the former parts. The mouth and buccal cavity are first dealt with and then the pharynx or pumping organ, the mechanism of this in suction being explained by the contraction of the latero-ventral dilator muscles making the slit-like lumen nearly circular. The authors thus agree with Meinert, who long ago described this organ. Three theories as to the function of the three sacs given off at the posterior end of the oesophagus are mentioned; (1) That of Giles, who claims that they act like the air-spaces in birds, but as this author has fallen into the error of estimating the number as two without any organic connexion with the alimentary canal, his contentions are untenable; (2) that of Grassi, who claims for them a suctorial function; and (3) that of the authors, who believe them to be food reservoirs. A series of fourteen experiments consisting of feeding mosquitos with sugar-carmin serum or sugar serum shows clearly that food does go into those sacs, and the explanation is therefore probably correct, though the presence of the air bubbles still requires clearing up. The extension backwards of the ventral or large reservoir to the sixth or seventh abdominal segment does not agree with Grassi's figures, which show it extending only for a short distance into the abdomen, and certainly sections support the latter's views. The other parts of the intestinal canal are admirably described, and the salivary glands are dealt with fully. The effects of the salivary secretion on different individuals is a subject that might well be taken up, as also the saliva of the different genera of mosquitos, as it is well known that some cause great irritation and others hardly any. It is unfortunate that the other systems—circulatory, nervous, respiratory, and reproductive—have been omitted, but a promise is given that they will be published elsewhere. A bibliography of recent literature on malaria relating chiefly to prophylaxis, epidemiology, and mosquitos, forms a useful appendix.

INDIAN HISTORY AND FOLK MEDICINE.

THE origin of Lieutenant-Colonel CRAWFORD'S *Brief History of the Hooghly District*,¹ is in this wise. Colonel T. H. Hendley, Inspector-General of Civil Hospitals, Bengal, while serving in Central India, prepared a medico-topographical account of Jeypore, which was followed by several others compiled by medical officers serving in other native States. These were published by the Government of India in the Foreign Department. One volume of this series—a description of the Western Rajputana States by the late Lieutenant-Colonel Adams, I.M.S.—was reviewed in the *BRITISH MEDICAL JOURNAL* of February 10th, 1900, p. 322, and the remarks made thereon indicate the scope and value of these works. On his appointment to the Civil Medical Administration of Bengal, Colonel Hendley invited the civil surgeons under his control to prepare similar reports, and the book under notice is one of the first fruits of this movement. Dr. Crawford appears to have devoted himself to his task with energy, and to have produced a most elaborate and able account of his district. The volume under notice is but a fraction of it relating to the history of this, the most interesting portion of Bengal in which Portuguese, English, Dutch, French, and Danes established settlements, for purposes of trade, fought with the native rulers and amongst themselves, until the English eventually asserted their supremacy, and with the exception of the small French settlement of Chandernagore, succeeded in ousting their rivals and supplanting the natives in the government of the country. The story of these struggles is told by Lieutenant-Colonel Crawford, who has a special talent for historical and antiquarian research, systematically, clearly, accurately, and most entertainingly. In addition, information is given regarding ethnology and folk lore, and a description of the deities who preside over diseases and crafts, and of the rites and offerings by which their favour is propitiated or anger appeased. The work is a most valuable one, and offers in moderate compass a complete account of events which contributed materially to bring India under British domination.

¹ *A Brief History of the Hooghly District*. By Lieutenant-Colonel D. G. Crawford, M.B., I.M.S., Civil Surgeon of Hooghly. Calcutta: Bengal Secretariat Press. (Demy 8vo, pp. 184. 1s. 10d.)

THE COST OF CONSUMPTION.—From a compilation of statistics, Dr. H. Biggs, of New York, shows that the prevalence of consumption among the poor alone costs the city of New York £4,600,000 and the United States £66,000,000.

RADIUM.

A METHOD OF APPLYING THE RAYS FROM RADIUM AND THORIUM TO THE TREATMENT OF CONSUMPTION.

By FREDERICK SODDY, M.A.

(From the Chemical Laboratory of University College, London.)

SOME strikingly successful results obtained by Mr. Mackenzie Davidson in the cure of rodent cancer by the use of the rays from radium, the success of Professor Gussenbauer in the same direction recently reported from Vienna, and the well-known general germicidal action of the rays from radium, have suggested that possibly medical men will be interested in some recent physical discoveries which make it practicable to apply the same agency to the treatment of consumption. What is needed, of course, for this purpose is a radio-active gas which can be breathed into the lungs. Such an agent is to be found in the so-called "radio-active emanations" which are being spontaneously and continuously produced by the elements radium and thorium, and which were discovered and fully investigated from the physicist's point of view by Professor Rutherford, of McGill University, Montreal. A short account is given here of the properties of the two emanations, so far as is necessary for the present purpose, and of the methods by which these agents can be most efficiently employed, in the hope that those who have the opportunity may be induced to carry on research in the treatment of consumption with these new weapons.

Radium and thorium are both spontaneously radio-active elements, the former being roughly a million times more powerful than the latter. The general resemblance in the rays of the two elements make it extremely probable that the physiological action will prove to be the same in kind, differing only in degree. The difference of degree is, however, enormous. Thus five minutes' application of a radium salt, would, *caeteris paribus*, be equivalent to ten years' application of the same weight of thorium salt. Both elements continually and spontaneously produce (in addition to their "rays") radio-active emanations, that is, gases in infinitesimal quantity, capable of giving out on their own account rays of exactly similar kind to the rays from radium and thorium themselves. It may be said at once that the absolute amount of these emanations is so infinitesimally small, being at present beyond the most refined means of detection, either chemically or spectroscopically, that no toxic action whatever is to be feared from their use. But their radio-activity, or power of giving rays, is very considerable indeed, and this is all we are now concerned with. The unceasing production of these emanations by radium and thorium is an unalterable property of these elements and takes place under all chemical and physical conditions at exactly the same rate. Sometimes, however, the emanations escape freely into the surrounding air, sometimes they do not, but remain stored up in the compounds producing them, or as the chemist would say "occluded." This depends on the physical condition of the compound in question, and those conditions under which the emanation freely escapes, so that it can mingle with the air the patient breathes, need only be considered here. The best and most certain condition for this to happen with both radium and thorium compounds occurs when they are dissolved in water. Radium compounds especially hardly give off any emanation at all in the dry solid state. Three-quarters of the radio-activity of solid radium compounds is due to the emanation which has not escaped from the compound but is stored up within it. When a soluble salt of radium is dropped into water, all of this emanation is instantly evolved as gas, and mixes with the air above the solution.

We now come to the crucial fact about the phenomena. Let the emanation be removed from the radium solution by passing a current of air through it, and let this air with the emanation be stored in a gasholder away from the original radium altogether. One-half of the emanation present in the gasholder will disappear every four days, so that in eight days there is only one-quarter of the original amount left, in twelve days one-eighth, and so on, until after about three weeks the amount remaining is negligible. But the radium solution from which it was obtained, in the meantime has grown a fresh crop as fast as the old disappeared. The law is that the sum total of the emanation in existence at any one time is a constant, provided of course that the vessels used

to store and contain it are airtight, so that no leakage of emanation occurs during the processes. When the emanation removed from the radium solution has diminished to half its initial quantity, one-half of the initial quantity has reappeared in the bottle containing the radium solution; when it has diminished to one-quarter, three-quarters is to be found in the radium solution. After about three weeks the quantity re-formed by the radium solution is a practical maximum, the same as was originally obtained on dropping the solid salt into water. The emanation from thorium behaves theoretically precisely similarly, the only difference being that instead of four days being required for one-half of the thorium emanation to disappear or be reproduced as the case may be, it only takes one minute. This makes an enormous practical difference. For a very few minutes after removing the emanation from a thorium solution it has practically all disappeared, and the original stoppered-up solution of thorium again contains as much emanation as it ever did or can contain. In about five minutes in the case of thorium, and in two or three weeks in the case of radium as much emanation disappears as is reproduced, and the quantity present is at a maximum, in the same way as the population of a country is at a maximum when the number of births for any given time equals the number of deaths.

These considerations serve to regulate the "dosage" of the emanation to the lungs of the patient. Two essential points are to be noted. First, in the case of thorium to secure the most efficient action of the emanation, the patient should breathe continually through a thorium solution. The longer he breathes the greater the dose. But in the case of radium, once he has breathed in all the emanation from any quantity of radium solution, further inhalation is without effect until the latter has stood, carefully stoppered, for a certain definite time. If the patient breathes in the emanation once a day, and the solution is kept tightly stoppered between whiles, he will get practically the maximum dose possible for any one amount of radium solution. To increase this more than one quantity of radium must be employed. The second point to be noted is that it is essential in the case of thorium to get the emanation from the solution into the patient's lungs in the least possible time, say within half a minute, or else the greater part of the emanation will disappear *en route*. For this reason the "dead air space" above the thorium solution should be as small as possible. If it is found advisable to absorb water vapour, a tube of drying material—such as pounded caustic potash—may be introduced between the solution and the mouth, but this for the reason cited should be of the smallest possible volume. In the case of the radium emanation these considerations do not apply.

A few words must be said about another property of the two emanations. Wherever they come in contact they leave behind a film of radio-active matter, which is, like the emanations themselves, invisible, unweighable, and undetectable, except by means of the rays it emits. These deposits of radio-active matter (again like the emanations) disappear at definite fixed rates; at least their activity disappears, which is all we are now concerned with. This is the cause of the much-discussed "induced" or "excited" activity produced by the elements radium and thorium on all objects in their neighbourhood. For present purposes this phenomenon is important because the excited activity would be left behind in the air cells of a patient's lungs after the emanations themselves had all been exhaled, and the action of the rays would therefore continue for a certain definite time after the treatment. In each case the effect of this excited activity continuously gets less and less, and finally disappears. The excited activity from the thorium emanation falls to half its initial intensity after eleven hours, and disappears practically in about two days; that from the radium emanation disappears in three or four hours. In both cases this effect will constitute a feeble continued action after the more powerfully radio-active emanations have all been exhaled. For medical purposes it is sufficient to know that a given dose of emanation will always carry with it a fixed and unalterable proportionate dose of "excited activity," and all considerations connected with the manner and duration of the administration of the emanation, therefore, do not affect this result.

The question might be asked, How is it possible to state all these facts so dogmatically until the treatment has been practically tried? It is the essential feature, however, of all these radio-active processes that they go on their appointed courses absolutely without regard to the environment or to

the action of any known force which may be brought to bear upon them. Thorium and radium in solution give off their emanations whatever chemical compound of the elements is employed. The emanations disappear and the excited activities are produced in their place, and these in turn disappear, at exactly the same rates, whatever the conditions under which they exist. It is, therefore, to be confidently predicted that the same laws will be found to apply when these agencies are made to act inside the living organism.

With regard to the important question as to which emanation is likely to prove the more suited for the purpose in hand; this of course is primarily a matter for trial, but it by no means necessarily follows that the advantage will be found with the more powerful agent. In the first place, there is the question of cost and available supply. A milligram of radium salt equals roughly a kilogram of thorium salt in radio-activity, but the cost of a kilogram of thorium nitrate—about £2—is only two or three times as great as the cost of a milligram of radium bromide, and whereas the former can if necessary be obtained by the ton, the supply of radium is notoriously limited. A very important point in this connexion must not be overlooked. For direct application of the rays it is probable that the thorium salts can never be sufficiently powerful to replace radium for medical purposes. A limit in the quantity effectively employable is very soon reached in practice. In the solid salt so large a proportion of the rays is absorbed that the effect is practically proportional to the surface, and this is almost always strictly limited. But with the emanations no such absorption occurs. It is as though we extracted from the radium or thorium the very essence of its radio-activity, and obtained it as a gas, in as concentrated a form as we could desire. There is no reason why the emanation from a kilogram or even, with special arrangements, from a ton of thorium salts, should not be effectively employed on the lungs of a single patient. The sole condition to be satisfied is that the air should reach the patient's lungs within, say, half a minute of time after leaving the thorium solution. The immense advantage already mentioned of thorium over radium, namely, that the effect of the emanation in the former case is proportional to the time of inhalation, must also be remembered. Indeed, every physical consideration would suggest that the feeble but more continuous action of the thorium emanation should be first tried, and this can, if necessary, be increased indefinitely by increasing the quantity of thorium and the time of inhalation. Thorium is, moreover, within the reach of every one who cares to make the trial.

A few points in the practical application of these emanations may be of value. The cheapest and most convenient salt of thorium to employ is the nitrate, as this is very soluble and is manufactured in large quantities for the Welsbach mantle industry. But this salt contains a very large amount of free nitric acid, the inhalation of which would be apt to be extremely injurious. This may be neutralized by addition of ammonia to the solution in water, with constant stirring until precipitation (of thorium hydroxide) is just about to take place. An ordinary gas-washing bottle with outlet and inlet tubes ground in would prove a convenient form of inhaler, and this should be filled as full as possible with the fairly concentrated solution. A small caustic potash tube could be inserted in the air stream before it enters the mouth, and would serve to remove moisture and also any free nitric acid, in case the neutralization had not been properly performed. If a large quantity is employed so that several bottles are necessary, these should be connected up in parallel and not in series; 100 grams of thorium nitrate in solution, and one hour's daily inhalation, might be suggested as a commencing "dose," to be increased indefinitely if no harmful results accrue. If this is without effect the more powerful radium emanation might be tried. The gas-washing bottle must be provided with two taps, so that no leakage of the precious and slowly formed emanation occurs during accumulation. A few milligrams of the dry salt—radium bromide, for example—should be introduced, and a few drops of water drawn in to dissolve it, and the taps immediately closed. For the first trials a few bubbles only of the total gas contained in a fairly large bottle should be drawn into the lungs with a deep breath of air, which should then be retained as long as possible before being exhaled. If no ill-effects follow the dose may be gradually increased, until finally the whole gaseous contents of the bottle may be inhaled into the lungs, a few bubbles at every breath, this treatment being repeated once every twelve

or twenty-four hours. But the very powerful nature of the agent must be remembered. The emanation from a few milligrams of radium bromide mixed with air glows quite brightly in a dark room. In an atmosphere containing oxygen the emanation possesses a surprisingly powerful oxidising effect on carbonaceous matter, and even upon metallic mercury; so that great caution must be observed during the preliminary trials that too great a dose is not given before its effects on the system have been carefully studied. But there is not much fear that the action of the thorium emanation, at least in moderate quantity, would prove too powerful, and it is advisable that its action should be first tried.

To sum up, the absolute immunity of these processes from external interference, the simple nature of the treatment proposed, the infinitesimal quantity of the active agents employed, the manner in which the emanations may be inhaled to do their work at the very seat of the disease, leaving behind the excited radio-activity to continue the work in a gentle manner after they have been exhaled, make out a strong case why the attention of medical men should be directed to the new weapons physics and chemistry have placed at their disposal. Indeed, if Nature had designed these phenomena for the purpose proposed, it is difficult to see in what way they could have been improved upon.

ON THE THERAPEUTIC EFFECTS OF THE SALTS OF RADIUM.

By JOHN MACINTYRE, M.B., C.M., F.R.S.E.,

Surgeon for Diseases of the Throat and Nose, Glasgow Royal Infirmary. In an article written by me and published in the *BRITISH MEDICAL JOURNAL* of June 6th, reference was made to the possible therapeutic effects of radium or its compounds. I then pointed out that the results were not sufficiently definite to state whether or not any effects had been obtained in certain cases on which I had been experimenting. That the salts of radium have, however, an action on diseased tissues cannot be doubted, but it cannot yet be said whether they will take the place of some of the other forces, such as x rays, high-frequency and potential currents, or Finsen's light at present employed in the treatment of lupus, rodent ulcer, or superficial epitheliomata. All that can be said meantime is that something emanates from the compounds of radium which has a very exciting, and, if pushed far enough, even a destructive, power on healthy tissues, and that to some extent the radio-activity for which the substance and its compounds are famous is also capable of stimulating diseased tissues in something like the excited Crookes's tube.

In the paper referred to a description was given of a burn of my arm, brought on artificially by allowing the rays from a few milligrams of radium to pass through a thin layer of air and another of mica for one hour. The reaction, which was described at the time, did not come on at once, and the results have not yet disappeared; that is to say, the reaction has continued for over two months, and looks as if some time would yet be required ere the wound is healed.

At the present time it is impossible to say how this agent produces an action on the healthy or unhealthy tissues, but the same thing may be said of any of the other forces. In the case of radium, however, there are some things known from the physical standpoint with which we have not yet reckoned in the case of others. At least if they are present, say when the patient is being subjected to the action of an excited Crookes's tube, we have not that definite information about them which is at our disposal in the case of radium, thanks to the admirable work of Monsieur and Madame Curie, Professors Rutherford, J. J. Thomson, and others.

The study of radium is evidently going to throw a considerable amount of light upon questions hitherto obscure in the region of physics, and it is not altogether improbable that we shall be able to say the same thing of it in medicine. To begin with, it seems tolerably certain that the extraordinary power of emission known as radio-activity possessed by the substance is not a simple one. Already three kinds of rays are distinguished: (a) Infinitely small positively charged atoms of matter flying at great speed, which can be measured, and the result seen by the bombardment on zinc sulphide screens; (b) rays which seemingly correspond to the cathodic rays in a Crookes's tube, and also described by Leonard as passing through an aluminium window in the same; and (c) rays which evidently correspond to the x rays.

In this connexion it is interesting to note that in an excited Crookes's tube one can also get a variety of rays, some of them invisible. Some of these are got when pumping out the air in a Crookes's tube before the vacuum is high enough to give the green coloration of the x -ray tube. I satisfied myself on this point four years ago, and found that these rays had great penetration, were capable of acting on a photographic plate enclosed in envelopes, and also capable of producing burns on the skin.

The a rays of radium are easily stopped by thin interposed substances, and the b or second set have great penetrating power.

There is another curious property of radium and its salts which we have not hitherto had to take into consideration in x -ray work generally—namely, that property which has caused such great excitement in the physical world, the power of emitting heat. Evidently the substance is constantly generating heat. If properly packed in some enclosure of a heat-insulating nature, 5° F. may be registered above the temperature of any other substance enclosed in the same way. What effect this may have in therapeutical questions cannot at present be stated.

Bearing in mind the serious destructive effect on the normal tissues and the many resemblances to x rays, I thought it well in my experiments to keep the substance at a considerable distance from the diseased tissues. The method of application is simple, and it need hardly be pointed out that if equal effects could be obtained therapeutically by radium or its salts it would be a great saving in complicated and expensive apparatus. The method I adopted was to have the radium enclosed in a small cell with a mica front $\frac{1}{2}$ in. in diameter. This was surrounded by a small piece of indiarubber tube. The glassblower made me a number of cones with an opening at the apex into which the indiarubber fitted. They varied in size and depth, but those chosen were usually about $\frac{1}{2}$ in. in depth. The radium is thus applied to the parts for a period of twenty to forty minutes daily or longer, and the effects on the patients can be watched with comparatively little risk.

The first case in which the experiment was tried was that of a patient suffering from lupus of the nose and nostrils; but inasmuch as she had recently had x rays applied to the diseased part, it was thought better not to apply the radium in this situation. The patient, however, had developed a small patch of lupus on the dorsal surface of the right hand. The radium was applied daily to this, the exposures varying from twenty minutes to half an hour according to the reaction. Within a week it was evident that the part was healing up, and in three weeks the lesion, which was about $\frac{1}{2}$ in. in diameter, had disappeared.

The second case was that of a woman, aged 28, suffering from lupus of the nostrils and nose. The area selected was just at the side of the left ala. The same treatment was pursued as above indicated, and within four weeks the lesion, nearly an inch in diameter, had practically disappeared. In this case Finsen's light treatment had been tried last year, and, as far as the face was concerned, it healed up. The result was not, however, satisfactory, as recurrence took place within two months of stopping of the treatment, and the affection had been spreading for the last four months.

In another case of rodent ulcer under the influence of radium the discharge soon dried up, reaction set in, and within a fortnight improvement was evident. This patient is still under treatment. Other cases are under observation, and the results are being carefully noted.

A considerable time must yet elapse ere any opinion can be offered about the true value of radium compounds in the treatment of such cases. Even if its therapeutic value be thoroughly established, there will remain the questions of the time taken to produce the desired effect, the kind of cicatrix or covering which forms, and last, but not least, to what extent they are likely to compete with the x rays, high-frequency, or other forces.

THE LONDON HOSPITAL MEDICAL SCHOOL.—The prizes and certificates gained during the year by the students of this school were distributed on July 20th by Mr. W. Douro Hoare, Chairman of the College Board. The Prize Scholarship in Science of £120 was awarded to Mr. R. C. Roberts, and that in Anatomy and Physiology (£60) to Mr. J. T. Macnab. The entrance scholarships in Science of £60 and £35 went to Mr. S. J. A. Beale and Mr. H. L. Morgan. A large number of minor prizes and certificates were also awarded.