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LUNG TOMOGRAPHY

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IN normal radiographs the parts of the body close to the film are more contrastfully and sharply reproduced than the parts further away from the film. That is, *ceteris paribus*, much more the case the greater the focal distance of the film and the nearer the body lies to the film. On the basis of this argument, an almost isolated reproduction of superficial parts of the body is possible, placing the tube as close as we can to the back of the body. In such a way, we may, for instance, obtain a dorso-ventral radiograph of the sternum. This radiographic "short-distance method" is, however, disadvantageous because too great superficial doses are given to the patient (25 to 30 r). A similar isolated reproduction of internal organs, for instance the lungs, is not possible for geometric reasons.

Lung radiography is very difficult, as it is a relatively thick organ, and it is, therefore, difficult to obtain a lung radiograph which reproduces all parts of it, closer as well as more distant ones, in an equal manner. Previous radiographs made at 70 cm. or 1 m. focal distance of the film gave a better reproduction of the nearer lung parts, while that of the distant parts is, on the contrary, unsharp and therefore not clear. For this reason tele-radiography became the general method for lung diagnosis. With 2 metres focus-film distance the linear dimensions of distant parts of the lung appear in the radiograph only 7 per cent more magnified than those of the nearer lung. The contrasts are equal for both, but the degrees of sharpness are still very different. Their ratio is 1 : 2, 5, and it cannot be appreciably diminished by further increase of the focus-film distance. Furthermore it cannot be influenced by reducing the focal size. By the introduction of tubes with revolving anodes the absolute values of degrees of sharpness have been increased and lung radiographs improved.

The difficulties in lung radiography are chiefly caused by the fact that the lung is a very translucent object and is girdled by less translucent parts. Two-thirds of the lung radiograph are covered by shadows of the ribs. In respect to the skeletal parts, namely, the muscle and fat layers surrounding the lungs, harder rays must be used than those which would be most convenient for the reproduction of the lungs themselves.

In a lung radiograph numerous shadows (blood vessels) and bright areas (alveoli) are superimposed. Each need not be very intense, but where two or more of them are superimposed, visible contrasts arise. For instance, if the projections of three or more blood vessels lying at different depths accidentally cross each other, the crossing points give contrasted shadows. In such a way shadows arise, the form and size of which are coincident, and do not permit one to draw conclusions about the shadow producers or their sizes. Pathological structures generally produce shadows of great contrasts between them and their environs. Even in such radiographically convenient cases errors can be caused by shadow superimpositions. It may happen that the dense shadows of uniformly strewn seats of infections cover the light area caused by a cavity, so that it cannot be discovered.

The problem of reproducing a plane free from superimposed shadows has been solved by A. E. M. Bocage (1921), E. Portes and M. Chausse (1921), E. Pohl (1927), B. G. Ziedses des Plantes and by D. L. Bartelink. It seems that the inventions have been made independently of each other, but the partially identical solutions are based upon the same idea, that is, to move the tube focus, and, in conformity with it, the film, during the exposure in such a way that the Röntgen shadows of a certain point permanently fall on the same point of the moved film. In accordance with the different possibilities of moving the tube focus, many variations of the method are conceivable. However, the same theoretical geometrical argument led all the authors mentioned above to the choice of very complicated focal paths. They necessitate too complicated mechanical devices, with many disadvantages in practice, and need unacceptably lengthy exposures. Ziedses des Plantes and Bartelink have used the method for years, but it did not find entry into practice.

A. Vallebona (1930) is using two simpler methods, both called Stratigraphy, but they do not fulfil the main condition of giving a truthful reproduction of a plane. Thus, they do not enable a clear picture outside of a very small strip of a plane or sheet.

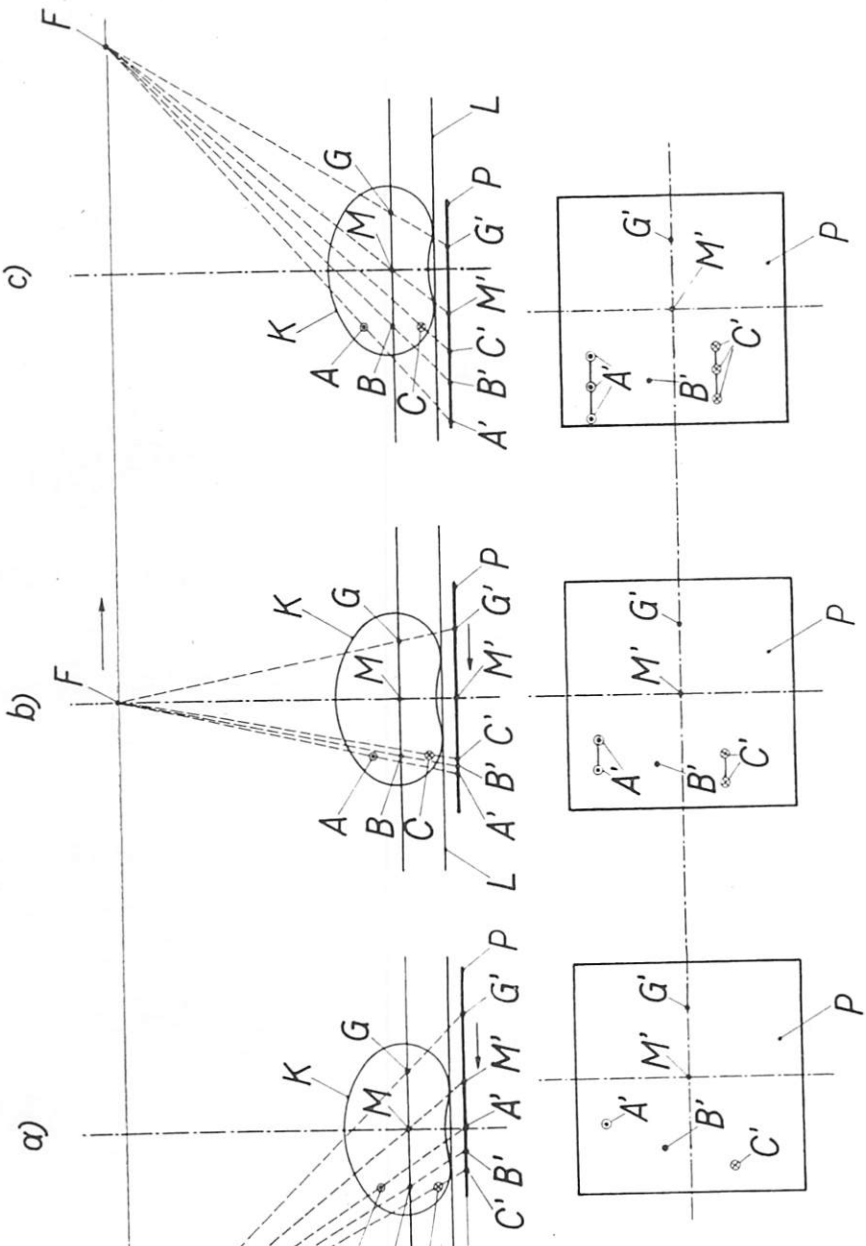


Fig. 1. The focus F and the film P are moved along straight lines.

The new tomographic method is also based upon the principle of the method already mentioned. To explain it as simply as possible, it is supposed that the focus F (Fig. 1) and the film P are moved along straight lines within the planes I and III respectively, which are both parallel to the body section II to be radiographed. Fig. 1a shows the start, Fig. 1b the middle, and Fig. 1c the end position of the focus and the film. The focal ray FM passing through the middle point M of the body section strikes the film at the point M'. We imagine the ray FMM' should be replaced by a telescopically extensible rod, which is rotable around the fixed point M and pivotably connected to the film P. It is further supposed that the film is movable only parallel to itself in the direction of the linear focal path. With the focus movement from (a) over (b) into the end position (c) the rod FMM' revolves around the fixed point M and drives the film to the left. It can be easily proved that, with this relative movement of focus and film, the shadow of each point being situated in the plane II, for instance those of B and G, are projected to the same points, B′, G′, of the moved film. Thus, all points of the plane II are reproduced as points (*vide* the plans of the film P in Fig. 1). They were reproduced in the same manner as if the focus and film were stationary. A truthful picture of the plane II and of all geometric figures within it results. The same picture can be had, if the focus and the film remain fixed.

The situation is different for points situated above or below the panel II. The projections A' and C' of the points A and C move relative to the shadow point B′. In the initial position (a) the shadow A' is on the right side of B', but already in the position (b) it is on its left side. The shadow point C' on the contrary changed from the left side of B' to the right side. The focus movement being continued, A' and C' move more and more away from B'. The shadows of A and C have a linear movement relative to the moving film. In the plan of P in Fig. 1a A' and C' are still reproduced as points A', C'; the plans (b) and (c) show the integral shadows of A and C which result during the displacement of F and P from (a) to (b) and from (a) to (c). The shadows of A and C are drawn out accordingly in the form of straight lines, that is they are blurred. They are the more blurred the greater their distances from plane II.

The shadows of body parts in close proximity to plane II are only slightly blurred, so that they are still reproduced distinctly. Therefore not a mathematical plane, but a layer is reproduced. The more rapidly the shadow blurring increases with the distance from plane II, the thinner the layer. This is the case, the greater the focus movement from its middle position.

If we let the focus and the film move around circles within planes I and III respectively (Fig. 2a), the shadows of each "disturbing point" Q describes a circle on the moved film. When the focus and the film move along spirals (Fig. 2b), the blurred shadows of all disturbing points become spirals. If the focal path is an Archimedean spiral with six windings, and the maximum focus excursion ρ from the central point L is equal to the radius of the circular path, then the spiral focus path is threefold longer than the circular one.

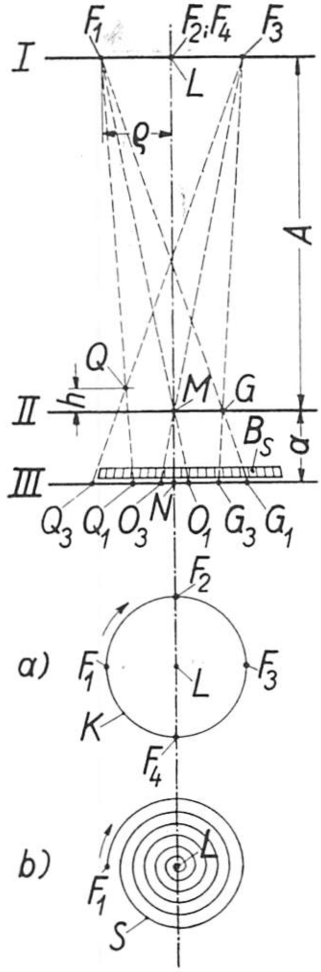


Fig. 2. The focus describes a circle K (Fig 2a) or an Archimedean spiral S of six windings (Fig. 2b) within the plane I. Within the plane III the film makes a conform movement in the same sense but with 180° phase difference.

On the basis of such suggestions, the former authors considered it most important to choose a focus path as long as possible. The considerations are truly valid for points or very small disturbing objects. But in practice the question is to blur shadows of finite and sometimes of very large dimensions. The conditions for an efficacious blurring of large shadows are different from those for points.

As disturbing objects, we take a series of homogeneous circular discs which weaken the Röntgen rays to the same extent and which are arranged

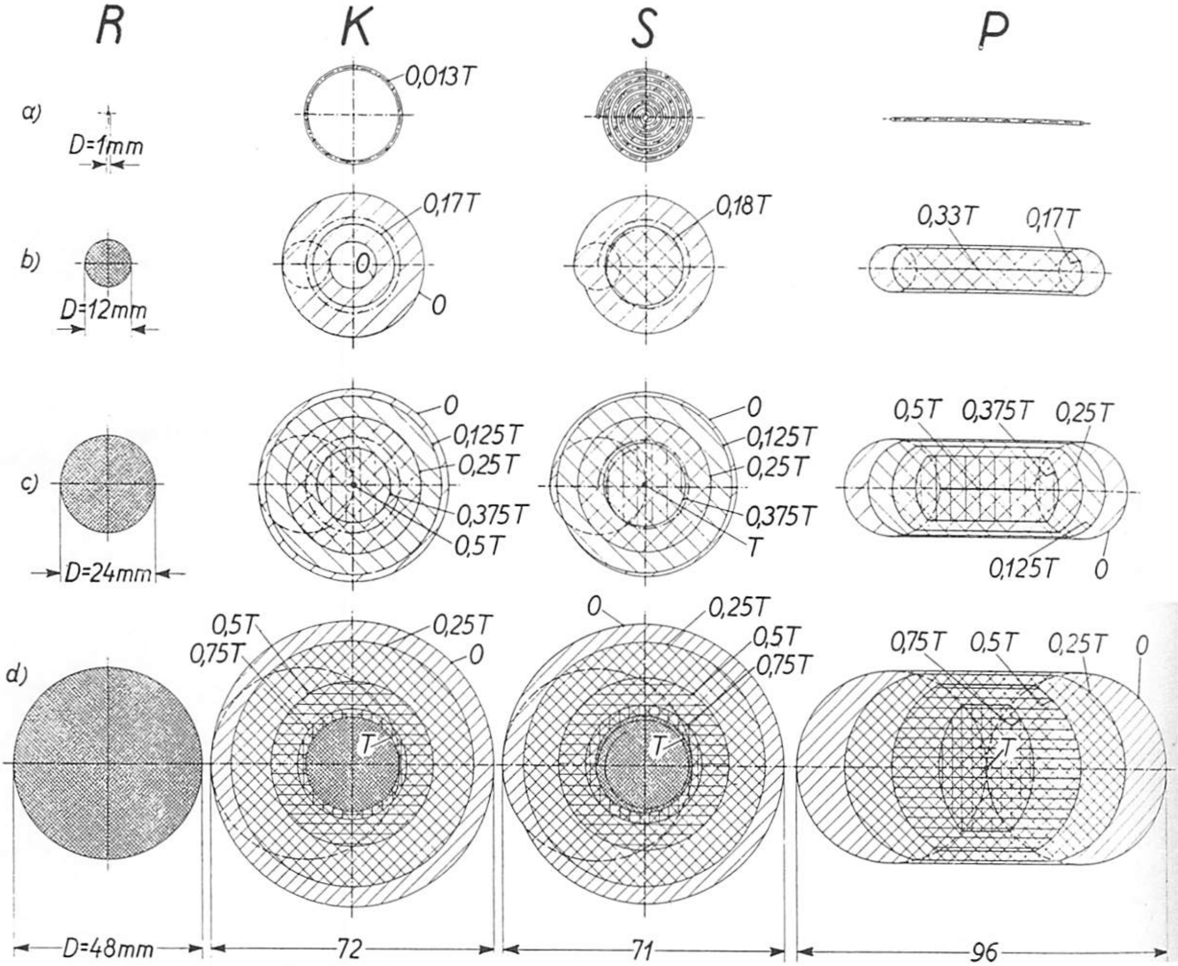


FIG. 3. The blurring of circular shadows R, the focus being moved around a circle (K), a spiral (S) both within a plane parallel to the body sheet or along an arc (P) within a plane perpendicular to that of the body sheet.
The cross hatching of the blurred shadow surfaces illustrates the distribution of shadow density. The geometric places of the same duration of shading time aie shown. The duration of shading time is expressed in fractions of the time T of exposure.

parallel to the layer to be radiographed at the same distance (4·75 cm.) from it. The diameters D of the "stationary shadows" R (Fig. 3) arising with the resting focus on the resting film may be equal to 1, 12, 24 and 48 mm. Fig. 3

shows how the stationary shadows become blurred when the focus is moved with a constant velocity around a circle (K) or an Archimedean spiral (S) as in Figs. 2a and 2b respectively, or along an arc (P) within a plane perpendicular to the plane to be radiographed. (This is the focus movement with the tomograph.) Herewith it is assumed, that the excursion ρ of the circulating focus is in relation to the focal distance A of the body section as great as admissible in respect to the working conditions ($\rho = 0{\cdot}2A$). In the two other cases (S and P) the ratio $\frac{\hat{\rho}}{A}$ ($\hat{\rho}$ = maximum excursion) is equal to 0·2 and 0·4 respectively so that the stationary shadows in all three cases are extended to almost the same extent. It is to be remarked that $\hat{\rho}$ in the third case could in practice be increased.

Even if the stationary shadow is homogeneous, the blurred shadows become inhomogeneous. At first, disregarding the inequalities of the shadow densities, we can consider the size of the blurred shadows in relation to that of the stationary shadow as a measure for the blurring effect. This ratio may be called the "geometric blurring."

As Fig. 3 shows, the geometric blurring diminishes with the size of the disturbing shadow. It has the following values under the conditions mentioned above:—

D in mm.	1	4	12	24	48	60
Path of the focus:						
Circle (K) ..	102	24	9	4	2·3	2
Spiral (S) ..	287	42	8	3·7	2·1	1·9
Arc in perpendicular plane (P)	62	16	6	3·6	2·3	2·1

Therefore, under the conditions mentioned, we must be content to be able to spread a shadow over a greater area in the ratio 1 : 2. Under the same conditions, disturbing shadows of small sizes extend to the fiftyfold and hundredfold of their original area. Thus, small shadows can be obliterated, large ones can be only weakened in a moderated measure.

Fig. 3 in conjunction with the values of geometric blurring, shows further that with the spiral focus motion small shadows can be blurred three times more than with circular motion. That is of no practical significance, because such shadows are still totally obliterated with the circular motion. The same holds for the sinusoidal or zigzag motion. All complications in the focus motion are superfluous. They bring no advantages in comparison with the

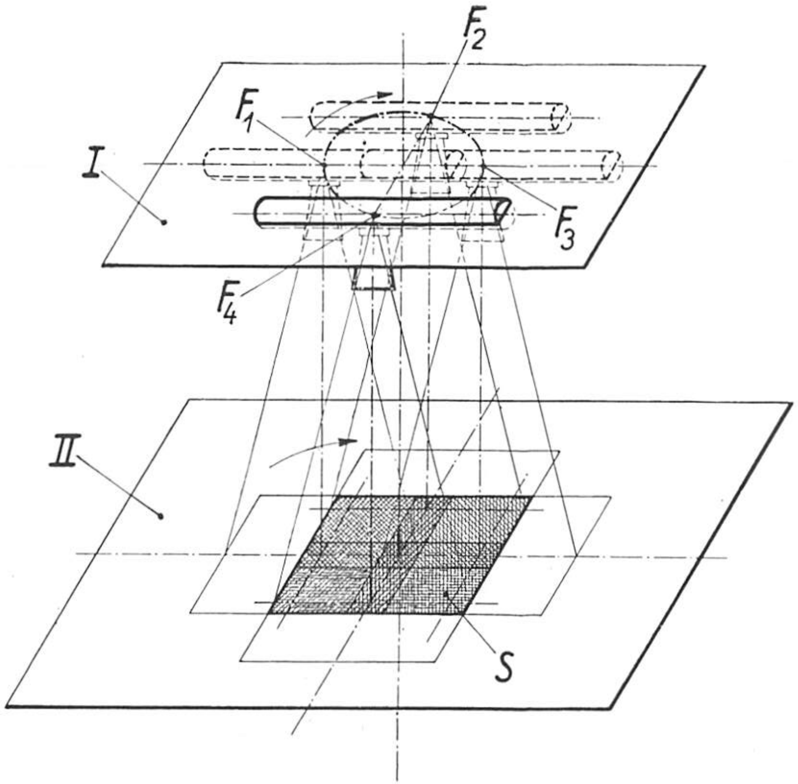


Fig 4 (a). The circulating tube is moved parallel to itself ($F_1F_2F_3F_4$). A rather small central part of the body section S is permanently exposed.

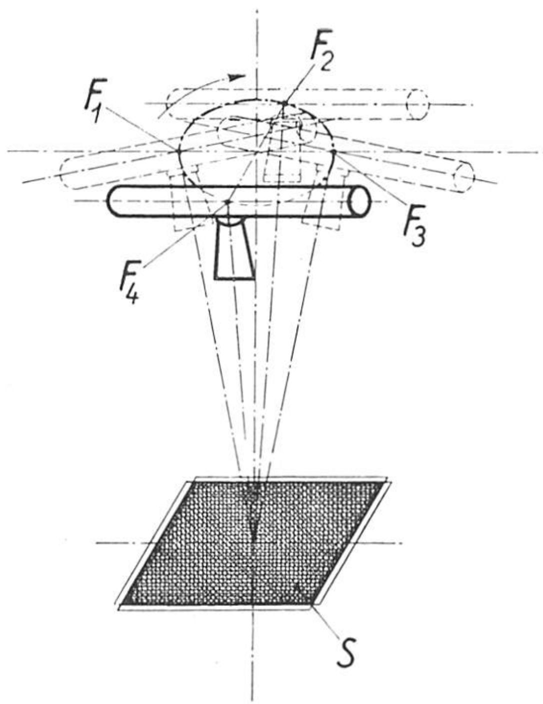


Fig. 4 (b). The circulating tube is supported in cardanic bearings and so guided that the central ray is permanently directed to the centre of the layer to be radiographed. The whole area of section S is permanently exposed.

circular motion and, on the contrary, lead to complicated devices, not useful in practice.

Even the circular motion is not so simple as it seems at first. The practical solution of the problem is not settled by the choice of the focus path: it depends considerably on the tube movement. It is not permissible to let the tube move along the focus path, when it is moved parallel to itself and to the plane to be radiographed (Fig. 4a). In such a case only a very small central part of the body layer is permanently exposed. To get a radiograph of the whole layer area two different movements are to be imparted to the tube: the movement along the focus path and a staggering movement around two axes perpendicular to each other in such a manner that the central ray is permanently directed to the centre of the body layer to be radiographed (Fig. 4b).

The main disadvantage of the circular movement and all similar ones consist in the fact, that with the use of a Potter-Bucky diaphragm the film is temporarily and partially shaded by the grid elements. It is obvious that the Potter-Bucky diaphragm admits free passage to the Röntgen rays only in two positions of the circulating focus, namely, when it is just in the plane of the middle blade of the diaphragm. In all other focus positions the film is partially shaded, the more so as the focus moves away from the said plane. That causes a great loss of time in exposure.

If the diaphragm is used with the focus film distance for which the diaphragm is arranged, the same loss of time results for each film point. It amounts to 64·5 and 78 per cent respectively of the shielded time, if the radius ρ of the path is equal to 20 or 30 per cent of the focal distance A of the body-section. (0·2 can be considered as the practically admissible highest value of $\frac{\rho}{A}$ and already here inacceptably long exposures result.)

The time losses caused by the diaphragm shadows could be avoided, if the diaphragm were to make the same movement as the focus, or a pendular movement in such a way that the focus remains continuously in the plane of the middle diaphragm blade. Those ideas are not practicable, as they entail mechanical constructions difficult to attain.

By moving the tube focus in a plane perpendicular to the layer to be radiographed we can avoid the difficulties with the Potter-Bucky diaphragm, if it is arranged that the plane of the middle grid element coincides with the plane in which the focus is moved. Then no time loss occurs in comparison with the normal radiography, whatever the focus excursion may be. This arrangement is made with the tomograph.

The fact that the excursion of a moving focus is limited, causes difficulties with the blurring of large shadows. As Fig. 3 shows, a nuclear shadow is originated, which has the same density as the stationary shadow. Under the same conditions the smaller the focus excursion, the smaller the stationary shadow, with which the nuclear shadow begins to form. Since with the unidirectional movement of the focus and the film much greater excursions can be chosen than with the circulating focus, a more efficacious blurring of large shadows can be attained in the first way than with circulating focus.

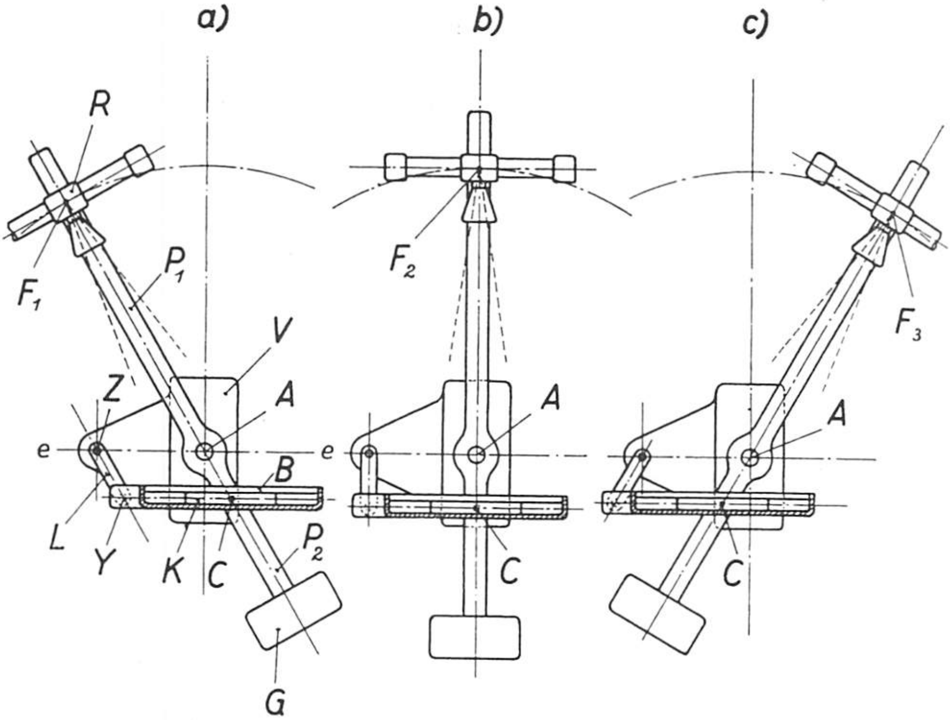


Fig 5. Schema of the tomograph in three positions.

On the basis of those considerations the author chose a focus movement within a plane perpendicular to the body layer. A tube movement has to be selected which enabled a kinematically simple and reliable solution. The linear movement of the focus shown in Fig. 1 is not practical. The reproduction of large layer areas is possible only when we let the tube rotate around its axis perpendicular to its linear path, so that the central ray permanently aims at the layer centre. A further disadvantage of this movement is the necessity of using a telescopically extendible or elastic apparatus. The exact correspondence of tube and film is not then guaranteed.

With the tomograph (Fig. 5) the tube R is attached to the arm P_1 of a pendulum P_1P_2 rotable around the axis A. The other arm P_2 of the pendulum carries a frame and therein the cassette K and above it the secondary ray diaphragm B. During the exposure the tube focus describes the arc $F_1F_2F_3$, and the cassette swings in the opposite direction. The lever L rotable around the axis Z assures that the film, and with it the diaphragm B, is always held horizontally, in other words parallel to itself and the middle plane of the layer to be radiographed.

This mechanically simple device has the advantage that the tube movement

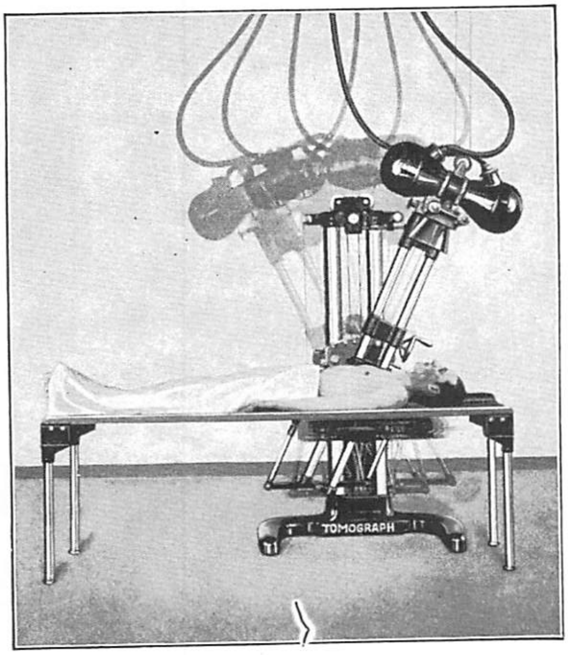


Fig. 6. Tomograph.

is transmitted to the film by rigid members rotable around fixed parallel axes and that, therefore, an accurate correspondence of tube movement with that of the film is secured. The central ray of the tube is permanently directed to the centre of the body layer, so that films of any size can be fully exposed. The secondary diaphragm is arranged in such a way that the tube movement is executed parallel to the edges of the diaphragm blades. No loss of exposure time occurs in comparison with a normal radiograph. Therefore a short exposure, *e.g.* one second, is attainable.

If the pendulum axis is raised or lowered a certain distance, in order to reproduce another layer, the film holder is automatically lowered or raised, so that a constant body-film distance is guaranteed. Fig. 6 shows the construction of the apparatus by Sanitas-Berlin.

Before beginning an exposure the pendulum is placed in its initial position and fixed in it by a lock. This is released by actuating a button on the switch-table of the Röntgen apparatus. The pendulum is then set in motion by

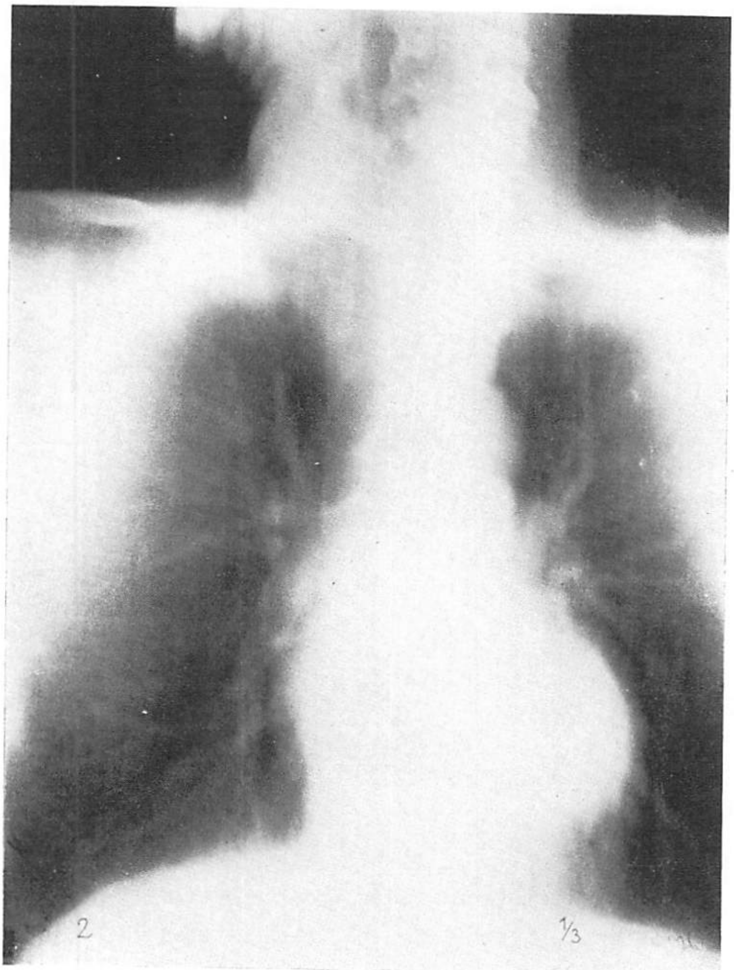


FIG. 7.* Hilar layer of a normal lung. The pulmonary vessels. Dorso-ventral tomograph; layer is 10·5 cm. distance from the resting surface.

stretched springs. It actuates a short time later an electrical contact and puts the Röntgen apparatus in operation. A moment before the pendulum reaches its end position, it opens the primary circuit of the apparatus. Its kinetic energy is taken up by springs.

*The tomographs are made in the Roentgen Institute of Professor Chaoul.

In accordance with an idea due to H. Chaoul, an arrangement was made by which the pendulum falls to a regulated extent, for instance 12 mm., simultaneously with its rotation. Herewith it is possible to reproduce layers of different thickness with maintenance of the blurring degree.

On varying the layer to be reproduced, the layer-film distance is changed and thus the magnification rate of the tomograph is altered. In order to obtain tomographs magnified in the same ratio, the focus-layer distance can be varied. The tube is also adjustable in the direction perpendicular to the focus movement piane. The cassette holder can be set close to the table. The

Fig. 8. Sagittal tomograph of a normal lung. Body resting at the left side. Layer is 10·5 cm. distance from the resting surface.

device is suitable for normal radiography with short and wide focal distances as well as with sloping direction of the central ray.

The tomograph gives a unidirectional blurring. Therefore in all cases, when the disturbing shadows have a preferred direction, it is necessary to move the focus perpendicular to it. In frontal lung tomographs the shadows of ribs must be blurred or effaced. In this case the focus is moved in the longitudinal direction of the body. The blurring degree with the tomograph is such that the shadows of the ribs are obliterated even if the layer is not more than 7 cm. away from the resting surface. We obtain a tomograph without disturbing shadows showing the right pulmonalis, its radial ramifications and the arteria pulmonalis on the left side (Fig. 7). For making sagittal lung tomographs, or those in a sloping direction, the tube focus is moved transversely to the body. Then the shadows of the vertebræ and of the heart are blurred and those of the sloping parts of ribs effaced (Figs. 8 and 9). In most cases the vertebræ

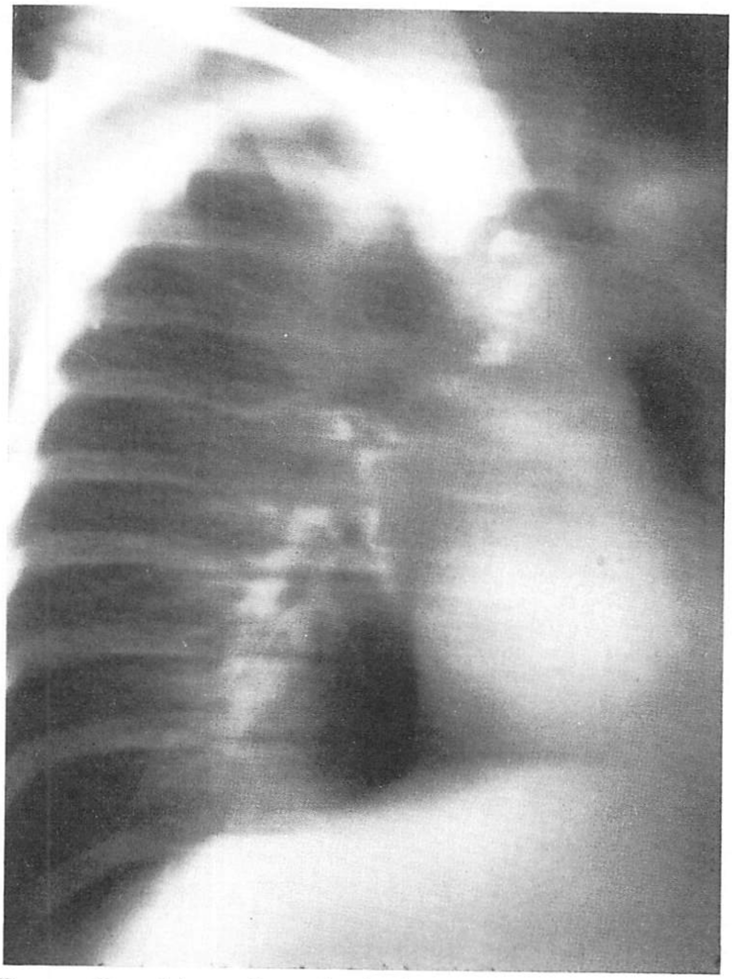
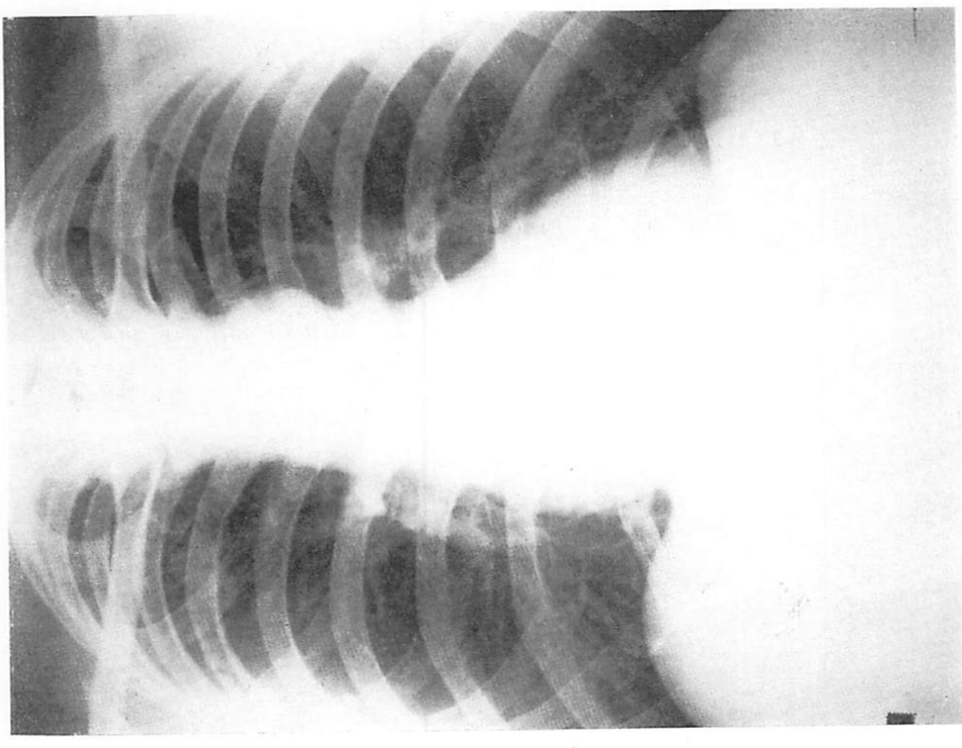


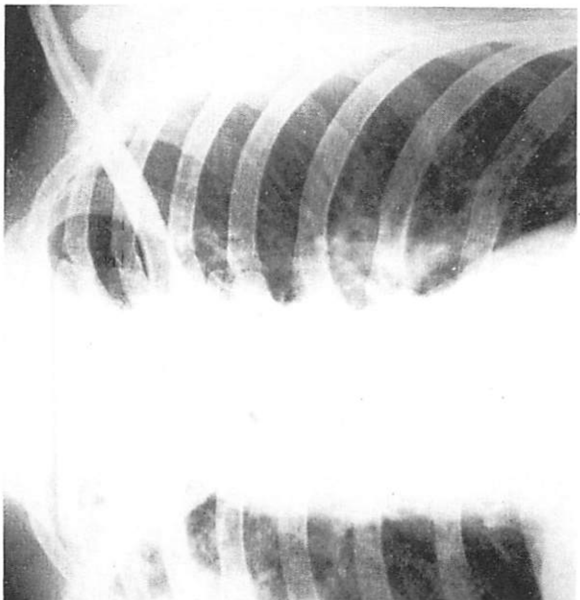
FIG. 9. Normal lung. Layer in the direction of the second sloping diameter. Hilar parts of the arteria and the veine pulmonalis.

are so close to the layer reproduced that their shadows cannot be effaced; and can only be blurred, but this is possible to such a degree that the blurred shadows do not disturb the view. The pulmonary vessels are distinctly reproduced. We can follow their ramifications in ventral and dorsal directions. In the tomograph made from the hilar district we see the cross section of bronchi.

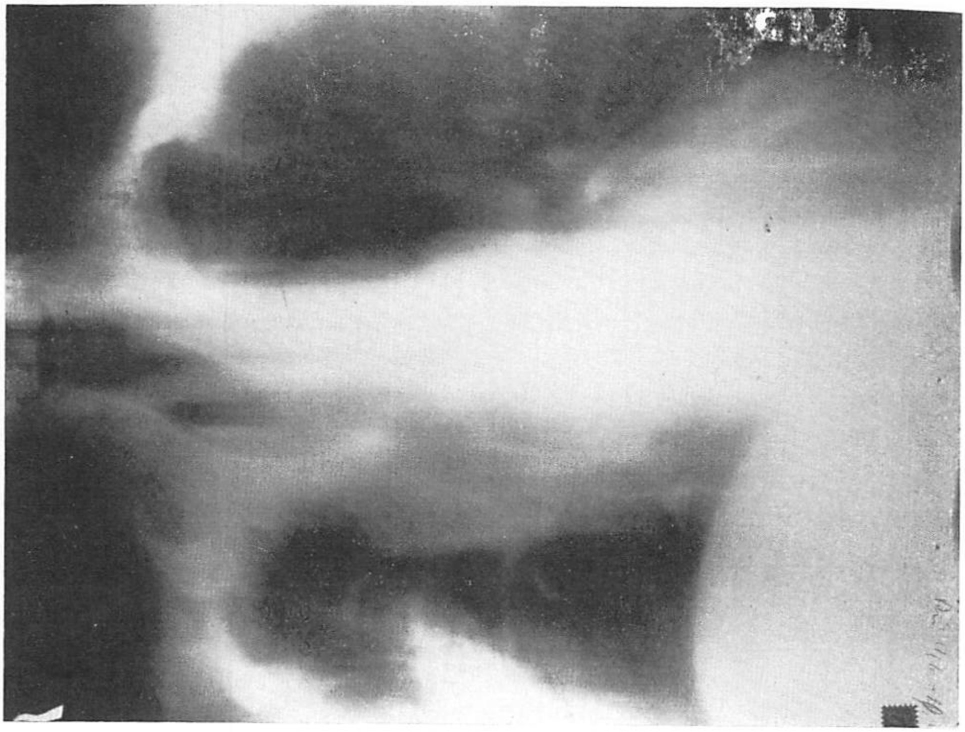


(a) Normal radiograph. (b) Ventro-dorsal tomograph. Layer is 12 cm. distance from the resting surface.

Fig. 10. Infra-clavicular infiltration on both sides.



(a) Normal radiograph.



(b) Ventro-dorsal tomograph. Layer is 11 cm. distance from the resting surface. Trachea and bronchial tree deformed because of shrinkage.

Fig. 11. Fibro-cavernous tuberculosis of the upper part of the right lung.

The tomographs of normal lungs are attractive, but still more instructive are those of pathological cases. As H. Chaoul showed, they enable us to detect (Figs. 10 and 11) pathological defects and cavities, which could not be detected with the radioscopy or the methods of normal radiography, especially if they are covered by shadowed zones or paraffin plugs. It is possible to recognise

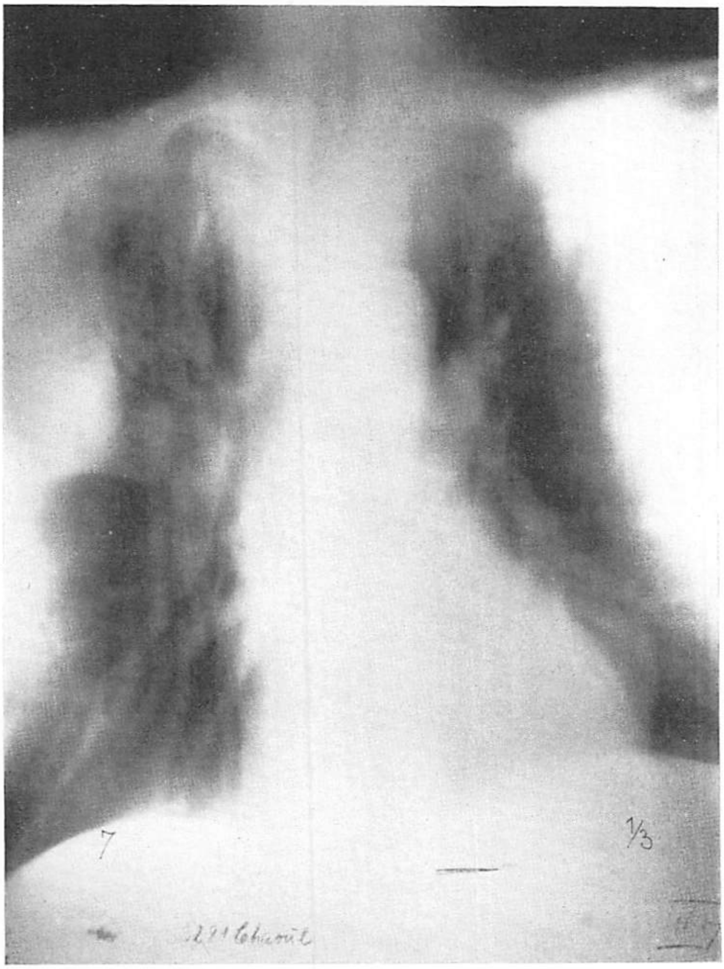


Fig. 12. Fibred tuberculosis of the upper part of the right lung. Lighter defect on the left side. Ventro-dorsal tomograph. Layer is 10·5 cm. distance from the resting surface. Bronchials and atelectasis.

the character of cavities, to localise them, to ascertain their form, dimensions and relations to the bronchi, to study the infection in marginal parts, which are never reproduced in normal radiographs, and in cases, in which the environs of bronchi are shadowed, to recognise the bronchi (Fig. 12) and to follow them up to the periphery. Furthermore it is possible to recognise bronchiectasis without the use of contrast agents, and to study the pathological alterations of bronchial tubes.

Three tomographs are generally sufficient for lung diagnosis, and in many cases we can use films of the size 24×30 cm. The frontal tomographs are made at 63–70 KV. p.v. with 100 to 150 ma., the sagittal ones at 85 KV. p.v. with 100 to 120 ma., both in 70 to 120 cm. focus layer distance in 1 second exposure time.

The chief domain of tomography ought to be lung diagnosis, but it is useful for the study of the cranium, also. It may be suitable for bone diagnosis if the blurring is reduced in comparison with that for lung tomography.

The tomographic effect does not consist in a technical improvement of the picture as it is attained in normal radiography by reducing the focus size or by other means, but its advantage is to enable us to reproduce parts of the body, normally not reproducible, especially of lungs, distinctly and clearly in all details.

Summary

The most significant field of application for the method of reproducing body layers (tomography) will, in practice, be lung diagnosis. For just this purpose the methods with omni-directional shadow blurring (with focus movement around a circle, spiral or sine curve in a plane parallel to the layer to be reproduced) are least suitable. They entail unacceptable long exposures.

A new device, the tomograph, is described, which permits the radiography of body layers of any size and variable thickness within a short time with efficacious blurring of large disturbing shadows. With a relatively simple mechanical construction accurate correspondence of tube movement and film movement is secured. The usefulness of the method is demonstrated by several lung tomographs.

Zusammenfassung

Das praktisch wertvollste Anwendungsgebiet des Verfahrens der Körperschichtdarstellung dürfte das der Lungendiagnostik sein. Insbesondere dafür eignen sich die Verfahren mit allseitiger Störschattenverwischung (Kreis-, Spiral- und Sinusbewegung des Fokus in einer zur darzustellenden Körperschicht parallelen Ebene) am wenigsten. Sie führen zu unannehmbar langen Belichtungszeiten.

Es wird ein Gerät (Tomograph) beschrieben, mit dem es möglich ist, Körperschichten beliebig grosser Ausdehnung in kurzen Belichtungszeiten bei vorzüglichem Verwischen grosser Störschatten röntgenographisch darzustellen. Bei einfachem mechanischem Aufbau ist die genaue Korrespondenz

von Röhren- und Filmbewegung gewährleistet. Die Leistungsfähigkeit des Verfahrens wird an Hand einer Reihe von Lungentomogrammen dargetan.

Résumé

Les recherches diagnostiques sur le poumon constituent dans la pratique le champ d'étude le plus démonstratif de la méthode de reproduction de coupes du corps (tomographie).

Les méthodes qui précisément dans ce but emploient des ombres se projetant dans toutes les directions (avec mouvement focal en rond en cercle, en spirale ou en sinus courbe dans un plan parallèle à la coupe à reproduire) sont les moins convenables. Elles entraînent des temps de pose inacceptables.

L'auteur décrit un nouvel appareil, le tomographe, qui, dans un temps court, avec taches efficaces de larges ombres mouvantes, permet la radiographie de coupes du corps de toute dimension et d'épaisseur variable. L'exacte correspondance du mouvement du tube et du film est assuré par un mécanisme relativement simple. L'utilité de la méthode est démontrée par plusieurs tomographies du poumon.

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DAVID ANDERSON-BERRY PRIZE

The Council of the Royal Society of Edinburgh have made the first award of the David Anderson-Berry Prize to Charles Melville Scott, M.A., M.B., D.Sc., Lecturer in Materia-Medica in the University of Edinburgh, for his essay "On the Action of X and Gamma Rays on Living Cells."

This prize, which consists of a gold medal and a sum of money, was founded by the late Dr. David Anderson-Berry in 1930, and is awarded triennially to the person who, in the opinion of the Council, has recently produced the best work on the nature of X rays in their therapeutical effect on human diseases.

ABSTRACT.

The Removal of Lymph Nodes in Cancer of the Cervix. Fred J. Taussig, M.D., Gynecologist, Barnard Free Skin and Cancer Hospital, St. Louis Mo. *American Journal of Roentgenology*, Vol. 34, No. 3, p. 354.

The results of irradiation of mouth lesions followed by removal of tributary lymph nodes, suggested to the writer the same method in cancer of the cervix.

As radiation therapy so often clears up the primary lesion and adjacent parametrial and gland involvement, only to be followed by more distant gland metastasis later, and because such metastases prove so radio-resistant, the author tried surgical removal of the more usually involved gland groups. At the same time radon seeds were inserted into the cervix and in some cases gold seeds were implanted intra-abdominally. Only Group II and III cases were treated and the results in Group II and the younger patients were sufficiently good to encourage the further trial of this method.

G.R.N.