chances of recurrence should be used. Under such conditions the Roentgen rays will be found of most value.

Sarcoma.—Sarcoma is seen occasionally in the female pelvis and here as in other portions of the body may run an extremely rapid course, or grow so slowly as not to cause suspicion as to its exact nature. Treatment by radiation is not dependable in all cases, but occasionally brilliant results are seen.

CHAPTER XVI.

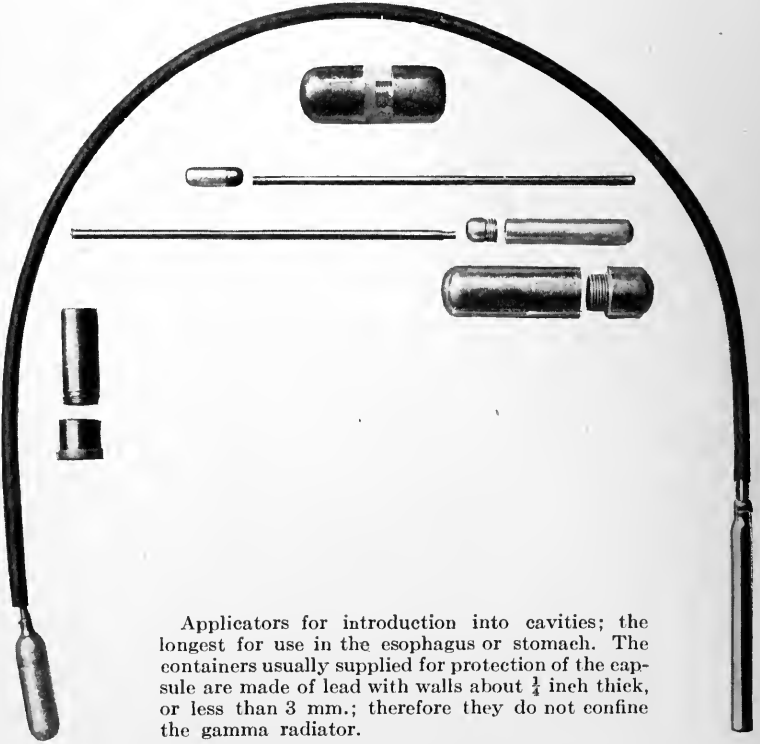
APPLICATION IN EPITHELIOMATA AND CARCINOMATA.

Consideration for Selection of Cases—Comparison of Published Lists—Epithelioma of the Face, Lip, Mouth, Pharynx, Larynx, and Hands—From Roentgen-ray Burns and Degenerated Scar Tissue—Carcinoma of the Stomach, Rectum, Intestinal Tract, Liver, Gall-bladder, Pancreas, Breast, and Thyroid.

When and under what condition radiation should be applied to malignant diseases is a difficult question to decide, and from numerous instances of recovery reported by competent observers, under circumstances that appeared to be hopeless, it would seem that there is no limit, and so long as the patient has vitality to breathe, the benefit of the doubt should be given and the application made. There are, however, more or less distinct limitations which, while not defined, are of value in the selection of cases for treatment and the prognosis as to the amount of relief to be expected or ultimate subsidence of the process.

Malignant processes that are inclined to remain localized and of a slow course, usually yield to the influence of radiation, and if the disease has not advanced too far are as a rule likely to remain quiescent for years. The slower the process the more rapid the resolution. When, however, they have advanced to the extent that the surrounding tissue has suffered materially, or upon subsidence of the mass the ulcer that is left has not vitality enough to produce sufficient granulation tissue to bridge over the damage done by the growing process, the same or similar diseases soon develop in the ulcerated portion, leaving the individual

Fig. 51



Applicators for introduction into cavities; the longest for use in the esophagus or stomach. The containers usually supplied for protection of the capsule are made of lead with walls about $\frac{1}{4}$ inch thick, or less than 3 mm.; therefore they do not confine the gamma radiator.

in practically the same condition as before treatment. Extensive ulceration need not necessarily mean a gloomy prognosis, as even in recurrent diseases with ulceration, yet having a good supporting base, it is quite often observed that the ulcer and malignant process will yield and leave the surface of the skin with the same appearance as before this recurrence; even in some instances showing the operative scar with stitch marks. At times large tumors with the overlying integument inflamed, broken down, and necrotic from pressure, will undergo exactly the same regeneration, so that upon disappearance of the tumor there is practically nothing to be observed.

The forms of malignant diseases that are rarely benefited to a great extent by radiation are those that tend to a rapid metastasis; even when treatment is applied early in these cases it appears to be of very little value. While the local condition may yield to the influence of the rays, the likelihood of its rapid recurrence in some other portion of the body is to be expected. Under these circumstances treatment often relieves the local process, causing a subsidence of suffering, with less mental anxiety, and perhaps to some extent prolongs life; and in many instances where the local manifestation heals, it saves the sufferers a wound that is often repulsive.

The *application of radiation* to these cases of *malignant disease* must be *made carefully,* for it is possible under some circumstances to irritate a slow-growing process and cause it to grow more rapidly, thus changing an inactive condition into one of rapid proliferation; or where a low-grade application of activity is applied over a long period, *producing stimulation* instead of *atrophy,* it is possible to cause an entirely new malignant process to replace the older form. This has been reported on several occasions where sarcomas have been treated for a long period and the radiation has caused a proliferation of the epithelium, giving rise to carcinoma of greater malignancy than the sarcoma.

If, however, the radiation has been pushed to the other extreme, it is possible to produce an ulceration that fails to heal, leaving a focus of irritation for malignant degeneration. The prognosis as to the benefit of radiation upon individual cases of malignancy must be determined entirely by clinical observation. The histology of the disease, failing to give any enlightenment for the cellular formation of these processes, seems to have very little significance, and is often contradictory.

The following lists from several sources will prove interesting; they have been selected for the reason that it is believed they are unbiased, and the knowledge gained from them will give an understanding of ultimate results; whereas a compilation of cases from literature reporting only beneficial results is likely to be misleading:

Beckel[1] reports a list of 54 cases taken in all stages of disease:

	Total.	Improved.
Larynx	2	
Tonsils and pharynx	2	1
Arm	1	
Uterus	9	1
Pancreas	2	
Breast, primary	4	2
Breast, secondary	10	3
Cheek	1	1
Lip	1	
Parotid	2	1
Rectum	7	1
Colon and mesentery	3	1
Esophagus	3	
Stomach	3	
Urethra	1	
Ovary	3	
	54	11

The following list published by Mr. Pinch[2] is most complete and is of unusual importance, having been taken from an article written in a most conservative manner.

[1] Modern Radium and Thorium Therapie, Berlin, 1913.
[2] Brit. Med. Jour., 1913.

Diseases.	Examined but not treated.	Recently treated but results not yet noted.	Received prophylactic irradiation only.	Apparently cured.	Cured.	Improved.	Not improved.	Abandoned treatment.	Dead.	Total.
Carcinomata, squamous-celled epitheliomata, buccal, lingual and pharyngeal mucous membranes	6	3	18	..	..	10	15	9	9	60
Larynx	2	1	..	..	..	..	..	..	3	6
Cheek and hand	..	3	2	4	..	3	2	2	..	16
Neck and scalp	1	..	1	..	..	1	..	..	..	3
Vagina and vulva	..	..	3	..	..	3	1	1	..	8
Uterus	..	1	1	3	..	19	2	10	5	41
Penis	1	..	..	..	..	1	..	..	..	2
Spheroidal-celled breast	2	5	9	1	..	34	11	15	12	89
Liver and gall-bladder	..	..	..	..	..	..	..	..	3	3
Thyroid	..	..	..	1	..	1	..	..	..	2
Paget's disease	..	..	..	1	..	1	..	..	..	2
Columnar-celled large intestine	2	..	3	..	..	1	..	1	..	7
Rectum	3	1	2	1	..	9	6	17	4	43
Stomach	..	..	..	..	..	2	1	2	2	7
Ovary	1	..	..	..	..	2	..	..	2	5
Testicle	..	..	..	..	..	..	..	1	..	1
Prostate	..	..	..	..	..	..	1	1	..	2
Rodent ulcer	..	10	1	31	..	41	12	6	..	101
Sarcomata, spindle-celled	3	1	7	..	..	4	2	1	1	19
Round-celled	1	..	..	1	..	2	3	2	2	11
Melanotic	..	..	..	..	..	..	..	2	1	3
Endothelioma	..	..	..	..	..	..	..	..	1	1
Lymphosarcomata	..	..	..	1	..	1	..	..	2	4
Lymphadenoma (Hodgkin's disease)	..	..	..	..	..	1	..	..	..	4
Malignant disease of the glands	..	1	..	..	..	3	1	2	2	9
Parotid tumor	1	..	..	2	..	4	..	..	..	7
Abdominal tumors	..	..	..	..	..	2	..	1	1	4
Mediastinal tumors	..	..	..	..	..	1	..	..	..	1
Villous tumor of bladder	3	2	2	..	..	2	..	1	..	10
Granulomata	1	..	..	..	2	1	..	1	..	5
Adenoma of breast	..	..	..	..	..	..	1	..	..	1
Fibroid disease of uterus	1	1	..	..	..	3	..	..	..	5
Fibroma of penis	..	..	..	..	2	..	..	..	..	2
Enchondroma	..	..	..	..	..	1	..	..	..	1
Leukoplakia	..	..	..	..	2	1	..	..	..	3
Nevi, capillary	..	2	..	..	3	25	1	..	..	31
Nevi, cavernous	..	1	..	..	2	7	..	..	..	10
Moles, warts, and papillomata	2	1	..	..	6	6	1	2	..	18

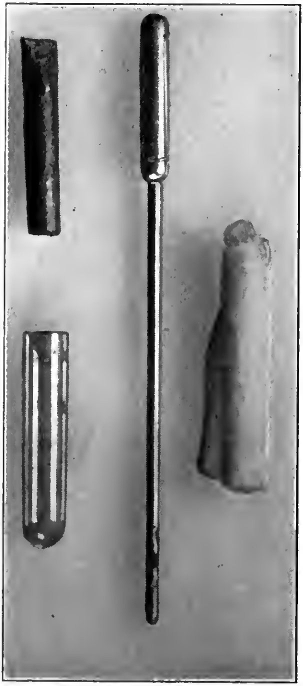
In the following list cases were not selected, and only placed under treatment with radium when all other means failed. Most of them had, where it was at all possible, previously received radiation from x-rays. (Treated at American Oncologic Hospital.)

Diseases.	Disease disappeared.	Marked improvement.	Improvement.	Doubtful.	Left.	Unimproved.	Died.	Remarks.
Epithelioma:								
Ear	2	..	..	..	..	1	..	Those placed under *left* were improved
Eyelid	..	..	..	..	..	3	..	to some extent,
Face (rodent)	1	..	..	..	..	..	..	otherwise would
Forehead	3	..	..	..	..	..	..	have been included
Hand	..	1	..	..	..	..	..	under the unim-
Larynx	..	..	1	..	..	..	..	proved.
Lip	..	2	..	..	..	1	..	? Operative treat-
Buccal surface	..	1?	..	..	..	..	..	ment substituted.
Mouth	..	..	..	..	..	3	1	
Leukoplakia	1	1						
Nose (rodent ulcer)	3	..	1	..	..	1		
Palate	1	..	..	..	..	5	1	
Pharynx	..	..	..	..	..	..	1	
Scalp	..	1						
Tongue	..	..	..	..	..	..	1	
Carcinoma:								
Axillæ, neck	..	..	1	..	1			
Breast, recurrent	..	..	..	..	..	3		
Colon	..	..	..	1	..	1	..	Doubtful case placed under that group as diagnosis was uncertain.
Face and neck	..	..	..	..	..	1		
Nose, mucous surface	..	1	..	..	..	1		
Palate	..	..	..	..	..	1		
Pharynx	..	..	..	..	..	..	1	
Esophagus	..	..	..	..	..	1		
Rectum	..	..	..	..	1	3		
Tongue	..	..	1	..	?	2	..	? Improved when he left.
Tonsil	..	..	..	..	..	2	..	
Uterus, body	..	..	11	..	..	1		

Diseases.	Disease disappeared.	Marked improvement.	Improvement.	Doubtful.	Left.	Unimproved.	Died.	Remarks.
Uterus, cervix	..	2	6?	..	2	4	..	? Operative treatment substituted.
Uterus and vagina	..	..	..	..	..	1		
Uterus, vagina, and bladder	..	..	..	..	..	1		
Vagina	..	..	..	..	..	1		
Vagina and bladder	1							
Papilloma:								
Chest	1							
Tongue	..	..	..	..	..	..	1	Died of angina pectoris, chronic heart disease.
Mouth, leukoplakia	1							
Cyst (recurrent):								
Mouth	1							
Sarcoma:								
Antrum	..	..	..	..	..	1		
Choroid	..	..	..	1	..	..	..	Case not confirmed by operation or section.
Multiple	..	..	..	..	..	1		
Orbit	1							
Orbit (osteo)	..	..	..	..	..	1		
Skull	..	..	..	..	..	1		
Sternum	..	1						
Serocystic (face)	..	..	..	..	1?	..		? Used for an individual case.

Epitheliomata of proliferative type usually appear first as warts or crusts and may be easily rubbed off, with more or less bleeding, which under some circumstances is difficult to check. This may be followed by healing. When the process recurs it frequently appears in a slightly exaggerated form. If the ulceration or tumor formation has only involved the superficial layer of the skin, a few short, active treatments will cause a rapid healing; if, however, the ulceration has extended below the surface and involved the deep layer and muscles, healing depends more upon the possibility of the new tissue finding sufficient structure to bridge the gap. Very often large ulcers, even 10 cm. in diameter, ulcerated to the muscle, will yield and remain in good condition. These processes are, as a rule, very slow in their progress, frequently extending over a course of ten years, and several have come under observation with a history of over thirty years. The slow, indolent nature of the disease makes it a typical one for the application of radiation. Metastasis rarely occurs and even in the cases which fail to come under treatment, death seldom results from this cause. The process involving the skin about the eye invades and extends inward upon the mucous membrane, where it is likely to give rise to deep pus infections and possible meningitis. When this condition occurs upon the forehead, the muscular contraction of the scalp often interferes with healing; but if this is taken into consideration and the part put at rest, many will yield where they would otherwise fail.

Fig. 52



An applicator, with the lead screen, glass protector, and gauze, to cut off the secondary radiation from the lead filter and glass shield.

This same state of affairs is often observed in the nose about the alæ, which at the same time are often irritated by the collection of sebiferous matter.

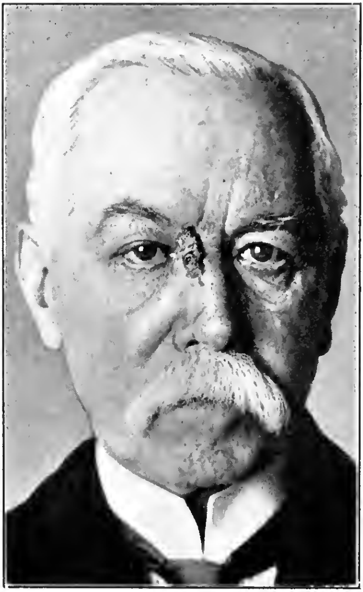
Epitheliomata of this character occurring upon the skin of other parts of the body usually yield easily to radiation; except those involving the dorsal surface of the hand which are prone to recur. When ulceration has extended so far that no tissue remains upon which granulations can grow, radiation in any form will fail. Recurrence either at the site of original disease or upon other places is common; if, however, they are not allowed to progress they usually yield easily to treatment.

Treatment.—The mode and method of treatment in these cases is a matter of election; they yield as readily to the Roentgen rays as they do to radium, and many are permanently healed by plasters of arsenic. Radiation has in its favor that its application is painless and produces less scarring; therefore, if the disease is upon the face the cosmetic effect is better, and the result is more likely to be permanent.

If radium is to be elected, application should be made through a thin filter, only thick enough to cut out the low β-ray. The applications under these circumstances should be short but in proportion to the amount of radium employed. In small ulcers of little depth, 2 mg. applied in several applications for twenty to thirty hours have produced healing. This, however, is not to be recommended. The usual treatment consists of the application, for two hours, of a 50-mg. applicator with 0.1 mm. lead screen, and proper protection from secondary radiation. The surrounding tissue must under all circumstances be carefully guarded. Considerable latitude must be allowed, due to the exigency of the occasion. The following case illustrates the condition:

Mr. Y., aged sixty-nine years; Philadelphian by birth; about four years ago developed a small sore upon the side of the nose, which previously had been scaly for several years. (See Figs. 53 and 54.) It had been treated by the Roentgen rays and yielded easily, but remained healed about nine months, when it broke down again. At the time he came under treatment the ulcer measured about $\frac{1}{2}$ by $\frac{3}{4}$ inches, was more or less indolent, and covered with a crust. When removed, it left a granulated surface, which did not tend to bleed. Radium treatment

Fig. 53



Epithelioma, recurring after x-ray treatment, treated with radium.

Fig. 54

After treatment (about 9 months).

was given for two hours every other day; 11 mg. "element" being protected by aluminium and glass filters wrapped in rubber tissue, in all twenty-four treatments. There was considerable reaction, which caused swelling and induration about the eye; this eventually subsided, and left the surfaces in a normal condition. The excessive radiation was employed in this case on account of the tendency toward recurrence.

Rodent Ulcer.—A type of epithelioma occurring upon the face; usually near the nose; begins generally as a pustule, which may heal and recur a number of times; however, this healing may be misleading, as often only a thin layer of tissue covers the underlying disease. In time the ulcer widens; edges are undercut with no granulation tissue extending above the rim of the crater-like ulcer. There is generally a slight inflammatory area surrounding this ulcer which bleeds easily and is often difficult to check. The ulceration widens and grows deeper, eroding everything in its path, even the bone, leaving a cavity with ragged wall that seems to possess no inclination toward regeneration. Sections of the border show the same histological appearance as other epitheliomas. This process is frequently placed in the same class as the proliferative or fungoid type, which is by no means so malignant, and is far more amenable to treatment. Both types remain local, rarely giving rise to metastasis.

The prognosis in these cases is by no means as favorable as in those attended with considerable tissue overgrowth. However, in the early stages, when the disease has not invaded the deep structures, they usually respond readily to treatment. Recurrence is common, although, with the proper amount of radiation, this to some extent may be avoided.

Treatment in Mild Cases.—The radio-active salts may be protected with a thin sheet of aluminium, or applied entirely without a filter. The radiation from a 10 mg. applicator for six to ten hours usually proves sufficient.

Some General Considerations of Superficial Epithelioma.—All forms of epithelioma, occurring upon the face, previously treated with caustics, carbon dioxide, electric needles, fulgeration, and other such methods, causing the formation of hard masses of scar tissue of low vitality, must be considered as unfavorable cases for treatment, as the character of the tissue is of such a nature that upon the least injury extensive sloughing is likely to follow.

It will be found that many cases will yield to the use of radium which have been rebellious when previously treated by the *x*-ray; the explanation being that the character of the rays emitted from these radio-active elements is entirely of a different nature.

The healing of these ulcers is often delayed from lack of ordinary care in cleansing the parts of discharges, which dry along the edges, producing an irritation from their position by not allowing the free escape of pus; thus causing further breaking down.

Epithelioma, occurring upon or adjacent to the mucous membranes of either the nose or mouth, must be considered in quite another class from those occurring fully upon the dermal surfaces. When the mucous membrane is involved, the disease is usually very rapid, and metastasis occurs early. It appears past middle life as a small wart-like growth upon the lip, which tends to break down and bleed. There is, however, a class of low-grade epitheliomata occurring upon the lip that is extremely indolent and extends slowly, usually observed as a flat ulcer that does not go deeply into the tissue and involves only the mucous membrane. These ulcers usually respond easily to either *x*-rays or radium; and when once healed do not tend to recur. These cases must not be confused with the other form, which is very malignant and where recurrence after operation is extremely common; treatment, either primary or secondary, after operation with the *x*-ray, has not yielded results at all satisfactory. A number of instances have been reported where there has been a recurrence of the disease locally or where the local disease has not recurred but the glands of the neck have produced a large tumor. Even where the local disease and metastasis were treated by the rays of radium both have yielded and the condition has been temporarily arrested. These very fortunate results are not the rule, however, the malignancy of this class of cases borders upon that of the true carcinoma of the glandular class. In those cases that do not yield to treatment the pain and swelling is often benefited, at least for a time, and the course of the disease is decidedly extended, as shown in Figs. 55, 56, 57.

Wickham mentions treating cases of this type with an applicator containing 0.04 gm. radium sulphate filtered by lead 0.6 mm. thick, application extending over twelve hours in divided sittings.

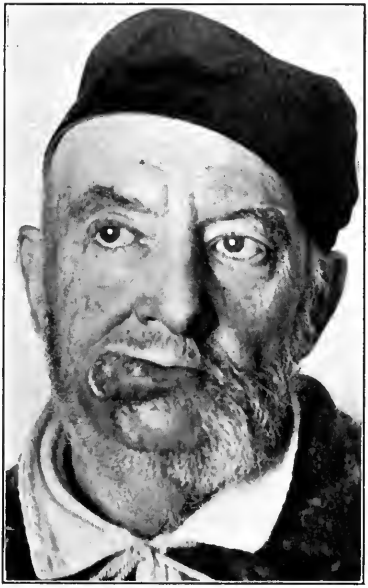
Epithelioma of the lip has been successfully treated by Heinatz[1] and others. Both cases were of extreme types.

Leukoplakia is often associated with cases of epithelioma of the mucous membrane of the mouth. The course of the disease is often very slow and under ordinary circumstances does not cause very much discomfort. Aside from those of a syphilitic nature their cause is usually obscure. When the patches are small they should be left absolutely alone, as the usual forms of treatment recommended cause irritation, and only advance them toward their ultimate end in the formation of epithelioma. However, if they are carefully treated with radium in small amounts they rapidly disappear. Bayet advocates the employment of about 10 mg. radium element, protected by a thin filter of 0.1 mm. of lead, administered in one-hour sittings for about six hours.

[1] Münch. med. Woch., 1904, No. 31; Exner, Münch. med. Woch., 1910.

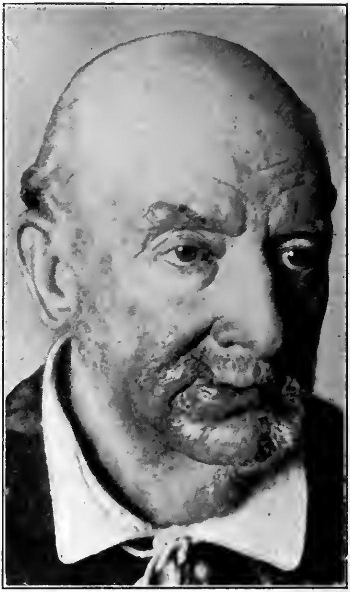
Carcinoma of the mucous membrane of the buccal cavity or tongue is the ultimate end of leukoplakia. Even those of a syphilitic nature might be included in this class. When once developed as carcinoma the prognosis is serious. Even under

FIG. 55



Recurrent carcinoma of the lip, with involvement of cervical glands.

FIG. 56



After treatment. Notice the difference between the gland of the neck; radium was only applied over lip.

radiation of the *x*-ray or where radio-active salts are used the outlook is by no means encouraging. Pinch reports only 10 cases improved out of a total of 60. The extension is rapid, as early metastasis of the neck is not unusual.

Successful cases do occur, however, and have been reported by many authorities. Exner[1] reports two cases: one a man, seventy-seven years of age, with involvement of the right side of the mouth and extension into the antrum and nasal cavities. The second involved the mucous membrane of the cheek, from the lips back and

Fig. 57

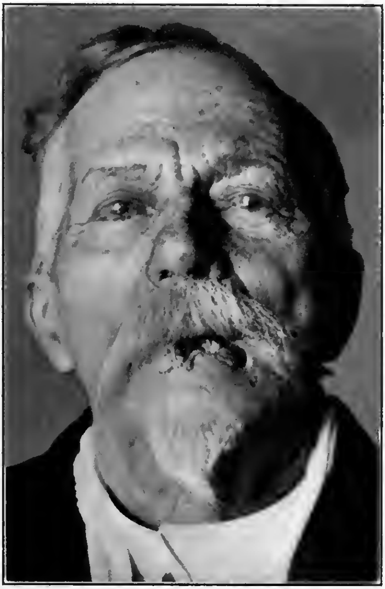


Illustration showing effects of radium upon a carcinoma of the lip with extensive infiltration. Original mass was about the size of an apple.

down over the alveolar process; the glands of the neck were also enlarged. The neck and mouth were treated for three weeks; during this time six radium treatments of

[1] Wien. klin. Woch., 1903.

fifteen minutes each were given, which resulted in complete subsidence of the growth.

The following case will be of interest:

A man, aged forty-seven years; German workman, of temperate habits; used tobacco moderately; generally healthy; denied venereal history; usual laboratory test negative. About four years ago he developed a small white spot on right cheek, which extended gradually. A short time afterward the left side became involved, and upon this side extension was somewhat more rapid. At the time of examination there was a patch upon the left cheek two inches long and one inch wide, the bottom of which was ulcerated. The deepest part seemed to extend from the steno duct forward. On the right side there was a patch about 1½ inches long and one inch wide; there was no ulceration on this side, nor were the edges so well defined. While this was the original site of the disease, it had not progressed to the same extent as the opposite side. He had previously received *x*-ray treatment, evidently with no effect. Nineteen treatments of radium, of two-hour sittings, about two days apart, were given. The right side was treated first until it cleared, then the opposite side. A small ulcerated patch remained on the right side, which was excised and healed perfectly, and since then he has had no further trouble.

Epithelioma of the tongue has been treated by Wickham and Degrais[1] with 0.04 gm. radium sulphate filtered through 1 mm. of lead properly protected from secondary radiation. The applications consisted of twenty-four sittings of two hours each. Healing resulted with a fissure at the site of the disease.

[1] Radium Therapie, Berlin, 1910.

The palate is frequently the seat of epitheliomatous or carcinomatous disease, which usually runs an extremely rapid course, causing extensive infiltration of the fauces with extension to the glands of the neck. Loewenthal[1] refers to several instances which have been benefited by the application of radio-active salts.

The following case is interesting on account of the complete recovery from applications of an extremely small amount of radium.

B. Mc., aged fifty years, reported for treatment April 18, 1910, at the American Oncologic Hospital. He had an operation upon his throat performed at one of the larger hospitals by a competent surgeon. This had been followed by Roentgen radiation administered by one of equal distinction, but the disease gradually progressed. Upon consultation, another surgeon at one of the other colleges advised a radical operation, which the patient refused. At that time he came under observation. The disease was of about four months' duration and had progressed rapidly. His general and family histories were negative. To exclude any chance of error he was put upon antisyphilitic treatment, with no result, although a Wassermann test proved negative. At the time treatment began there was a nodular ulceration on the left side of the soft palate, in which the end of the thumb could be inserted, with involvement of the palatoglossal fold extending down and over the tongue. The alveolar process of the superior maxillary bone was also diseased and necessitated the removal of three teeth. The glands of the neck were palpable on the same side.

The amount of radium used in this instance was equal to

[1] Grundriss der Radium Therapie, Wiesbaden.

1 mg.; it was contained in an aluminium capsule, and this in turn placed in a thin glass tube for protection. Treatments were given daily for one hour, and the patient was fairly regular in his attendance, which continued for seven months. After the first seven applications he had much relief from pain and was able to swallow food with some degree of comfort. This improvement steadily continued until the whole process in the mouth had healed, when the glands of the neck were subsequently excised. Three years later the man was in good health; since that time he has not been seen.

This instance shows the results that do occasionally follow the use of small amounts of radio-active salts, but under ordinary circumstances it would be safer to employ from 40 to 50 mg. of radium element, well filtered, applied both without and within. Under this treatment the more widespread diseased areas are likely to be included.

Fungoid epithelioma of the mouth usually occurs near or along the alveolar process, caused by the ragged ends of teeth, bone, or rough plates of artificial teeth. As a rule, they are slow in growing and not very malignant; they are prone to recur upon being removed by surgical means. Microscopically they show a low-grade epitheliomatous degeneration, usually of a typical class. (See Fig. 60.)

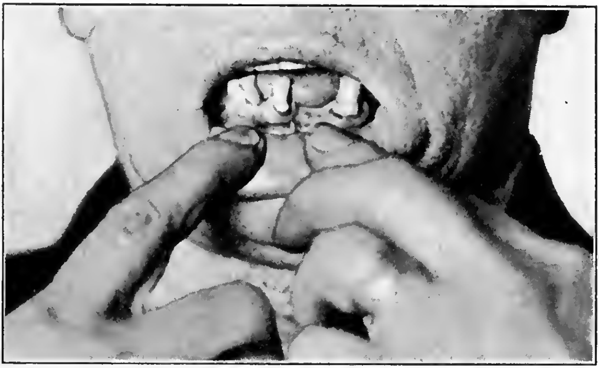
These cases, as a rule, do very well if the mass is removed and the base radiated thoroughly. Under this procedure recurrence is not likely, provided the source of irritation has been removed. The following history illustrates an instance:

E. R., aged forty-eight years, developed upon the mucous membrane over the site of the second lateral incisor a small mass about ½ inch long and ½ inch wide, having about the same density of the natural gums, also the same color, and showed no tendency to bleed upon manipulation.

Fig. 58

Epithelioma before treatment.

Fig. 59



Epithelioma after treatment.

The cause was supposed to be due to the friction of the plate supporting artificial teeth. The mass was removed by a simple cautery knife, after the injection of a small amount of cocain, and no bleeding followed. Four treatments with radium were given to the base over the site of the tumor.

Fig. 60

Microphotograph of the epithelioma from section of tumor, Fig. 58.

Another form of growth in this locality is the papilloma; they, however, have more the appearance of a wart or a number of warts. Their color is a deeper red and they usually bleed freely upon manipulation. Microscopically they show more derangement of the epithelium and may, as a rule, be regarded as being slightly more malignant.

Laryngeal cancer has been treated with radium and mesothorium with a fairly good average of success. For this form of disease an ideal method of applying the radiation directly to the parts affected is by introducing a small tube containing the radio-active salt into the larynx, and in conjunction giving treatment through the skin externally from all sides. Loewenthal[1] has reported several eases of this disease successfully treated.

A case of unusual interest has been reported by Worden,[2] where the primary seat of disease was to the left of the epiglottis. The glands of the neck were also involved and upon section it proved to be an epithelioma. As much of the disease as possible was removed, then a tube of 40 mg. of radium bromide was applied to the larynx through the wound, and four applications were made to the neck. About nine months later the disease recurred and radium treatment was again instituted, 45 and 25 mg. tubes being used upon the neck, in the neighborhood of the glottis. The applications were followed by recovery and the patient had no further difficulty two years after the last recurrence.

Carcinoma of the tongue is usually very malignant, both in rapidity of ulceration and involvement of the surrounding lymph glands. The site of the disease is usually posterior and to either side. Here again the exciting cause is usually a rough tooth or like process causing irritation. The patient when seen is usually far advanced; the disease is so widespread that even the most extensive procedure of removing the organ with all glands on both sides of the neck is likely

[1] Grundriss der Radium Therapie, Wiesbaden.
[2] Brit. Med. Jour., October 25, 1913.

to be followed by a rapid recurrence. A less malignant form following upon a previous condition of leukoplakia usually occurs upon the dorsum, and not upon the sides. This condition presents more the appearance of an epithelioma. However, when the stage of ulceration has been reached the extension is apt to be rapid.

Wickham and Degrais,[1] Weidenfeld[2] and many others have reported success in the treatment of these conditions with the use of radio-active salts. Carcinoma involving the deeper tissues in or near the *parotid gland* usually grows in the form of a tumor, and until examined microscopically is thought to be sarcomatous. Ulceration often does not occur until the disease has well advanced, and at that time extensive neck involvement is not uncommon. When removed surgically, recurrence is frequent; but on account of the locality, as a rule, surgical procedures are difficult and dangerous, and it is necessary under these conditions to operate very early in the disease, and widespread dissections should be made. Operations in late cases are hopeless; in these cases radiation will at times be most beneficial. In the list of 56 cases treated by Beckel,[3] 2 cases of carcinoma of the parotid were included with recovery of 1. Pinch[4] includes 7 cases of parotid tumor with 2 apparently cured and 4 improved.

Epithelioma or carcinoma occurring near the eye usually extend in time to the deeper structures of the *orbit,* requiring excision of the eyeball. If, however, the disease has not reached this stage, thorough radiation should be administered. Ordinarily recovery is prompt and recurrence is

[1] Radium, Berlin. [2] Wien. med. Woch., 1904.
[3] Moderne Radium und Thor., etc., Berlin.
[4] Brit. Med. Jour., 1913.

not usual. If, however, the disease has included the deep structure of the orbit, operation for removal of all disease is the best procedure followed by thorough radiation to prevent recurrence; but on account of the number of air cells contained in and about the orbit, complete removal of disease is quite impossible; therefore, in all cases of malignancy about this portion of the head, it is upon radiation that dependence must be placed for its complete eradication. In most areas about the face superficial radiation may be employed; but in and about the orbit the radium should be arranged with fairly thick filters; otherwise the deep penetration of these air cells will be lost. Loewenthal[1] refers to a deep carcinoma of the orbit treated with radium filtered by 1 mm. lead; three applications of twenty-two hours were made. This was followed by complete recovery, the exophthalmos, pain, and light flashes in the eye disappearing with improvement.

Epitheliomata of the hand reported by Pinch.[2] The skin of the face and hands was deeply freckled and had several warty growths upon it, which resembled somewhat xeroderma pigmentosa. Eighteen months previously a small tumor was removed from the back of the hand; microscopic examination proved it to be carcinomatous. At time of treatment there was an ulcer 1.5 cm. in diameter with everted edges and indurated base, which had originated at the end of the scar of a previous operation. It was situated over the centre of the middle metacarpal bone of the right hand, and was not painful. Radium was applied for fifty minutes without metal screens; a sharp reaction followed the application which resulted in complete healing of the ulcer. The same

[1] Grundriss der Radium Therapie, Wiesbaden.
[2] Brit. Med. Jour., 1913.

author reports a similar case, but the ulcer was somewhat larger and more painful. Seven treatments of radium one-half the strength of that used in the first instance were employed without a screen. Each sitting was of two hours duration and one month apart. The full strength applicator contained 10 mg. of radium to the square centimeter.

Epitheliomata occurring upon the hands usually follow a condition of senile keratosis which for years has been subject to some irritation; often occupations where the hands are continually coming in contact with irritants, as lime, soot, acid, barbs of plants, and many others. In some instances its origin is difficult to explain, while exposure to cold or to rays of the sun will often cause it. Residents of rural districts seem specially prone to the development of this condition. When the spots are isolated and not too extensive they yield easily to a few mild applications; but where the vitality is low or the local damage great from previous outbreaks and applications of caustic and other methods calculated to produce scar tissue, the prognosis is uncertain even where radiation has been previously employed.

Burns from the Roentgen rays have been healed by the application of radium even after they reached the stage where they partook of the character of an epithelioma. The application under these circumstances must be carefully made and the surrounding parts guarded against irritation.

Epitheliomata developing in old scar tissue are not uncommon, and are always most rebellious to treatment. They are slow in growth and very indolent. The part of the scar involved is usually that portion which seems to lack vitality. Scars that have existed for a number of years in a perfectly healthy state at times develop a form of epithelioma that from general appearance and rapidity of growth would lead one to suppose they were sarcomatous. Histological examination under these circumstances will prove the true nature of the condition. They are also, as a rule, unfavorable cases. Both forms are particularly rebellious to treatment, and, when healed, show a constant tendency to break down. This is particularly noticeable in extensive scars due to burns, and usually those that are not associated with keloids.

Carcinoma.—The treatment of carcinoma developing in the glandular structure of the body has not been so favorable as that noticed in the more superficial structures. Occasionally decided improvement has been reported, and no doubt as the technique improves and the cases are selected earlier for treatment better results may be expected; but the pathology of these tumors must be carefully considered and some method adopted for checking metastasis which is so prone to occur. In a list of 7 cases of carcinoma of the stomach only 2 were improved; while in another list containing 5, none were benefited. In one, which came under observation seven years ago, and submitted to an exploratory incision, carcinoma of the pylorus was found. Roentgen radiation was applied, with complete recovery, and at the present time the woman is still in good health. Therefore in these deep cases it must not be forgotten that the Roentgen rays will at times yield as good results as these radio-active salts. In fact, there are some instances when there is not the least doubt that the Roentgen rays would be the method of election. There are some who prefer to use both forms of radiation in these deep cases, claiming that the combination of the two yields better results than the employment of one alone. At the present time neither form of radiation, from the results so far presented, can be considered ideal.

Gastric Carcinoma.—In a case treated by Gaultier *et al.*[1] where the tumor at the pylorus necessitated a gastro-enterostomy, a tube containing 10 mg. of radium sulphate, filtered by 0.1 mm. lead was passed through the gastric fistula; later this amount was raised to 50 mg. of radium sulphate and was filtered by 0.5 mm. of lead foil. Finally a capsule having 12 sq. cm. surface, containing 120 mg. radium sulphate, was employed externally and was frequently changed, always keeping the tumor in range. The treatments were given during two months; eight, followed by two in three weeks, and three in four weeks. The internal treatments were of two hours' duration and the external ones often lasted twenty-four hours. The fistula healed, tumor disappeared, and the patient gained in weight from 120 pounds to 157 pounds. Czerny[2] treated 14 cases, with improvement in 8; in all he combined both the radio-active salts with Roentgen radiation.

Rectal carcinoma has seemed to yield somewhat more regularly to the influence of radiation, and various lists show a far better proportion of improvements. From a series of 43 cases, 1 was apparently cured and 9 improved; while in another series of 7 cases treated, 1 was cured. This may be due to the different methods that can be employed in treating these rectal cases, for it is often possible to bring the radium in direct contact with the disease. The peculiar anatomical construction of the parts must also be taken

[1] Löwenthal, Grundriss der Radium Therapie, Wiesbaden.
[2] Beitr. z. klin. Chir., 1909.

into consideration. The technique adopted by Pinch is the employment of 50 to 100 mg. of radium screened with 2 mm. of lead and 3 mm. of rubber. The capsule is introduced through a sigmoidoscope and is held in position by a wire of silver, which is soft enough to be bent in the desired position and be held firmly by a bandage. Each exposure is from six to twelve hours' duration, and is repeated daily until thirty to sixty hours' exposure has been given. This series is then repeated in about six weeks. The following cases illustrate its application:

M., aged fifty-three years. For several years suffered from severe rectal hemorrhage which was found to be due to a craggy, hard, annular mass; lower margin, 3 cm. above anal orifice, while upper margin was 9 cm., moderately fixed, especially posteriorly; bled freely upon examination. A 60 mg. tube of radium bromide was used, screened with 2 mm. of lead, and applied for sixty hours, extending over ten days. Six weeks later the growth was much smaller, no longer ulcerated, and less fixed to surrounding tissue. At this time the patient submitted to a Kraske's operation, followed by a course of prophylactic irradiation with the same amount of radium, with the same screen, for thirty hours. The patient regained perfect health.

Mrs. F., aged fifty-six years, had an indefinite history of abdominal pain and obstinate constipation which was found to be due to a hard, annular growth about the bowel 16 cm. above the anus. It was slightly ulcerated anteriorly and bled upon examination; the surrounding tissues were invaded. The lumen of the bowel was very small and irregular, about the size of a crow's quill; an offensive discharge was continuously present and in consequence the patient was weak and emaciated. A tube containing the emanation of radium with the initial activity of 83 mg., screened with 1.5 mm. of lead was placed in the lumen of the growth and left for twenty-four hours. Six weeks later a severe reaction was reported, but afterward improvement followed, discharge ceased to be offensive and pain was only slight; the lumen of the bowel was much larger and ulceration disappeared. Two months later another tube of emanation with the initial activity of 63.2 mg., guarded by a screen of 2 mm., was placed in the bowel for another exposure of twenty-four hours; but no reaction is mentioned as following this application, and since that time the patient has been about the house attending to her usual duties and is in perfect health. Other cases equally interesting are mentioned.

Carcinoma occurring in the intestinal and colonic portion of the bowel seems to bear about the same relation in regard to the cause and treatment with radio-active salts as that occurring in the stomach. The difficulty of recognizing and locating the mass until too late, when the process has become widely disseminated, is even more likely to happen, due to the obscure symptoms they present.

Carcinoma of the liver or gall-bladder does not seem to be benefited by the application of radiation in any form, and most of the cases reported offer very little hope of being benefited. There seems to be a degree of malignancy in these conditions that radiation fails to control. This is also true of malignant disease of the deeper glandular structures such as the pancreas, and, to some extent, primary disease occurring in the glands of the chest. However, most carcinomas occurring within the chest cavity are secondary; and when recognized the person's general state of health has been so far dissipated that treatment is of little avail, due to lowered vitality. However, where the progress of the disease is not too rapid, and the patient is able to endure fairly vigorous treatment, satisfactory results may be expected.

Carcinoma of the breast is a condition that must be considered from several stand-points before a prognosis of the individual case can be given. This tumor is one of the commonest seen by the radiologist; it occurs at all ages, and malignancy varies in a wide degree. Fulminating forms are seen where the process from the time it starts until death occurs is less than a year, and at the present we have no remedy that for one instant stays its pace. On the other hand, within one week two women presented themselves for treatment, one with the history of the disease of fourteen years' standing. Her age was sixty-seven, and at that time the involvement included her left breast: The tumor was about as large as a child's fist, with the whole upper surface ulcerated; glands involved the axilla and the neck, possibly from pus and not from actual malignant disease. Her general condition was excellent and there was no sign of cachexia. The condition healed, yielding easily to the influence of radiation, the Roentgen rays being employed. The second case was of about the same age, with the disease extending over both breasts; ulceration quite extensive on the left side about the size of one's hand, while on the right side it was somewhat less. The process was of nine years' duration. This woman was also treated by the Roentgen rays; but, living at a distance, she concluded the annoyance from the ulceration did not warrant the inconvenience experienced in making the journey for the treatments, consequently they were discontinued.

The point of interest in both these cases is the indolent character of the disease, which no doubt could have been controlled by any of the more conservative forms of treatment if adopted in the early stages; therefore deduction in all these numerous methods recommended for the control of malignancy must be guarded with the utmost conservatism.

Paget's disease of the nipple, a condition of eczema, is usually the forerunner of malignancy. The exact relation is not definitely understood, but where it cannot be controlled without recurrence, early operation by complete removal of breast and all surrounding glands is to be recommended. The actual condition is one that usually heals easily, both after radium and Roentgen radiation; however, cases have been known to be completely healed, and a few years later to have developed a mass in the tissues of the breast. While many have been permanently relieved, this unfortunate sequellæ must be constantly borne in mind. From the stand-point of radiology this disease might be compared with the superficial epithelioma which appears in all parts of the body, but has the one difference that the usual underlying condition resembles more an eczema than the dry, scaly, wart-like conditions usual to those upon the face or hands. There has been a report of several cases of Paget's disease occurring about the umbilicus, but whether this condition can properly be included in this class is questionable, as the lack of glandular tissue, either resembling or analogous to that of the breast, is not found in the neighborhood of the umbilicus. While the actual conditions may closely resemble each other the subsequent course must necessarily differ; therefore, in making comparison of these cases they must not be included with those that occur about the nipple.

Primary cases of carcinoma of the breast without extensive involvement should submit promptly to operation, and from our present knowledge this course offers the best hope of ultimate "cure;" delay under any circumstances is not justifiable. The position of the tumor at the time of development seems to influence to some extent the chances of metastasis; the inner two quadrants being much more liable to cause lymphatic infection of the mediastinal gland, while the two outer quadrants infect the axilla where there is more likelihood of removing them by thorough resection. When the axillary glands are infected recurrence is likely to be observed early, and, if the cervical glands are enlarged at the time of operation, statistics show that only 3 per cent. of these individuals pass the three-year limit after operation.

Radiation previous to operation has been recommended, and if employed it should in no manner be allowed to interfere with the operation, for the results of such a procedure are still *sub judice.* Radiation at the time of the operation in the open wound can do no harm, but just what advantage it will be to the individual is difficult to foresee. The employment of deep radiation under these circumstances can hardly be explained, for it would seem that if the rays used are to be penetrating and all kinds of metal filters interposed, a few inches of tissue would not obstruct many of these high rays. Postoperative radiation should be adopted in all cases of cancer; it will no doubt lessen the chance of recurrence, for if it is possible to heal cases when they have decided evidences of disease, certainly the chances are better before it has gained headway to that extent. If the disease reappears after operation in the form of scattered nodules in or near the site of the original, a second operation is not justifiable except for comfort; for it is likely that other processes exist, hidden, which cannot be removed and in these cases radiation should be pushed. The disease should not be allowed to progress to the extent of ulceration or deep glandular involvement before radiation is employed. Very few of these late cases recover, for even though the local condition be benefited the wide dissemination of the disease causes it to break out in other organs of the body.

Radiation of the primary case is a most difficult question. If a person refuses operation, is it justifiable to employ the *x*-rays or radio-active salts? Then, too, if this case is treated and the tumor disappears, the question is still asked, "What was the tumor?" From a diagnostic stand-point it is extremely dangerous; from a moral stand-point it is bad; for in the event of a recovery from some simple, benign growth that may degenerate under the influence of radiation others with a more fatal disease may take the same stand, thinking that to avoid operation would insure an easy road to recovery, and thereby not discover the error until too late, the metastatic processes having been sent broadcast over the entire system.

The usual case that is presented for treatment is where well-marked recurrence has been established; the superficial involvement may be slight, only a few scattered patches of the disease. Usually the axilla is bound down with scar tissue and a few glands in the neck may be evident. The mediastinal glands are, as a rule, involved, the patient having the short, hacking, dry cough, accompanied by some shortness of breath; yet, as formerly stated, the superficial involvement gives very little evidence of the actual amount of disease. Many such cases have been restored to health, but of the number presented comparatively few. It would be natural to suppose that the prognosis in these cases would be in relation to the amount of involvement. This, however, is not always a safe guide for many late cases will respond to treatment.

Neglected cases of carcinoma of the breast frequently come under observation where the amount of tissue involvement precludes operation. The breast is bound down to the underlying tissue, and the gland of the axilla and neck are involved, therefore it would be natural to suppose the mediastinal glands were in the same condition, depending somewhat upon the situation of the primary growth. By careful application of the *x*-ray or radium it is possible to produce a retrograde change that will in some instances cause the local disease to become absorbed and make it possible for a thorough operative procedure. In several instances that have come under observation the patients were restored to perfect health.

Epithelioma of the breast frequently occurs and differs from the deep glandular type of disease in that usually the process begins from without and extends inward. These cases are, as a rule, much more favorable for radiation than the adenomatous type.

The *x*-ray is the form of radiation that is most desirable in these cases of breast cancer, but it must not be forgotten that the radiation from these radio-active salts may in certain individuals be more acceptable, due to some personal idiosyncrasy. Where one form of radiation does not seem to benefit a given individual there is no reason to suppose that another form will not relieve the condition. From a series of 89 cases of carcinoma of the breast treated at the London Radium Institute 1 was apparently cured and

34 improved. In the treatment of these cases as much as 230 mg. of radium bromide was used for thirty to forty hours, given in a number of sittings. The form of disease that was usually benefited was the sclerotic type, while the encephaloid type was, as a rule, simply relieved.

Carcinoma of the thyroid has been reported by Pinch.[1] One case was apparently cured, while the other improved. The first case was a woman, aged thirty-five years. About six months previous to treatment she developed cough, dysphagia, and dyspnea, with an occasional slight hemorrhage; these symptoms were increased by excitement. When she reported, the disease was past operative interference, and a radiograph showed pulmonary involvement. 120 mg. of radium bromide was applied, screened with 2 mm. of lead. Applications were made for six hours the first four days. About one month afterward a second application of six hours, for five days, was performed, followed by a third application the following month for the same time. About three months later the tumor had disappeared as well as the concomitant symptoms, and the patient was able to pursue her vocation as a school-mistress.

[1] Brit. Med. Jour., 1913.

CHAPTER XVII.

APPLICATION IN SARCOMATA.

General Considerations of Sarcoma—Diseases of Bones and Joints—Head—Glioma—Lymphosarcoma—Lymphadenoma—Mycosis Fungoides—Idiopathic Hemorrhagic Sarcoma—Sarcoma of the Sternum.

Of all the malignant tumors, sarcoma is the most irregular in its course. The clinical history of the case may aid to some extent in the prognosis, but so far as the histological appearance is concerned, practically no exact deductions are possible. Often cases are observed where the microscope shows a small round-cell sarcoma, or even at times one of the distinct melanotic varieties that should under normal circumstances be extremely rapid in growth, and extending by rapid metastasis which will not follow the usual course but develop in such a slow manner as to give not the least suspicion of its actual significance. On the other hand, the slow-growing giant-cell sarcoma may become extremely rapid and develop in such a short space of time that one would place it among the most malignant diseases. Metastasis in sarcoma may be observed in its most unexpected parts. This often gives rise to considerable embarrassment. While the local growth may respond to treatment in the most orderly manner, the extensions to distant points may occur rapidly and be widespread, thus making many applications most difficult and more unfortunate from the fact that, if not upon the surface of the body, they are likely to be overlooked until their development reaches such an extent that constitutional infection causes a lowering of vital forces.

Spectacular results more often occur with sarcomatous tumors than any other class. These are not alone confined to radium or the other forms of radio-active elements, but occur also from radiation of the Roentgen rays. In fact, numbers of instances are on record of spontaneous disappearance, from no assignable cause; therefore, in the treatment of these sarcomas the actual results must not always be ascribed to the efficiency of the method. It is not unusual for a sarcoma to start rapidly and progress to a fair-sized tumor, then become quiescent and remain in that condition for years, even during that time undergoing a retrograde change; then, without the least warning, to take on another spontaneous growth until it results in a fatal issue. As a rule, however, sarcomas yield readily to radiation. Large growths are prone to undergo a very rapid degeneration, and if the person is debilitated the resultant toxemia is often severe, if not fatal.

Most sarcomata develop in the deeper tissue; therefore the radiation demanded under these conditions must be a large amount of high penetrating rays, with all low rays and secondary radiation carefully eliminated by proper filtration. These cases, as a rule, also respond promptly to the use of the Roentgen rays; therefore it must not be concluded that the radiation from these radio-active elements alone controls this disease. While results are equally brilliant and startling, the general rule must not be forgotten that there are cases of sarcoma as well as other tumors that will respond better to a certain form of radiation. This can only be determined by the actual application.

A class of sarcomas occurring in the lung with an exceedingly rapid course is not benefited by any form of radiation. These cases are rarely diagnosed correctly until a postmortem examination has been made. Some are so rapid that they closely resemble pneumonia both from their signs and symptoms, except the febrile reaction is never so high, and the pulse usually is less bounding. The usual case, however, runs a course of from three weeks to three months. Sarcoma of the lung is rarely primary, but usually follows as a secondary infiltration from some distant portions of the body. These processes are, as a rule, slower in their course, but when the patient reaches the stage of pulmonary invasion his general system has been greatly depleted, and treatment of the local conditions is not to be considered. The liver is the frequent seat of secondary involvement from sarcoma, and the tumor develops to such a degree before it is recognized that treatment usually has but little influence upon its course.

The small, isolated sarcoma may be considered as a most favorable tumor for radiation, provided there is no metastasis, and even masses of considerable size yield easily and promptly. The following cases of widely different natures illustrate these facts:

Mr. F. F., aged thirty-one years; Hungarian. History was obtained with considerable difficulty. Tumor of the left eye began several years ago, and on account of the pain and swelling he finally submitted to operation. About ten weeks before he came under observation the eyeball was removed and the tumor dissected out as well as possible; but as it had penetrated the antrum and the nasal cavities complete operation was impossible. Histological diagnosis was a fibrosarcoma. Recurrence was extremely rapid after the operation, with return of pain and eye symptoms upon the opposite side. More extensive operation was regarded as useless and he was referred for radium treatment. He was given twelve treatments of two hours each with 11 mg. of radium element, protected by 0.5 mm. aluminium and 0.2 mm. of lead, applied in different positions, and from these treatments the mass disappeared and the subjective symptoms subsided.

Bones are frequently the seat of sarcomatous tumors, and while at times they yield readily to the Roentgen rays many are rebellious, and in such instances radium or mesothorium will be found to be of value. Abbe[1] reports a case of giant-cell sarcoma of the jaw, with submaxillary involvement. The bone was softened and the tumor was about the size of a walnut. A few applications were made by applying the tube of radium to the gums, and later it was imbedded directly in the tumor; about fifteen applications being given in this manner. The mass gradually shrank, ossification began, and in about three months the condition of the bone was practically normal.

Sarcoma occurring within the auditory canal has been reported by Finzi.[2] A boy, aged eight years, had a small polypus protruding from the external auditory meatus, accompanied with more or less free discharge of pus. Removal was promptly followed by recurrence, and the hystological examination showed it to be an endothelial sarcoma. After the second removal Coley's fluid was administered with no relief, and when the child came under Dr. Finzi's care there was a large, bluish, fungating mass extending behind the ear, $1\frac{1}{4}$ inches in diameter, also a mass from the external

[1] Med. Record, 1904.

[2] Clin. Sect. Proc. of the Royal Soc. Med., 1910.

auditory meatus which discharged freely. Glands below the ear were also involved, under the sternocleidomastoid muscle as well as a few in the posterior triangle. Treatment was given as follows:

Date of treatment.	Radium; milligrams of bromide.	Thickness in millimeters. Silver filter.	Platinum filter.	Lead filter.	Rubber cover.	Time and position.
Feb. 21.	50	0.5	...	..	..	12½ hrs.; glands.
	17	...	1	1	1	15 hrs.; on meatus.
Feb. 22.	50	0.5	...	1	1	18 hrs.; behind ear.
	17	...	1	1	1	44 hrs.; in meatus.
March 30.	17	...	1	1	1	10 hrs.; lowest glands.
	50	0.5	...	1	2	13 hrs.; middle glands.
March 31.	50	0.5	...	1	..	21 hrs.; behind ear.
	50	0.5	...	1	..	8 hrs.; apex of posterior triangle.

The tumor had subsided and its condition was greatly improved when the patient was presented to the Society. A fairly good idea of the technique used is presented by this table.

Glioma occurring in the posterior portion of the skull, between the cerebrum and cerebellum on the left side, in a young man aged eighteen years, was removed by surgical procedure, and from all signs and symptoms promptly recurred. A second operation was performed about fifteen months later, and as much of the tumor as was possible again removed. This second operation did not, however, relieve the symptoms, which were headache and unsteady gait in walking; more or less pain associated with the back of the head over the site of the scar. These annoying symptoms began about a year before the first operation. His previous health had been good; family history negative, and at the time of observation was well nourished. Applications of radium, filtered through 2 mm. of lead protected by about one inch of cotton, were made in the neighborhood of the operative scar in different positions, three times a week, and continued for four months; 11 mg. radium element was used and each application lasted from four to six hours. The hair over the site had been removed, but only slight dermatitis was produced. The headaches have been dissipated and the normal gait restored. (See Fig. 48.).

A sarcoma of the neck treated with radium with recurrence in the mediastinum was reported by Finzi and Hill.[1] In the treatment of the portion that involved the esophagus they used 50 mg. of French radium bromide and 63 mg. of German radium bromide in a small tube with ½ mm. of silver for a filter. The whole capsule measured 9 mm. in diameter, and this was lowered into the esophagus to the constricted portion, where it was held from two to four hours. About the same technique was used in the treatment of the local condition in the neck as was employed in previous cases, except occasionally from eight to twelve layers of lint was substituted for the rubber protection.

Melanotic sarcoma has been treated by Czerny, Exner, Blauel, and Dominici[2] in a number of instances with success. In several cases more than one hundred small nodules existed, scattered over the whole body.

A method advised by Pinch in the treatment of sarcomata is to insert a tube of radium or radium emanation into the centre of the growth and leave it in position for twenty to thirty hours, and then repeat in about one month; 50 to 100 mg. of radium or its equivalent being used with

[1] Loc. cit.
[2] Grundriss der Radium Therapie, Löwenthal, Wiesbaden.

each application, and screened with 0.5 to 1 mm. of silver. Under this method the sarcomatous mass usually undergoes a retrograde change, leaving only a small nodule of fibrous tissue which, as a rule, gives no further trouble. Where this procedure is impractical the usual "cross-fire" method is employed as a substitute, about the same amount of radium being employed, and a screen of 1 to 2 mm. of lead substituted for the silver. The following cases illustrate these methods:

Sarcoma of superior maxilla occurring in a man, aged seventy-two years. The growth was of about three months' duration, and extended over the left half of the hard palate into the left nostril, pushing the central wall over against the nasal septum and causing epiphora and diplopia. An emanation tube of initial activity of 44.5 mg. radium, screened with 1 mm. of lead, was inserted into the growth and left there for twenty-four hours. Histological examination proved the growth to be a round-celled sarcoma. About two months later there was considerable improvement in the growth. Eye symptoms had disappeared and at that time another tube of emanation, equal to 30 mg. radium at its initial activity, protected by 1 mm. of lead, was inserted into the growth. Complete recovery followed.

Sarcoma of the thigh occurring in a lad, aged eighteen years, directly following an injury. The tumor had poorly defined edges, was slightly tender, and was situated at the junction of the middle and lower third. It was thought to be a periosteal sarcoma, but histological diagnosis proved it to be a spindle-celled sarcoma. A tube of emanation equivalent to 100 mg. of radium bromide, protected by 1 mm. of lead, was embedded in the tumor and left for twenty-four hours. Seven weeks later another tube, equivalent to 75 mg. radium, protected by 1 mm. lead screen, was inserted. The tumor decreased in size and the patient was able to walk with ease, and there has been no sign of dissemination.

Deep sarcomas occurring in the thigh show a somewhat greater tendency to give rise to metastasis than those in other localities. The usual site of recurrence is in the lungs.

Lymphosarcoma of the neck has also been reported by Pinch.[1] The patient had submitted to two operations with recurrence in a short space of time after each. When placed under treatment, the growth measured 6.5 x 4 x 1.3 cm.; was hard and firmly fixed to the underlying tissue, and was situated behind the jaw and below the ear. The skin over the growth was glazed and hyperemic; considerable pain was also experienced. Fourteen treatments of 200 mg. of radium, screened by 2 mm. of lead, were given from the effects of which the growth entirely disappeared.

Lymphadenoma (Hodgkin's disease) has been successfully treated by radiation; but the widespread character of the disease makes recurrence extremely probable. Czerny[2] reports a series of 8 cases treated by radium. In all the glands disappeared, which was accompanied by general improvement. They were all treated by injection of radium emanation in water; the amount varied from 28 cc. to 130 cc.; some of them also received more or less radiation from the Roentgen rays.

Mycosis fungoides is a form of sarcoma appearing upon the skin which is usually very widespread and is slow in its course. This disease has been treated by the Roentgen

[1] British Med. Jour., 1913.
[2] Grundriss der Radium Therapie, Wiesbaden.

rays and also by radium, and Bayet[1] concludes that the latter is much more efficient, causing a disappearance of the nodules in a shorter space of time with less scarring; the actual amount of radiation can also be observed. The filter employed in these cases was 1 mm. thick.

Fig. 61

Burn following application of radium to a sarcoma of the sternum that had been previously treated by the Roentgen rays.

Idiopathic hemorrhagic sarcoma of Kaposi, a rare condition of sarcoma usually following some long-standing irritation of the skin, such as a chronic eczema or epithelioma. Treatment of this rare condition with radium has been reported.

Sarcoma of the sternum, a mass about the size of a small apple, appeared over the upper end of the sternum, filling the suprasternal notch. It followed a blow upon that region from an accident. Two attempts were made at different

[1] Das Radium, Wien.

hospitals to remove it, but on account of its extensive infiltration it was found to be impossible and the wound was closed. x-ray treatment was employed, and for a time some benefit seemed to be derived from it. However, the mass continued to grow, and it was decided to use radium. Ten treatments were given, the radium being applied in different positions at each sitting, which lasted for three hours and were made at intervals of three days. The amount used was 11 mg. in an aluminium capsule protected by thin lead and several layers of cotton gauze. A terrific reaction followed over the whole area, no doubt due to the weakened condition of the surrounding skin from the previous x-ray treatment. Ulceration, which was very rebellious, followed but gradually healed, except a small patch over the site of the operative scar which remained for several months. The tumor in the meantime disappeared, although a gland still remains in the neck, but appears to be stationary. The case is interesting as illustrating the great care necessary in applying radium over areas which have previously received x-ray treatment.

CHAPTER XVIII.

APPLICATION IN BENIGN TUMORS.

Keloids—Warts—Papillomata—Cysts—Adenitis—Goitre—Angiomata—Nevi—Pigmented Moles—Granulomata.

Where there has been an overgrowth of tissue it is often possible to cause a retrograde metamorphosis and establish the part in practically the same condition as existed before this process was observed. Before the tumors are placed under treatment it is important to have a correct diagnosis, and where possible a histological examination should be made. The line of demarcation between the benign and malignant is poorly defined, and under our present knowledge of such conditions early removal of all suspicious growths should be the adopted rule. As a class benign tumors yield easily to radiation and disappear, leaving no operative scar, which under some circumstances is objectionable. There are some growths, however, which stand out clearly as types for radiation, and a good example of this is the keloid.

Keloids are overgrowths of fibrous tissue occurring in a scar. The colored race is particularly prone to these overgrowths, which often result from most trivial injuries. In one instance a colored man applied acetic acid to remove some warts from the back of his neck. The growth of these keloids where the small warts had been was many times more serious. Another case was that of a young colored girl who had her ears pierced for ear-rings, and from the site of each puncture hung a tumor about the size of a cherry. The removal of these keloids by a surgical procedure, cautery, or other similar process, is likely to be followed by a still larger growth. The only form of treatment to be recommended for this condition is radiation, either by the *x*-ray, radium or mesothorium. By these rays extremely large growths of fibrous tissue can be successfully removed; the slower they degenerate the better the result. Care must be taken not to produce irritation, lest the very action that originally caused these tumors be sufficient to start the re-formation of this excess of tissue. The results from the different forms of radiation seem to be about equal, and a matter of choice is difficult to determine. The method of election would simply depend upon the convenience of obtaining the source of supply.

The technique is most important, and while authors differ to some degree, the primary object is the absorption of the growth with the least possible scarring.

For removal of keloids, Pinch, of the London Radium Institute, uses half-strength applicators screened with 1 mm. of silver and exposure of fifteen to twenty hours, extended over three successive days, and repeated in one month where necessary. This gives a fair amount of penetration and yet does not cut out all the median rays. Bayet recommends using 0.1 to 0.25 mm. of lead as a filter, while Wickham used a 0.1 mm. of aluminium to 0.6 mm. of lead, depending upon the strength of the radium and the thickness of the tissue. He has treated a series of over 50 cases with good results and no relapses.

As before stated the colored race is especially prone to the development of these keloids, and they often attain an enormous size from the most trivial injury. The following instance is worth relating: A man, about twenty-nine years of age, developed one of these tumors about the size of three small apples extending, about an inch from the symphysis of the jaw backward and upward under the angle, just below the ear; the cause of this growth was the removal of a few small glands, which were supposed to be tuberculous. The glands were about the size of two or three hazel nuts. Radiation was employed to remove the excess of fibrous tissue. While under treatment and the area somewhat herperemic, he was accidently struck over the site of the tumor, which at that time was much reduced in size. The blow was sufficient to cause a slight abrasion of the skin, which removed the upper layer; this caused the absorption of the pigment and left the area blanched white. The keloids absolutely disappeared as well as the pigment over the site of the abrasion, which covered an area of about 1 inch by 1½ inch, with somewhat irregular borders.

While the masses that form upon the colored race are much larger than those of the white, when properly treated they rapidly disappear, leaving the skin of the affected area almost perfect.

Keloids following acne may be greatly benefited by radium, where it can be applied over the small area with greater ease than the Roentgen rays. The large number of small, well-localized areas which often exist call for more or less individual treatment. If the acne exists at the same time, radiation with the Roentgen rays is to be preferred, as the whole area and not the individual groups require treatment, and a general reaction should be produced. This causes a subsidence of the pus-forming process, and at the same time, to some extent, an absorption of the excess of fibrous tissues. Should well-marked individual keloids remain, they may then be treated by the application of radium.

Vicious scars, which are practically keloids, although not necessarily an overgrowth of fibrous tissue, are the causes of contraction and more or less deformity. These scars are often the result of extensive burns, and when they exist upon portions of the body where the skin is naturally soft and yielding they produce considerable contraction, which at times is not only annoying, but causes a lack of usefulness of the part. This is well exemplified in such scars about the eyelid, where it is drawn away from the palpable conjunctiva; and if not relieved will result in ulceration and perhaps the loss of that organ. Very often by careful radiation these scars can be softened to such a degree that the function is completely restored. Aside from this the comfort and cosmetic effect produced is gratifying.

For the treatment of these vicious scars there is very little difference between the use of the radio-active elements and the Roentgen rays; both must be applied carefully, and burning must be avoided, lest the condition be made worse from greater contraction.

Warts.—Warts at times show a marked tendency to recur; usually their removal can be accomplished by some caustic, such as nitric acid, glacial acetic acid, trichloracetic acid and many others, including carbon dioxide snow. At times peculiar influences will cause them to disappear, and most ridiculous remedies have been employed with success. The reason cannot be explained; but, as the pathology of a wart is practically unknown, these methods must be considered, for the simple reason that they are effective. The nervous influences, trophic or otherwise, bear upon the results, and

Fig. 62

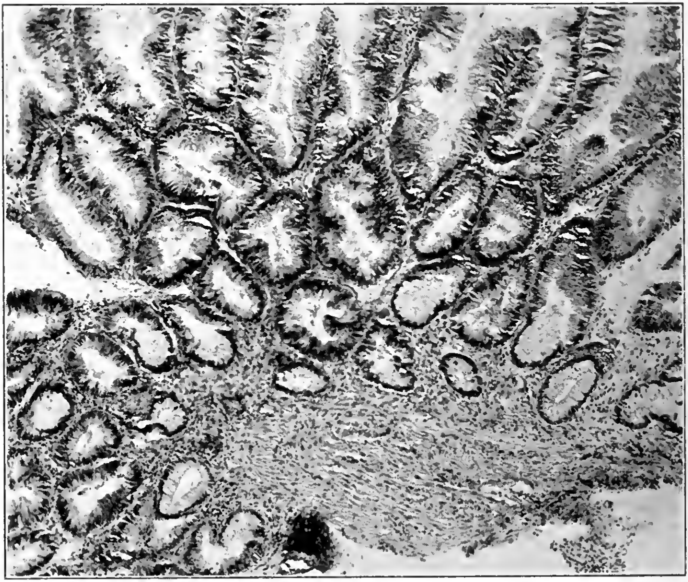
Specimen of a soft recurring fungoid wart; promptly disappeared after one treatment.

Fig. 63

Same finger after treatment.

for this reason the success of radiation must not be considered alone from its actual effect, but also from its psychical influences; and while the employment of radium, made in short applications, is usually successful, at times failures will result from some unknown influence. Where the wart

Fig. 64



Benign papilloma treated with radium. (From Records of Oncologic Hospital.)

is practically a papilloma, due possibly to some direct irritation, the application of radium will be attended with success and recurrence is not likely, provided the cause is removed.

Papilloma.—Papillomata are especially annoying when upon parts of the body where the skin is contracted and extended; in such places as the joints of the fingers, near the mouth, along the nose or eyelids. Here the base of the small tumor itself may be cracked or split, causing bleeding and irritation, which, if continued, in time may give rise to malignancy; therefore, under these circumstances their removal is important. Even if other parts of the body are not subjected to direct irritation, the same tendency to malignant degeneration is often observed. If their removal cannot be accomplished by the application of some caustic, radiation should be employed.

Papillomata or polypi upon the mucous membrane are often extremely troublesome, especially when occurring in the larynx or trachea. Their removal by some operative procedure leads to more or less destruction of the tissues, with the formation of objectionable scars, which usually injure the voice; besides these disadvantages, recurrence is usually to be expected. By the use of radium or mesothorium these tumors may be removed by a few applications and the result is often permanent. This, however, has not been observed from the treatment of the cases with *x*-rays. Here the results are variable and recurrence likely, in addition to the destruction of tissue surrounding the larynx from the needless hyperemia.

In the treatment of *laryngeal* and *tracheal* papillomas the applications may be made from within and directly to the part by using a small applicator and cocainizing the larynx sufficiently to tolerate the presence of an applicator. If, however, this is not desirable, the radium may be applied from without by "cross-fire" method and the tissue through which the rays pass to reach the mass will be different with each treatment. In this way only the diseased area receives the full amount of radiation. Both methods have their advantages. Where the radio-active element is applied internally, directly to the tumor, the duration of the application is much shorter than where the external method is employed. In the first instance a larger proportion of the energy can be used, while if it is applied externally filters are necessary to cut off the low rays.

Papillomas occurring within the mouth, nasal cavities, and pharynx can be readily treated by local applications of radium; these are more easily handled than the former class as exemplified by the following case:

Mr. H. R. S., aged forty-four years. About a year ago developed a small lump, one-half the size of a pea, upon the inner side of the mandible, just below the cuspid tooth. It showed no tendency to bleed nor to ulcerate. It had been removed on several occasions but promptly recurred. The histological report was made by Dr. Allen J. Smith, who reported it to be a hard papilloma, and, referring to the tendency of these conditions to become malignant, urged removal with wide dissection of the tissue. This operation failed and the tumor again recurred; then radium was employed, the mass having been removed by "diathermie." The base of the ulcer was treated for two hours, and two days later for three hours, with radium filtered only by a glass tube and aluminium, each about 1 mm. thick. There has been no recurrence.

Papillomatous conditions of the bladder and rectum may be treated in like manner. Where it is possible to bring the radio-active salts in direct contact with these tumors, the time of radiation is materially lessened and lower rays may be employed. Where this is not possible, the applications must be made by the "cross-fire" method and calculation drawn accordingly.

Small recurrent cysts are at times presented for treatment. The following is a typical example:

Miss A. J., aged thirty-five years, school teacher, had developed, about two years previously, a small cyst upon the mucous membrane upon the lip, opposite the root of the right lateral incisor tooth. It had been removed several times, and the last time the base was well cauterized. + 1 mg. of radium filtered by a thin aluminium capsule was applied directly over the cyst for three hours; three applications were made one week apart. At the time of application the cyst was about the size of a pea, and the very slight reaction, caused by the radium, subsided with the disappearance of the tumor. While the character of the cyst was never determined, the patient has been under observation over four years with no sign of recurrence.

Simple Adenoma.—Simple adenoma existing in other tissues such as the breast, mouth and glandular structure, should be carefully considered before treatment. While they yield, in a fair proportion of cases, to radiation the chance of error and the likelihood of malignancy must be considered. Therefore, a surgical operation is always to be preferred and an exact diagnosis established; radiation may subsequently be employed where the occasion justifies.

Tuberculous adenitis has frequently been treated by the various forms of radiation, and, as a rule, favorable results are to be expected. The cases, to some extent, must be selected; those having softened glands, containing a large amount of pus, must be opened and drained, before healing from the influence of radiation can be expected. Enlarged glands that are firm and in the inflammatory stage may be reduced in size and may at times even disappear, but as a rule they shrink to a small, fibrous nodule about the size of a pea and remain in such condition without recurrence.

Where previous surgical operations have removed the gland, leaving sinuses and a large amount of fibrous tissue and scarring, the application of radiation will aid materially in the absorption of this excessive tissue and favor healing, provided there are no pockets in which pus collects to form new abscesses. In this condition, or where the gland contains pus, drainage is most important; pockets of pus simply block the radiation from the walls of these cavities, while the surrounding tissues suffer the full force. Therefore, the damage done is doubled, the tissue that receives the radiation does not need it, and the diseased cell naturally escapes from it by the protection afforded by material which cannot be influenced by the effects of these rays. As a rule, these glands do not occur singly, but are spread over a wide area. Under these circumstances the Roentgen rays afford a method which fulfils the requirements somewhat better than the application of radium. Most cases of simple glandular affection are usually removed by some surgical procedure, which has the advantage of placing the tissue in condition for inspection and enabling the diagnosis to be confirmed, thus avoiding the possibility of a mistake, which under circumstances such as these is most likely to occur. Therefore, when these cases present themselves for treatment by radiation, and have previously submitted to several operations, the diagnosis can be absolutely confirmed, as the disease usually exists over a widespread area.

Reports of tuberculous glands treated by radiation without operation have been made, and where this proved successful the damage to tissue and the usual unsightly scarring, so frequently seen, was avoided. However, under some circumstances the results have not been favorable; the gland not being reduced in size an operation had subsequently to be performed. This is usually attended with considerable difficulty; as the fibrous tissue, formed under these conditions, is extremely dense and makes dissection most tedious. The assertion has been made that the treatment of these cases before operation is not justifiable; that the gland, being tuberculous, should be removed; and where this is not done, the infection is allowed to remain in the system to recur at some future time. This, however, has not been proved by the observation of cases, and it appears that recurrence is less likely in cases treated by the Roentgen rays or radium than in those treated by operation, where it is quite frequent. Therefore the infection of open tissue seems more probable than where the blood and nerve supply has not been injured.

Where these radio-active elements are employed in the treatment of tuberculous glands they are prepared in the same manner as where deep treatment is desired. The low rays are filtered by 1 or 2 mm. of lead and the applications arranged to cover the whole site of disease; this at times is difficult. The amount of radiation must not be excessive; it is better to adopt a procedure of several séances with a month intervening. This seems to be more efficient than continuous treatment.

Tuberculous laryngitis, papillomas or ulcerations of this nature, occurring in the larynx, heal in a large proportion of cases treated by this method; but as this local manifestation often depends upon the same disease existing in the lungs, the prognosis rests entirely on the possibility of relieving the latter. Where this is possible, the health of the individual may be completely restored, and therefore, when such cases come under observation, it is most important to instigate a thorough medical regimen.

Tuberculous diseases of the bones and joints are only influenced to a limited extent by radiation.

Goitre.—Goitre, in its various forms, has been treated by the Roentgen rays and also by radium; the results are by no means uniform although, a fair proportion are attended by success. This fact is all the more contradictory, for, as referred to in Chapter X, under the subject,

Fig. 65

Abbe's case of exophthalmic goitre before treatment.

Fig. 66

Same patient as Fig. 65. After treatment.

Natural Springs, there has been some tendency to attach the development of goitres, in certain localities, to the high radio-activity existing in these natural waters. This may or may not have a bearing upon this subject, for the form of goitre least affected by radiation is the cystic variety observed in those localities. This variety seems to have less systemic effect; its greatest annoyance being the disfigurement it produces. As a rule, it is a rather indifferent tumor and not likely to seriously interfere with the individual's comfort. Treated by either form of radiation, it may usually be greatly reduced, and in some instances be practically brought to the size of the normal gland.

Goitre occurring in Graves' disease, exophthalmic goitre, has also been greatly reduced in size by radiation, causing the local manifestation to subside, as well as the other signs and symptoms usually present in that disease. The rapid beating of the heart and the protruding eyes disappear, to a great extent, before the goitre itself is absorbed. This gives a degree of comfort to the patient while under treatment. The form of radiation usually employed in most of the cases that have been reported was the Roentgen rays. Dr. Abbe[1] reports an interesting case which is given in detail as follows:

"Miss B., aged twenty-one years, lived in the suburbs of New York and enjoyed the finest health until she was overcome by the present trouble while pursuing a course of study in a hospital training-school for nurses, a year and a half ago. She noticed her throat began to swell in the centre and at both sides. This has progressed steadily up to the present time. Palpitation soon followed, and became so bad that she had to give up her work and return home. She was then sick, and obliged to go to bed, with extreme nervousness, restlessness, and a feeling of heat and feverishness, though not having actual fever so far as she knew. Added to these were severe headaches, especially severe in the temples and eyes. This was relieved somewhat by lying down, so that she spent much time in bed; though in the recumbent posture she experienced a sense of suffocation and

[1] Archives of the Roentgen Rays, 1905.

smothering. Her muscles trembled, and she was unable to walk upstairs, except very slowly, on account of palpitation. Her eyes felt full and burning, and began to protrude. One year ago her voice became husky. Her weight was 175 pounds; appetite hearty; digestion excellent, and bowels a little torpid; pulse-rate 140. She has been obliged to remain quietly in her home.

"*Examination.*—The patient was able to walk about slowly; any exertion at once showing in smothered breathing and palpitation. This long ago incapacitated her for any household duties. The photograph shows the outline of the thyroid enlargement marked in iodine before photographing. The circumference around her neck was $16\frac{1}{2}$ inches.

"Six weeks later I sent her to a private room at St. Luke's Hospital, and made an application of radium as follows: Under cocain anesthesia I made a small median incision in the neck, dissecting down to the isthmus of the thyroid, carefully avoiding large veins. The hypertrophied middle lobe was apparently $1\frac{1}{2}$ inches thick. Into this I thrust a small, sharp bistoury, making a deep enough incision to bury a sterilized tube of radium at right angles to the skin, 1 inch deep. It was held in place by sterile dressing and straps, the patient keeping her head fairly quiet for twenty-four hours. The glass tube was $\frac{1}{8}$ inch in diameter, and contained 10 cg. of Curie radium (300,000 activity). The tube was removed after twenty-four hours, and the wound closed with strapping. Nothing could be seen unusual in the healing of the wound or in the appearance of the tissues.

"She returned home, and for a time was very much as before. Her own narrative is that for a month the gland seemed just a little more swollen and spongy. Then the swelling diminished rapidly, and eight weeks later was as small as shown in the later photograph. All her unpleasant symptoms disappeared except the husky voice, due, perhaps, to enlarged tonsils, which I have since removed. On examining her four months later, after the one radium application, I found, however, some remaining tachycardia; pulse 105, which could be run up to 120.

"The patient looks and feels entirely well; attends all household duties, runs upstairs without palpitation, plays tennis every day, and walks several miles; has no headache, eyes are normal, and is free from tremor, restlessness, or smothering feeling on lying down. The maximum neck measurement is now 15 inches, and the goitrous appearance would scarcely be observed.

"Examination of the thyroid shows it to be about one-sixth of its former bulk—a reduction in every diameter, as shown by the iodine outline in the photograph. No treatment or change in habits of life occurred during the four months, except the occasional use of a small quantity of Carlsbad salts in the morning and a rectal enema of warm saline solution.

"The complex symptoms of Graves' disease refer so much to a sympathetic disturbance that the goitre is regarded as only one disturbed organ; hence the operations on it and on the cervical sympathetic ganglia, which seem to control it, are disconnected by many medical men as not going to the root of the matter, but as relieving only part of the disturbance. Nevertheless, it would seem that where the goitre has been established, its own disturbed secretions add to the general systemic upset, and tend to complete the disaster.

"In what way can we imagine radium to act favorably? In two ways: on the hyperplasia of the gland, causing a retrograde change in all overgrown tissue, quite as we see it in other instances. Second, by irradiating the ganglia of the sympathetic, even of the unapproachable thoracic and cardiac ganglia. It is not inconceivable that the regular electrons (beta-rays) discharged from the radium, and which penetrate dense structures at a great distance, are not detrimental to living structures, but may supply to disturbed nerves the very electric nervation they lack, or to cells of hyperplastic tissues the necessary inhibitive power to control their erratic growth."

Angioma.—Angiomas and conditions closely allied to these tumors, such as nevi and "port-wine stains," have been treated by the Roentgen rays and also by the application of radium. The result from the Roentgen rays has not been particularly encouraging, as the resulting scar with the amount of telangiectasis is apt to be more disfiguring than the uniformly distended capillaries; besides, the reaction produced for the contraction of these vessels at times causes a burn that under some circumstances is difficult to heal. With radium, however, these protracted burns need not be feared, and while a number of authors claim most brilliant results at times, the actual effect cannot always be regarded as perfect. The contracted vessels produce more or less fibrous tissue which is by no means as sensitive to dilatation and contraction as the natural skin. Therefore, upon blushing or passing from heat to cold, the scars, which under ordinary conditions would not be observed, are perfectly evident; while the cosmetic effect may be good under ordinary circumstances, the traces of the original trouble are more or less in evidence.

The treatment of nevi requires some experience and must not be undertaken except by one who thoroughly under-stands the specimens of radio-active elements at his command. They must be carefully used, as too severe a reaction will bleach the tissue a dead white, and it is far better not to have sufficient reaction, which will only make another application necessary. As only the superficial effect is desired from these treatments, the exposures should be very short, the radium need not be of great strength, and the filter may be omitted, although under some circumstances, when the rays penetrate the tissues, a 0.01 to 0.1 aluminium filter is desirable. Pinch uses an aluminium filter that does not exceed 0.02 mm.; he also calls attention to the fact that these flat capillary nevi ("port-wine stains") are the most difficult to treat especially when they are infiltrated to some degree.

Fig. 67

Cavernous nevi treated with radium. The tumor was originally about the size of a cherry over the left eyebrow.

In the cavernous type of nevi the treatment must be necessarily deeper. While the conditions are similar to the former, the vessels are much larger and the amount of tissue absorption is in greater proportion. The results, however, are usually satisfactory and very little disfigurement is produced after the vessels have been destroyed. The radiation employed under these circumstances must necessarily be stronger, and a filter of thin lead is used. While some reaction may be desired, it must not be too severe, otherwise a scar may result.

Erectile angiomas are a still more exaggerated type of these tumors. The treatment must be regulated by circumstances, be of a penetrating character and "cross-fire" tactics usually have to be adopted.

Pigmented Nevi or Moles.—Moles may or may not be covered with hair, and while they might be included in the class of superficial nevi, they contain more fibrous tissue and therefore are somewhat more rebellious to treatment. They require more radiation and a heavier filter to produce reaction of sufficient depth to eradicate them. The results, however, from radiation are extremely good and far better than any other form of treatment.

Granulomas.—Granulomas include tumors of indefinite pathology; they usually develop upon ulcers of low vitality and cannot be assigned to any distinct group. Under ordinary treatment they are extremely rebellious and at times tend toward a malignant degeneration. Radiation, as a rule, causes them to yield, and the form adopted depends upon their depth and extent. It seems needless to call attention to the fact that if any direct cause of irritation exists it must be removed before treatment.

CHAPTER XIX.

ANALGESIC EFFECTS.

Relief of Pain from the Roentgen Rays; from Radio-active Elements—Neuralgias—Herpes Zoster—Pruritus—Application of Radio-active Mud—Baths—Compresses and Packs—Conclusions.

The effect of radiation upon the sensory nervous system is one of considerable interest, and was first noticed soon after the Roentgen rays became an accepted form of treatment for malignant diseases. Many early observers noticed that, before any evidence of change could be detected in the disease process, quite often patients would voluntarily state that the pain had to a great extent disappeared. This at first was thought to be due more to a psychic influence that is commonly observed in certain classes of cases when a change in any form of treatment has been made. Some doubt was cast upon this analgesic effect, for, not infrequently, cases that did not respond to radiation also spoke of the same relief. As the field broadened and the treatment of other diseases was included, the same relief from pain was frequently noticed; even at times certain conditions, simply submitted for a radiograph, would experience this relief; the exposures under those circumstances being much longer than they are at the present day.

Neuralgia.—From these different observations certain painful conditions, such as neuralgia, were subjected to radiation, purely for the relief of pain; and one of the first to call attention to the fact was Dr. Charles Lester Leonard, of Philadelphia; and since that time many other authors have reported cases treated by these methods with more or less success, depending to some extent upon their origin. In cases where the neuralgia has a direct cause, as pressure from tumor, indigestion, or disturbance of the eye, radiation necessarily fails, and before subjecting these cases to treatment, care should be exercised to eliminate any direct cause.

Herpes zoster is often relieved of its intense burning pain by mild radiation; and it will be found particularly useful in the more chronic forms, which tend to linger over one locality. Besides relief from the pain in these cases it is believed by some to hasten repair. Considering the fact that the exact pathology of this disease is not definitely known, the role radiation plays in repair must necessarily be doubtful.

Pruritus.—The action in pruritus is similar to that observed in herpes. The relief from the intolerable itching is often very prompt; here no doubt the irritation is entirely local, and due to the direct action upon the inflamed skin.

METHODS OF APPLICATION.

Under all these conditions the radio-active salt has been applied in such strength as to require it to be mounted upon applicators in some one of the different forms; either the capsule containing the salt or upon a flat varnished applicator, the latter form being usually more convenient where the cause of the pain is superficial, as in pruritus. At the same time a large area is covered and the amount of radiation is proportionately larger. Where the origin of the pain is deeper, as in neuritis or neuralgia, fairly deep penetrating rays are needed and a moderate amount of filtration is necessary.

Mud.—The relief obtained from radio-active mud is not to be questioned, but whether it is due to the feeble amount of radio-activity which it eliminates, or, like any of the other kaolin plasters, where the beneficial effect is due to the production of local warmth and fixation, might give rise to considerable argument. In fact, mud was used in exactly the same manner before radio-activity was known; and the majority of radio-active muds placed upon the market are either worthless or else so feeble that the ordinary brick clay would be a fair rival. As results have been reported from the use of such material it must necessarily bring some degree of skepticism upon this practice.

If these clays are to be used for their radio-activity they should give off enough radiation to be detected by the ordinary electroscope and under ordinary conditions; this amount of activity should also be registered. Before deductions are made upon the effects of these applications, the relief afforded by the ordinary kaolin plaster must be taken into consideration.

Baths.—The beneficial effects of bathing-waters should be considered in exactly the same manner as the muds, and again the radio-activity must be of such strength as to have some distinct effect. The addition of a certain quantity of water containing refuse of old emanations or even a small quantity of active emanation or radium salt, hardly gives enough activity to a bathtubful of water to make it rate favorably with many ordinary wells.

No doubt the relief afforded under these conditions is as much due to the process of bathing as it is to the activity of the water; and when these waters are to be used for their radio-active effect, they must be of sufficient strength and administered under a proper regimen.

The painful conditions treated by local applications of radio-active mud or water are of an entirely different nature from those where radiation is received directly from radium. They are, as a rule, less acute, and tend more toward the chronic type of disease, such as the arthritic conditions of so-called gout or rheumatism, inflammatory conditions of the serous membrane in general, and neurogenic conditions which are somewhat localized. It has been claimed that the pain in such diseases as multiple sclerosis, tabes, and other spinal degenerations, has been greatly relieved in some instances.

Compresses.—Under some circumstances the local applications of these radio-active elements are made in the form of compresses; or in a pack, when the whole body is to be covered. These compresses are usually made of several layers of gauze saturated with radio-active water, then bound to the affected part; and when the moisture is desired, should be covered with oiled silk, or rubber tissue. This depends entirely upon the effect desired and compares exactly with moist and dry compresses when applied without the radio-active material. The same procedure is adopted when a general pack is given. The disadvantage of this method is that the radio-active elements of the outer layers of the compress have very little action upon the part; while in the bath, the free movement of the liquid favors enosmosis and exosmosis. The compresses, however, have much the same effect, to a limited degree, and can be adopted when baths are not desired. They can also be continued for a longer time than the bath, and the absorption of these radio-active elements will be more prolonged, although not so intense, for the same amount of area exposed.

The actual amount of relief afforded by radiation under these procedures is still *sub judice*, and requires the correlation of a large series of cases before actual conclusions of any definite nature can be made possible.

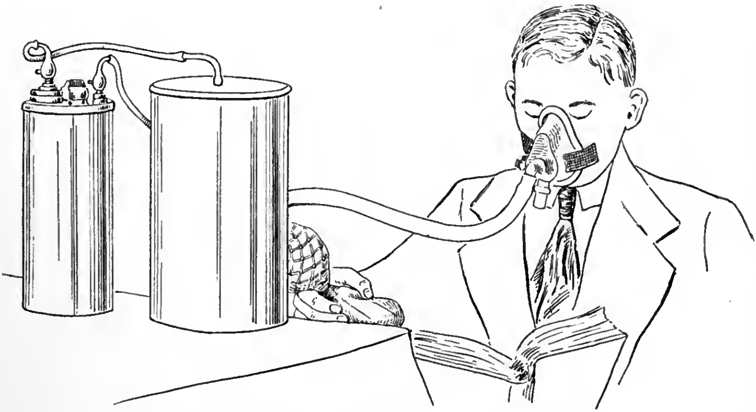
CHAPTER XX.

RADIUM IN INTERNAL MEDICINE.

Its Absorption and Elimination—Dosage—Effects upon the System—Diseases in which it has been Employed—Contra-indications—Conclusions.

THE systemic effect noticed after the internal administration of radium is believed by many authors to be due to the α-radiation. Considering the minute dosage and aside from any possible influence it could have as a salt, this view cannot be refuted as the β- and γ-radiation are in such small proportions that it would seem quite probable they played only a minor rôle. It is usual to employ the emanation in solution with some liquid, as water, for bathing, drinking or injections hypodermically. It may be used in other liquids or even solids, such as charcoal, and in those instances where it is desired, air or oxygen can be charged and taken into the body by breathing this mixture directly from some form of apparatus or in an enclosed cabinet or room. If the action of radium is derived from the α-radiation, the emanation and the first two elements of the "product of rapid change" are responsible for most of this action; and as the amount of the emanation is responsible for the subsequent rapidly changing elements, the dosage in all events depends entirely upon the emanation. It must also be remembered that the emanation, being a gas, is eliminated from the body under exactly the same law of the mixtures of gases, in any osmotic change, but is much slower, due to its density, which is far greater than most of the ordinary gases known. However, where a slower elimination is desired, radium salts are to be preferred; but here the proportion of activity is only equal to that of the emanation which is undergoing disintegration at that time, plus the very feeble α-radiation of the radium element proper, which in contrast to the three successive elements

Fig. 68

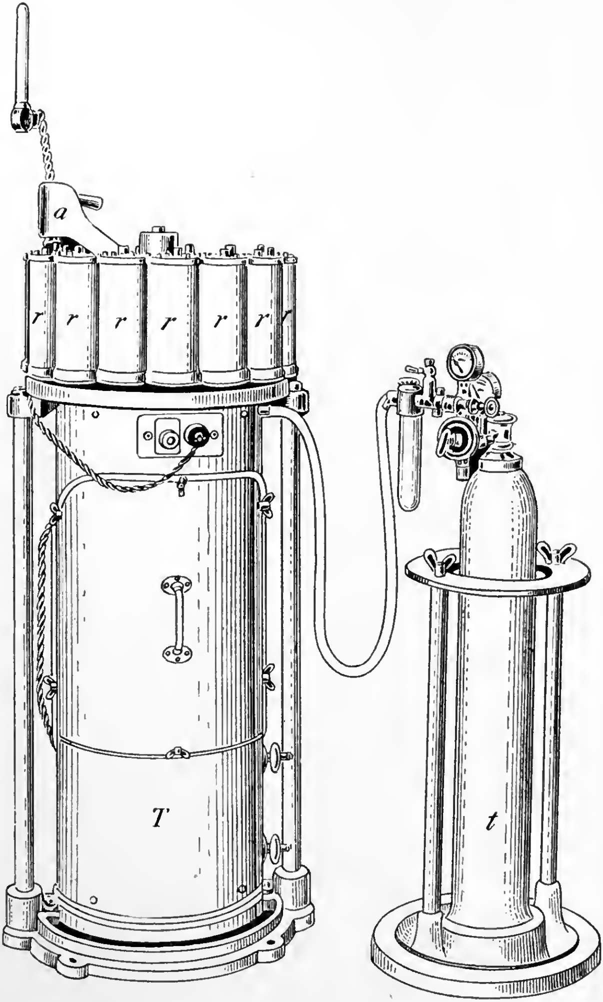


Apparatus and method employed for breathing air charged with the emanation of radium or thorium.

is rather meager. In other words, the radium salt gives a slower and more prolonged effect than the emanation; the time depending entirely upon how long these salts are contained within the body, which in turn depends upon their solubility. The insoluble salts, if administered by mouth, in all probability simply pass through the gastro-intestinal tract, and are to all intents not absorbed; but the emanation given off by them is absorbed and this in turn disintegrates into the other radium elements in the juices of the body, in the proportion of that which is contained within the body before elimination. There seems to be less likelihood of producing alarming results with the radium elements than with those of the corresponding salts of thorium, possibly due to the fact that the radium salts are less active in their disintegration. The usual method of employment of radium is in the form of the emanation, which has an average life-period of five and a half days. The emanation of thorium has a period of life of seventy-six seconds, and therefore its rapid disintegration does not permit its partial elimination from the body as a gas in the same manner as the former. However, where a very marked reaction is desired, the thorium elements are to be preferred.

Dosage.—Dosage depends somewhat upon the desired effect but may be divided into two classes. First, those which call for slight exhilaration in the physiological forces, and second, those which call for a profound effect. In the former baths, drinking-water, and the breathing of relatively small amounts of radio-active water or air are employed, and continued for some time. A month or two before cessation, then after an intermission of a few weeks or a month, another course begins, and this regimen is continued until the desired result is obtained or the treatment for some reason is abandoned. On the other hand, where a profound effect is desired, hypodermic injections are given into the deep muscular tissues, or where a still more rapid action is desired, are given directly into one of the veins. Where this procedure is adopted, the ordinary method of giving these injections must be rigidly employed. At times there may be some reaction locally, particularly if

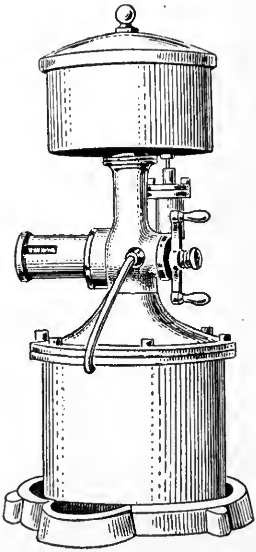
Fig. 69



Large emanator for charging air. The small cylinders (r) contain a solution of radium; the arm (a) rotates and is adjusted by a lock attachment that mechanically opens the cylinder (r) to which it is attached. Oxygen is supplied by the tank t, while the apparatus contained within T is used for pumping the exhausted air from the room. The emanation from one small cylinder is for one day's treatment.

the salt is one of those which is not easily dissolved; it, however, is rarely employed.

Fig. 70



Emanator for charging drinking-water. The handle on the side prevents the withdrawal of an excess amount.

The different metabolic processes of the body are materially affected and there is more or less disturbance of the relation of change in all albumin and sugar compounds, as well as in the purin products. These changes produce a decided difference in the gases eliminated by the lungs; the interchange of the oxygen and carbon dioxide are relatively higher, as are the compounds of nitrogen, which is noticed more especially in the formation of urea; and by its diuretic action the amount of urine and its constituents are decidedly increased. There is also a marked stimulation of the organs of generation, both in the male and female, which is specially noticeable in women suffering from amenorrhea.

Changes are often observed in the blood, particularly in the beginning, when there may be a decided leukocytosis. This may be influenced by the action of these radio-active salts upon the bone-marrow, where it is supposed to be stored. The blood-pressure often rises abruptly, then gradually sinks until it goes below normal and remains there for an indefinite period, depending upon the dosage. Cases having myocarditis and extensive arteritis must be observed carefully when under treatment. While the secondary effect is most desirable, the primary effect must be carefully guarded.

Pneumonia and Other Pulmonary Diseases.—Von Noorden placed a patient suffering from croupous pneumonia in a room where the air was charged with 100 Mache units of emanation per liter for the influence upon the circulation and metabolism. This caused a decided fall in the temperature, with a rapid absorption of the exudate. The subjective symptoms were also much influenced during the time spent within the emanatorium, the patient being able to breathe with decidedly more freedom. Other authors have treated obstinate cases of chronic bronchitis, bronchiectasis, and allied conditions by similar methods.

Rheumatism and Gout.—The various forms of rheumatism, gout and diseases of this nature are to a very marked degree influenced by drinking or bathing in waters charged with radium or its disintegration products, and where the severity of the case calls for a more profound influence, the desired result may be obtained from hypodermic or intravenous injection. To these points reference has been made under other chapters.

In diabetes mellitus the influence upon metabolism is reported to have caused to some extent a lessening of the glycosuria. This was accomplished by drinking water containing a high percentage of emanation. The influence in lessening the pain that often accompanies the neuritis in these cases was also quite marked.

It has been found of value in corpulency for the same influence upon the metabolism of the tissues of the system.

Anemia.—In the various forms of anemias, both primary and secondary, radium may be found of value in conjunction with iron and other forms of treatment; especially in those cases where there is a decided splenic involvement; or where the lymph glands are enlarged as in tuberculosis of these glands; or in those cases which tend to bronchial asthma. In splenomegaly the internal treatment should be aided with external radiation. While the blood in these conditions may be markedly influenced, the actual cause of the existing disease is not materially altered.

Diseases of the Nervous System.—Cases of neuritis and neuralgia have been influenced, and under some conditions relief has been complete. This, however, depends to some extent upon the direct underlying cause. In a list of 73 cases of sciatica, published by Sommer, 40 were cured, 23 improved, and 10 were not influenced by the treatment. The pain that accompanies the cases of locomotor ataxia is also relieved in the same manner. Even such diseases as paralysis agitans, multiple sclerosis, syringomyelia, and Friedreich's ataxia were reported to have been improved. The usual method employed in the treatment of these conditions has been the drinking of water containing the emanations, accompanied with baths or external radiation, where the local character of the process favors this method. Intravenous injection is only employed in acute cases where a reaction of a most decided nature is desired. Where the baths or local applications of packs or compresses are to be employed, the routine procedure of some institution is most desirable, and the results from favorable surroundings seem to be far better than those where the patient has the liberty of his home. In cases such as trigeminal neuralgia or sciatica the process may require local radiation from a strong applicator containing enough radium to produce some reaction, made by ordinary methods; while in cases of syringomyelia and other spinal disorders the radiation of the spine may be required in the same manner.

Caution should always be taken in the administration of radium internally in all cases of low vitality; in severe grades of anemia; heart disease of various forms, particularly those associated with a myocarditis; or where there are severe degenerative changes in the nervous system. The profound changes in the blood and blood-pressure are liable to cause considerable disturbance in hysterical cases, also in women about the time of the menopause, and for the same reason cases of pulmonary tuberculosis where there exists a tendency to hemorrhage.

Conclusions.—The exact status of these radio-active elements in internal medicine is by no means a settled question, perhaps the observations in some instances have been greatly exaggerated; yet, at the same time, from an experimental stand-point, these elements produce changes which have been noted by most careful observers who practically agree upon the salient points, and from their deductions it is rational to adopt some of the conclusions which have brought about the application of these elements. But as most of the diseases in which they have been employed belong to a class for which certain forms of treatment have been periodically promulgated to be used for a short time, and finally be forgotten, more proof must be given of their efficiency before they can be universally adopted.

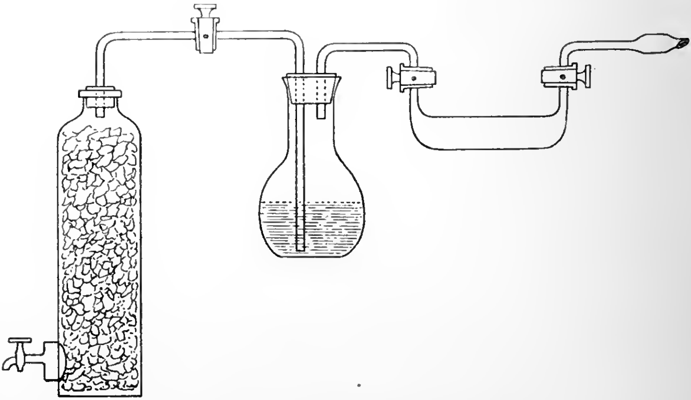
CHAPTER XXI.

THORIUM IN INTERNAL MEDICINE.

Properties of Thorium—Lethal Doses—Methods—Rheumatism—Gout—Anemia—Leukemia—Diseases of the Circulatory and Nervous Systems.

THE physical properties of thorium X have led to its almost universal adoption for internal administration. Of all these radio-active elements it is best adapted for this purpose; the reason being its rapid decay. If, for instance, a given quantity of a soluble salt of radium is taken into the body, it is absorbed, and most of it is eliminated as radium in the same proportion, except that small amount which passes into the emanation during the cycle and which remains in the tissues. If it is supposed that the radio-activity of this salt is to be the therapeutic agent, only that portion which changes into the emanation, and then the small portion of the emanation which changes into the "product of active decay," will fulfil this mission. The emanation being a gas, will, like all gases, be eliminated through the lungs and to some extent by other excretory organs. Most of this emanation leaves the body before it has time to change into the lower radium elements, and thus under these circumstances rapid elimination is to be expected. If the salt of radium is insoluble, the "radium element" remains in the system somewhat longer; but the same eliminative process holds in regard to the emanation which it produces. In comparison with this, the salts of thorium show a radical difference, and should, from a therapeutic stand-point, be more efficient under these conditions. The element employed is thorium X, an element of the salt-forming class, with a disintegration period of about the same time as radium emanation. Its disintegration forms the thorium emanation, which is also a gas but with a very rapid period of disintegration, being a cycle of only

Fig. 71



Apparatus for charging air with the thorium emanation. Large flask contains lime for drying the air, while the small flask contains one of the thorium elements.

a few seconds. It then passes into thorium A, which has a still shorter life. This is the first element of the "product of active change;" it disintegrates by degrees to thorium B. Under these circumstances the amount of energy is far greater than that eliminated by radium in the same space of time; and, therefore, if this energy is of therapeutic value, it would seem that thorium X is by far the most rational to be employed for internal administration. Even where the emanation is employed, if it is taken into the lungs as a gas, the circulation absorbs it and before it is returned to the lungs again it has been changed to a solid that must be eliminated by such organs as serve that purpose.

From the observation of the effects of thorium upon individuals, and from experiments upon animals it has proved to be much more active than radium; and large doses of these thorium elements must be given with care, particularly to the weak and debilitated. Deaths from this cause have been reported; therefore the administration of large amounts of radio-active solutions is attended with more or less risk, and under all circumstances must be carefully guarded. The effect upon the blood-pressure is sudden and profound, swinging from a decided increase, which may be maintained for some time, to a rapid decline, passing as far below the normal as it had been above. These changes are not prone to be accepted without a marked impression upon the whole body, and caution must be used in those conditions attended with a poor cardiovascular system.

The internal employment of thorium X for its therapeutic value has been recommended in such diseases as the various forms of rheumatism, gout, in blood diseases, such as pernicious anemia, leukemia of various kinds, and even to reduce the amount of fat in extreme cases of corpulency. In all these cases the desired action of the thorium is that of a powerful alterative, causing an extremely rapid tissue change; and, by the effect upon the metabolism of the body, causes a reconstruction and thus restores healthy conditions.

In some acute diseases it has been employed to absorb an exudate, and with its effect upon blood-pressure, von Noorden has found it to be of value in croupous pneumonia, the daily amount being about 100 Mache units per liter, and its influence is believed to be upon the air in the lung from the contained emanation. Where radium or thorium is to be employed hypodermically or intravenously, it should be prepared in a sterile ampula and given under aseptic precautions, the dosage depending upon the element.

In common with the other radio-active elements, it has a decided diuretic action, which in gout seems to be of more or less value. Combined with this action is the powerful effect upon the blood; and according to His, the proportion of uric acid contained in the urine and blood is decidedly altered. The metabolism of all nitrogen products is favored.

Gout.—Gout may be treated either by the drinking of waters containing thorium X, or air may be drawn through the water containing thorium X, which is constantly giving off the emanations; this, taken into the lungs, enters the circulation. In these cases, however, the amount of water taken into the system aids somewhat the elimination of the effete products.

Anemias.—Both the primary and secondary forms are most decidedly benefited by these radio-active elements. In the secondary forms resulting from hemorrhage due to various causes, such as gastric ulcer or duodenal ulcer, also those incidental to childbirth, recovery may be hastened by the administration of waters charged with this element. Obstinate cases of chlorosis will be assisted, especially in the exaggerated grades. The administration of iron also seems to be necessary.

In *pernicious anemia* these radio-active elements have in some instances produced an increase in the blood supply for a temporary period. The changes that have been observed are by no means constant, and while a few react favorably for a time, in many others absolutely no change is observed; this may be due to the fact that very few practitioners have the courage to give large enough doses to produce this change, realizing that by so doing death is likely to occur, and since the benefit enjoyed is at least only temporary, it would seem that these large doses are scarcely justifiable. The secondary anemia has been treated by the administration of radio-active waters by the mouth or by inspiration of air containing the emanation, but Meseth[1] recommends the injection of a solution of thorium X, given slowly and injected deeply into the gluteal region. He usually begins with a solution containing about 50 electrostatic units, increasing gradually to about 300; each injection is given about five to seven days apart, the total number being from six to twelve. The more severe grades of anemias are all treated by hypodermic or intravenous injection, the strength of the solution varying with the judgment of the observer, as no standard has been established.

Leukemia, both the lymphatic and myelogenic varieties, has been treated by all forms of radiation and often temporarily benefited, and if under some conditions one form of radiation fails, this is no indication that the other will not prove beneficial. The fact is frequently observed that in cases where the Roentgen rays produce no improvement, they will be singularly influenced by these radio-active

[1] Münch. med Woch., September, 1913.

elements; and in those cases of myelogenic leukemia where the spleen is greatly enlarged, powerful applications of mesothorium will reduce this organ considerably, with the same improvement in the general symptoms. Besides the local application, the method that has been employed with some success is the intravenous injections of thorium X. The amount of improvement is still questionable, and while some have reported what they consider brilliant results, others have failed to observe any change whatsoever. Rosenow[1] presents a series in which the injections of thorium X failed to produce the least improvement. One case, however, is particularly interesting, where the blood-counts are given, showing the effect of these injections in comparison with the Roentgen rays.

A Russian woman, aged thirty-six years, developed myelogenic leukemia three years before coming under observation, and was for a time treated by the Roentgen rays with some benefit. At that time the leukocyte count was 159,000 and dropped to 11,300; while the red cells were increased to 4,140,000, the hemoglobin from 58 to 80 per cent. The spleen, which was several finger-breadths below the border of the rib, receded until it was well within that line. For a time her general condition was good, but about a year after the treatment was discontinued she was in practically the same condition as when she first came under observation. At this time it was decided to try the injections of thorium and the following table gives the results:

[1] Münch. med. Woch., October 7, 1913.

Date.	Hemoglobin.	Red.	White.	Date.	Hemoglobin.	Red.	White.
Nov. 14	60	3,632,000	110,800[1]	Jan. 2	42	2,720,000	64,000[4]
15	..	....	114,000	4	..	....	....[4]
16	..	....	98,400	6	44	2,802,000	60,200[4]
17	..	....	80,000	9	..	....	....[4]
18	52	3,061,800	98,200	11	50	3,016,000	54,000
19	..	....	118,200	14	..	....	....[4]
20	40	....	120,000[2]	16	58	3,245,000	43,000[4]
21	32	2,910,000	103,000	18	..	....	....[4]
23	30	3,182,000	89,600	19	60	3,290,000	31,900[4]
24	40	2,980,000	100,000	23	..	....	....
25	40	3,190,000	93,000	24	..	....	....[4]
27	40	3,184,000	86,000[2]	25	..	....	34,600[4]
29	40	3,750,000	62,800	27	..	....	....[4]
Dec. 1	38	3,331,000	60,400	28	..	....	....[4]
3	42	3,344,000	54,800	30	..	....	....[4]
4	..	....	....[3]	Feb. 1	58	3,678,000	33,400
7	50	3,590,000	64,000	4	..	....	....[4]
10	50	3,541,000	59,000	6	58	3,496,000	24,600
11	50	3,262,000	68,000[2]	8	..	....	....[4]
14	..	....	47,000	11	55	3,100,800	19,200[4]
16	42	2,852,000	60,000	13	..	....	....[4]
17	40	3,198,000	72,400	17	48	2,932,000	31,800
18	..	....	....[2]	19	55	3,523,000	44,000[2]
20	40	3,240,000	95,200	22	55	3,127,400	28,600
22	44	2,870,000	81,600	Mar. 1	..	....	....[2]
23	..	....	....[4]	7	32	1,872,000	27,800
24	..	....	....[4]	13	33	2,124,000	25,400
25	42	2,500,000	116,000	15	..	....	....[2]
27	..	....	....[4]	26	20	1,040,000	78,200
30	..	....	....[4]				

The patient complained of more or less pain over the area of the enlarged spleen, and it was for this reason the change in treatment was adopted. Death occurred the day following the last treatment and the postmortem showed

[1] Thorium X solution, containing the equivalent of 0.4 mg. of radium, given intravenously.

[2] Thorium X solution, containing the equivalent of 0.5 mg. radium, given intravenously.

[3] Thorium X solution, containing the equivalent of 0.4 mg. radium, given intravenously.

[4] Splenic area subjected to the Roentgen rays.

the usual conditions to be expected in these cases. The author states that possibly more effect could have been produced if larger doses of thorium X had been employed; but the woman's condition was such that he did not care to risk the toxic effect, which, when produced, cannot be controlled. In contrast to the foregoing Meseth[1] reports the following case:

A man, aged forty-six years, first came under observation five years before. At that time he had previously been treated by the Roentgen rays, and during another period by arsenic. He had also submitted at one time to some surgical operation. For a time he improved under the Roentgen rays, but became discouraged and then tried injection of the kakodylates. The highest count of the leukocytes at this time was about 58,000, but usually ranged between 12,000 and 30,000, and while the spleen was greatly reduced in size it never approximated normal, while it had extended three finger-breadths below the border of the ribs, and the blood always showed the presence of myelocytes. About a year previous to this report the patient was placed upon injection of thorium X, given twice weekly, and the strength of the solution varied from 100 to 300 electrostatic units. Fifteen injections were given, and this brought the leukocytes down to 6,000. The myelocytes had disappeared and the spleen could scarcely be felt. Some time afterward, when he was again seen, the leukocytes had risen to 12,000. Another injection of thorium X was given and since then the patient has been in a fair condition of health.

Thorium X may be employed for lowering the pressure of the circulation in diseases of the cardiovascular system.

[1] Münch. med. Woch., September, 1913.

Where it is employed, small amounts should be given so as to accustom the organs to it. This is best accomplished by giving it in drinking-water, or by breathing the emanation directly from an emanation apparatus. Diseases such as myocarditis and arteriosclerosis have been treated by this method with considerable benefit from the fact that their blood-pressure, when lowered, remains constant for some time, allowing the circulatory system to regain its tone by meeting with less resistance.

Neuritis of various forms may be relieved by the radio-activity of thorium, which may be taken into the system in drinking-water; or in acute cases local injection of thorium X may be found to be of value. As in cases of sciatica, injection along the course of that nerve of from 100 to 300 electrostatic units, given at intervals of a few days, will aid in the relief of these most obstinate conditions.

The lancinating pains of tabes will be relieved by intra-muscular injection of thorium X, best given in the gluteal region. While it has no effect upon the course of the disease, the relief afforded in these cases is a distinct advance.

CHAPTER XXII.

RHEUMATISM, GOUT, AND ALLIED DISEASES.

Radium Salts in Solution—Emanation in Solution—Arthritis, Acute and Chronic—Infectious Arthritis—Arthritis Deformans—Gout.

While the exact pathology of diseases included in this class is not definitely understood, the adoption of any form of treatment for their relief has been purely upon empiric grounds. Perhaps they may be due to a toxemia from poisons eliminated within the economies of the individual, or they may be due to some influence from without; in either event the cause is not definitely known, and therefore at the present time is of no material concern. Radium or mesothorium introduced into the system produces more or less reaction, depending upon the dosage and the idiosyncrasies of the individual. From this reaction certain results are observed where the manifestations are a local inflammation of tissue, accompanied with pain and tenderness. A subsidence will be noticed with a restoration of the parts to a normal condition. Later cases with distinct changes in structure are also benefited by the relief from pain, and by checking to some extent the advance of the disease, even at times when these changes have passed to the stage of producing actual deformities. Such conditions as simple and chronic arthritis, chronic muscular rheumatism, progressive polyarthritis, infantile arthritis, gonorrheal monoarthritis, polyarthritis, arthritis deformans, and gout, have been included in the list. In the last two diseases, if the condition has advanced, only temporary improvement and relief can be given; for, if the bone changes have passed to the stage where deformities have resulted, repair is impossible. There are also some general contra-indications for the use of these radio-active elements, and if applied or given internally, the greatest caution should be exercised; the most important are those where a tendency to purpura is observed, and, to a lesser extent, where erythema exists. It must be remembered that where these elements are introduced into the system the changes in the blood are apt to be at times somewhat startling; therefore it is necessary to proceed carefully. In certain forms of acute arthritis of the specific type, or a very acute exacerbation of an old process, treatment should not be undertaken until it has subsided into the more chronic form. With the exclusion of these few contra-indications, treatment, if well regulated and used moderately, will, as a rule, be attended with a successful issue.

Cameron[1] reports a list of 66 cases treated.

In this list he has divided the cases according to the following classification:

Cases are placed in the *acute stage* when motion in the affected joint is not impaired other than by the acute inflammatory process, and when there is a constant temperature curve.

Subacute Stage.—When the joint can be moved by voluntary or passive motion without causing additional or recurring local inflammatory symptoms or fluctuations in temperature.

[1] Penna. Med. Jour., 1913.

Type of Cases.	Number treated.	Not improved.	Improved.	Cured.	Still under treatment.	Discontinued during treatment.[1]
Acute primary infectious arthritis . .						
Subacute primary infectious arthritis .	5	. .	. .	5		
Chronic primary infectious arthritis .	4	. .	. .	2	. .	2
Acute secondary infectious arthritis .	3	. .	1	. .	. .	2
Subacute secondary infectious arthritis.	14	1	1	7	2	3
Chronic secondary infectious arthritis .	17	1	2	2	5	7
Acute primary infectious arthritis .						
Subacute primary infectious arthritis .	3	. .	. .	3		
Chronic primary infectious arthritis .	6	1	1	2	1	1
Acute secondary infectious arthritis .						
Subacute secondary infectious arthritis.	2	. .	1	. .	. .	1
Chronic secondary infectious arthritis .	12	4	2	2	3	1
	66	7	8	23	11	17

Chronic Stage.—When degenerated or organized exudates cause fixation and deformity.

The method of treatment outlined in these cases was the inspiration of 0.025 to 0.1 microcuries per liter of air, in an emanation room, for at least one and one-half hours each day; with this, 1 liter of emanation drinking-water containing 15 to 20 microcuries per liter, which may be divided into four doses. This procedure is recommended in acute cases. Where they tend to a more chronic character it is necessary to carry large amounts of the emanation into the system by more and stronger emanation waters, and also by the inspiration of charged air for a longer period. If, however, the patient is not benefited in a period of sixty days, usually the case can be regarded as one not suited to

[1] Patients not under treatment long enough for any effects.

this form of treatment. Cameron has, however, observed several of these most refractory cases yield to this method. Under some circumstances he has found the hypodermic or intravenous injection of radium salts beneficial, and regards the dosage of 25 to 100 micrograms, administered about every ten days, as being perfectly safe except in cases complicated by any heart lesion or advanced arteriosclerosis. The microcurie per liter adopted in these observations equals a concentration of about 2700 Mache units.

The wide variation of different methods is extremely interesting, and while the results seem to be about the same under the several conditions, the application of one method will often be more adaptable to the convenience of a given case.

Acute articular rheumatism, under ordinary circumstances, yields to the administration of salicylates and the adoption of the ordinary routine treatment. However, there are frequent instances where at times the disease seems to be rebellious, and where such conditions prevail the use of these radio-active elements may be justifiable. This may be accomplished by the administration of emanation water, which should be slowly sipped; in this manner the emanation is taken into the body slowly and is eliminated in the same manner; or a small emanator for charging the air of the room may be installed for the patient's use. Packs or baths may also be employed. The amount of emanation recommended has been from about 200 to 10,000 Mache units per day. Von Noorden, in the treatment of these cases, has seldom given less than 200 Mache units per liter per day or more than 1200. Under the influence of this dosage the results have been most favorable; but he believes that severe endocarditis or pericarditis complicating acute rheumatism is a contra-indication for the employment of this form of treatment, due to the effects upon blood-pressure.

Secondary chronic articular rheumatism should not be treated until the source of infection has been relieved. Upon the removal of the offending foci the use of the emanation of radium or the radium salts is justifiable, and only the small dosage of about 100 Mache units should be employed. The best results are observed in those instances where, after the general conditions have subsided, the remaining infection has localized in one joint.

Arthritis of gonorrheal origin is often benefited by the local application of radium, and even in the later stages, where considerable exudates have been thrown out about the joint, much relief is afforded by the absorption of the products of inflammation.

Arthritis of specific origin is not benefited to a degree worth considering.

Chronic rheumatic arthritis of different types may be relieved and to some extent the fibrous exudate may be absorbed. Where, however, there has been absorption of the joint surfaces, with erosion, the outlook is more or less hopeless; though it may be possible even under these circumstances to soften the process to some extent and allow the limbs to be placed in better position. The muscular contraction that has taken place coincidently often limits this correction. Both the local and internal use of radium is employed in these cases; the emanation taken internally by breathing charged air, or the sipping of emanation water; locally by baths, packs, compresses of the emanation, or the use of radium from an applicator giving off a high activity. The emanation of radium is employed in doses of 100 to 1200 Mache units per liter per day. In those cases where these applications cause a rise of temperature, caution must be exercised.

Arthritis deformans, one of the most rebellious forms of joint manifestation, has to some extent been strikingly benefited by the use of radium. Pinch (London Radium Institute) has adopted the following technique in the treatment of cases in that institution. The individual receives 250 c.c. of radium emanation solution of a strength varying from 1 to 2 microcuries per liter each day, and this form of treatment must be continued for a long time. Usually, after the daily administration of the amount for about six weeks, some slight improvement is noticed. In favorable cases the articular and muscular pains lessen and disappear, the movement of the joints is much freer, with less grating, the muscles controlling the affected joints regain to some extent their lost tone, and the general health of the patient decidedly improves. Attention is called to the diuretic action of the emanation, and at the same time it seems to be slightly laxative but not purgative. Out of a series of 21 cases 1 was cured, 9 improved, 5 did not improve, 1 abandoned treatment, 1 was rejected, while 4 still continue under active treatment. The details of a few cases may be interesting:

A woman, aged fifty-two years; disease of twelve years' duration. First symptoms were limitation of flexion at the hip-joint and pain under the gluteus maximus of an intermittent character. These symptoms gradually increased in severity for ten years, but in about one year before treatment began she had an acute exacerbation, and all movements at the hip-joint became restricted and attended with intense pain. This increased until it became so severe and constant that she was only able to sleep for half an hour at a time, and became extremely worn and emaciated. Every possible form of treatment, dietetic and medicinal, had been tried without effect. This patient was under treatment for about eleven weeks, but no improvement was noticed for six weeks. From that time on it was both steady and rapid, and a year later, when seen, she could sleep in any position without discomfort, stand without effort, and even button her shoes, which she had not done for over ten years.

A man, aged thirty-five years, came under observation with disease of nine years' duration, which started in the knee-joint, and was thought to be tuberculous. Splints were placed upon the joint which caused ankylosis. A year or so later the disease appeared in the wrist and elbow; these also become completely ankylosed and other joints were also affected, but to a smaller extent. The patient had been treated with hot air, pine- and electric-baths, high-frequency massage, and various forms of medicine, but nothing served to arrest the progress of the disease. He was given two courses of treatment with radium emanation solution. Each course lasted six weeks, and the patient drank 250 c.c. of this solution every day except Sundays. There was an intermission between each course of treatment of about four months. A month later he was examined and found to be much freer in all movements and also free from pain. He could dress himself completely without help, except putting on his shoes. His general health was excellent. Other cases are also mentioned with equally encouraging results, and, like most of this class, other forms of treatment had failed or produced only very transient amelioration of the symptoms.

Gout.—These radio-active elements have been employed in the treatment of gout; and some claim that success followed their efforts, more particularly by influencing the course of the disease than relieving the inflammatory conditions. In fact, the acute stage of this disease is regarded by some as being a contra-indication for the employment of these elements. Where the disease has progressed to the stage of malformation very little benefit is to be derived from this form of treatment, but the influence upon the metabolic changes in the system no doubt has some effect upon its course. The treatment in these cases is usually confined to the drinking of emanation waters in conjunction with baths and local applications. The amount of water taken into the body also aids to some extent in carrying off the effete products, while the elimination of the nitrogen products is also decidedly altered. The inhalation of air charged with the emanation is also practised; but the injection, intravenously or hypodermically, is rarely necessary.

Gout, being a disease that seems to be influenced to a great degree by dietetic changes, may be often benefited by this regimen alone; therefore, when the cases are placed under treatment, this important point must be given some attention. It also explains why so many of these cases are benefited in well-equipped sanatoria and not in their own homes.

CHAPTER XXIII.

TREATMENT OF UNTOWARD EFFECTS OF RADIO-ACTIVE ELEMENTS.

Acute Burns—Chronic Dermatitis—Comparison with Roentgen Burns—Thorium Dermatitis.

THE deleterious effects of these radio-active elements upon the patient or the laboratory worker do not seem to be so refractory or dangerous as those of similar nature received from the Roentgen rays. Some have ascribed this to the care exercised in handling these elements, sufficient warning having been obtained from disasters caused in the early days of Roentgenology. This, however, cannot be the real basis, for it is evident that numerous burns have been caused experimentally and accidentally, and they invariably yield in a shorter time than similar conditions of Roentgen-ray origin. However, we must consider these "burns" in exactly the same manner from their method of origin, and divide them into acute and chronic, due to the length of time of exposure to the activity of these elements. Likewise, the patient is the usual sufferer from an acute "burn," while the laboratory worker will be the subject of the chronic "burn."

Acute burns usually appear at an indefinite period after the exposure to one of these radio-active elements, and may result from one application or a series of them. The extent and character depend upon the amount of radiation received and the idiosyncrasy of the individual. The pain varies in these cases and in no way seems to be dependent upon it. The time required for recovery is much shorter than that observed in x-ray cases, and both the subjective and objective symptoms are equally rebellious. The pain often necessitates a general narcotic, continued from the pre-ulcerative stage to long after the scar has formed. The ulcer should be dressed according to the usual surgical procedures. Ointments of various kinds have been recommended and tried, but they are of doubtful value.

In those cases where there is only a slight blistering or even an ulceration of the superficial structure, treatment of any form is not necessary, except for protection that would naturally be given. Healing in these instances is usually prompt, as the whole course is often only a period of a few weeks, and the patient suffers very little discomfort during its active stage; in fact, in some instances, where applications have been made in diseases where pain existed, the relief from suffering is frequently observed under these circumstances.

Where these burns occur in conjunction with Roentgen treatment the ulceration closely resembles that of the Roentgen burn and not that of the radio-active elements; this is not difficult to explain. If the tissues have been damaged by the Roentgen rays, then the radiation of these elements is more or less localized and these tissues, not being able to resist the influence of the combined radiation, necessarily break down. This condition is well illustrated by the case of sarcoma of the sternum reported under that designation in Chapter XVII, Fig. 61.

Here the healing has been most protracted, and the whole course resembled more the Roentgen burn, although decidedly more localized.

The treatment of these cases, like those due to the Roentgen rays alone, is extremely refractory, and nothing so far recommended seems to influence their course in the least; healing is extremely slow, and the accompanying symptoms may be just as variable as those of the true Roentgen ulcer.

Workers in radium laboratories are subjected to a condition differing from the usual action of radiation, in that usually the period of warning is sufficient to allow the victim to recover without the more malignant effects seen in the worker of the Roentgen laboratory. Where these workers are exposed to the rays alone, they usually develop a condition of the hands that renders them extremely sensitive to heat and cold, noticed particularly in washing or handling hot or cold objects. This is especially apparent about the finger-nails. If the person withdraws from his vocation and ceases to handle these radio-active elements the condition rapidly subsides, and in a few weeks or months he may return to duty and be perfectly comfortable until the exposure again causes this same condition of hyperesthesia.

A number of these attacks at times produces more lasting results, such as an anesthetic condition of the affected part, attended at times with peeling of the skin, which, while not as a rule painful, is most objectionable and annoying.

When, however, the person is handling naked radio-active elements, the effect is quite different, and depends to some extent, upon whether that element is a gas or a solid; although in either case if it once touches the surface of the body it cannot be removed without also including the surface. Reference to this phenomena has been made under other headings. Therefore, if one of these elements should come in contact with the body, the result must be a burn of some degree, and, strange as it may seem, these processes are not so violent as similar conditions from the Roentgen ray; the erythema produced not being so uniform over the radiated area. Although milder in character, they produce irritation, and while so far no cases of actual malignancy have been reported with the increase in the manufacture of this product and the usual carelessness observed, there is every likelihood that these conditions will be noticed in the future.

Thorium dermatitis has been reported among workers in this earth. It resembles a mild Roentgen-ray dermatitis of a chronic character. Keratosis, warts, stiff hairs, usually appearing upon the hands and upon the exposed portions of the body, were thought at first to be due to the irritating property of these thorium products, but could be attributed more probably to their radio-activity. The only relief in these cases is simply to have the victims abandon their occupation.

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