

DESTRUCTIVE AND REGENERATIVE CHANGES IN THE ELASTIC TISSUE OF THE LUNG IN IN- FLAMMATORY CONDITIONS.

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(PLATES XXIV.—XXVIII.)

THE changes which occur in elastic fibres under pathological conditions have been studied to a considerable extent in various organs and tissues ever since the discovery of elective staining methods for elastic tissue has made this possible. Such changes in lung diseases appear, however, to have received scant attention. This is all the more remarkable as the lung is the organ in which these fibres occur in greatest abundance. It is indeed the form of connective tissue present in largest quantity on which the structure and functions of the organ chiefly depend. One would have imagined that elective staining methods for this tissue would invariably be employed when studying or demonstrating pathological changes, especially as these methods are far from complicated.

There are two chief elective staining methods for elastic fibres—the Weigert and the Unna-Taenzer. The former was published in 1898, the latter having been in use for some years previously. In reality, however, the Weigert method has precedence, as it was first employed by its discoverer in 1884.

With regard to the question of the relative merits of the two methods, opinions differ widely. Krystalowicz (1903) strongly recommends the orcein method, quoting in its favour points in which, according to Herxheimer (1903), Weigert's method is at least its equal. Fischer (1902) and Katsurada (1902) agree with Herxheimer in preferring the latter method. Goldmann (1901), who has probably done more work than anyone on the subject, appears to prefer the Unna-Taenzer method. I have no hesitation in advocating Weigert's method, as being simpler, more rapid, and more sure.

Several modifications of this method have recently been suggested. Michaelis (1901) has substituted various stains for the fuchsin, with more or less success. Pranter (1902) has suggested the solution of the resorcin-fuchsin stain in acid. Fischer considers that this modification is no improvement; he suggests substituting vesuvin for the fuchsin, and he has contributed to the chemistry of the method by showing that if the fuchsin be left out a solution is obtained which, although it does not stain the elastic fibres, acts as a mordant, so that they may subsequently be stained by such dyes as safranin.

If, instead of the fuchsin, the resorcin be omitted a fluid is obtained which stains the elastic fibres exactly as in the original Weigert method, only a little fainter. Minervini employs 5 per cent. chromic acid solution after using the resorcin-fuchsin; but, according to Herxheimer, the original Weigert method remains the best.

Turning to the work done on the changes which elastic fibres undergo in various pathological conditions, one finds a fair amount of agreement among observers. In acute inflammatory conditions there is rapid destruction, as has been shown by Mesnil de Rochemont (1893), Melnikow-Raswedenkow (1890), and Katsurada, although the elastic fibres are relatively resistant. The same authors, and in addition Jores (1900) and Kromayer (1894), have shown that in chronic inflammatory and in cicatricial tissue new elastic fibres are formed after some weeks. Guttentag (1894), however, denies that elastic fibres are present to any extent in scars, and those which occur are probably simply the remains of old fibres. Goldmann, while admitting the formation of elastic fibres in ordinary scar tissue, has shown that in keloids they are entirely absent.

With regard more particularly to the changes in tuberculous inflammation, it has been shown by Wechsberg (1901), Watanaba (1902), Herxheimer (1903), and the author (1902), that an early destruction of the elastic fibres occurs in the walls of vessels blocked with emboli containing tubercle bacilli. Similar but less marked changes have been observed by Engelhardt (1902) after the introduction of dead tubercle bacilli.

Orth (1900) and Federmann (1901) have drawn attention to the marked destruction of the elastic fibres which occurs in tubercle of the testicle. They state, however, that it is not the process of caseation but the early stage of cell infiltration which is associated with this destruction. Schmaus (1895) has investigated the behaviour of the elastic fibres of the lung in tuberculous conditions, and concludes that the elastic fibres are wonderfully resistant to tuberculous processes, and that there is no real difference between the so-called tubercle and caseous broncho-pneumonia in the behaviour of these fibres.

In syphilitic conditions of the testicle, in contrast to tubercle, Orth and Federmann found the elastic fibres well preserved. Kroesing (1894), studying the papular syphilide, observed that so long as the syphilide was developing there was degeneration of the elastic tissue, and that the areas of destruction were coextensive with the areas of cell exudation. Investigating syphilitic disease of the aorta, Abramow (1904) observed destruction of the elastic fibres, which became massed together and ultimately broke up into small isolated homogeneous granules.

Turning to the question as to the method by which the elastic fibres are reproduced in these various conditions, and to the minute changes observed when destruction is proceeding, one finds, with regard to the former, two distinct opinions: (1) that the new elastic fibres are produced in connection with new connective tissue cells; (2) that they are derived by budding from pre-existing fibres.

Goldmann, investigating the histogenesis of elastic fibres in scars, and their relation to keloid formation, adopts the latter conclusion. According to him, the new fibres arise from the old ones, and chiefly from those of the adventitia of small vessels, but also from the elastic sheaths of hair follicles; they do not spring directly from the ends of these, but from the sides.

Enderlen (1897), as the result of experiments in skin grafting, comes to similar conclusions, but he also observed new fibres springing from the remains of the elastic tissue in the graft. Meinel (1902) and Inouye (1902), studying the new formation of elastic fibres in malignant tumours, also observed the intimate connection between the new fibres and the walls of vessels.

On the other hand, Jores, studying the formation of elastic fibres in scar tissue and in experimentally produced arteritis (1898), concludes that the cells

play a part in the new formation of elastic fibres, that the elastic fibres are laid down as colourless fibres, in the first instance, by young connective tissue cells, that later these become transformed into fibres which stain with Weigert's method. This opinion appears also to be held by Katsurada. Jores also holds that in endarteritis the connective tissue cells of the intima have a special capability for producing elastic substance. Iwanoff (1902), investigating the formation of the elastic fibres in the pregnant uterus, concludes that the new elastic fibres arise in the protoplasm of the young connective tissue cell, that they first appear in the form of granules within the protoplasm of the cell, these granules subsequently flowing together and forming fibres. This is also the view of those who have investigated the question from an embryological point of view, such as Gardner (1897).

Sawada (1902), studying the question in cases of thickened pleura and interstitial pneumonia, observes the connection between newly formed elastic fibres and the pre-existing ones, but also concludes that they do not arise from these, but that they have their origin in connection with young fibrous tissue cells.

Fischer (1904) observed the occurrence of elastin between the cells of malignant tumours, and regarded it as a product of secretion.

Lastly, with regard to the question as to the method by which elastic fibres undergo destruction, Katsurada, as the result of an experimental investigation on the elastic fibres of the skin, concludes that these fibres are relatively resistant. Destructive changes, however, show themselves as the result of the inflammatory process after two to three days. These degenerative changes consist in a loss of staining reaction, the fibres at first staining pale with resorcin-fuchsin and ultimately disappearing. At the same time, in places there could be observed a breaking up of the fibres into fine granules. As already mentioned, Abramow noticed a similar granular degeneration in the elastic fibres of the aorta in syphilis. Similar changes were observed by Goldmann, Mesnil de Rochemont, and Ziegler (1904) in oedema.

It is unnecessary to give in detail the method of preparing Weigert's resorcin-fuchsin stain, as it is fully described in Weigert's original communication and in most of the text-books on staining methods. The author has found it advisable, however, in preparing the stain, to add excess of Liq. ferri perchlor. in order to ensure complete precipitation. It is well also to remember that the stain improves on keeping, and ought to be used over and over again. At first the stain is not perfectly elective, the ground substance taking on a purplish tinge; this improves, however, as stated above, with repeated use.

Formalin, alcohol, and Müller's fluid may all be used as fixatives. The author has employed the first mentioned as a rule. The tissue may be embedded in celloidin or paraffin, and cut in the usual way, but probably the best plan is to cut with the carbonic acid freezing microtome, first suggested by Aschoff, and supplied by Becker of Göttingen. The advantages of this method are: the specimen can be cut the day after the post-mortem, if desired; it is not subjected to any heating process, and very large sections can be obtained. As regards the first of these advantages, it may be stated that it is better, when possible, to keep the tissue several days in formalin, then to pass it through successive strengths of spirit and subsequently to wash it free of spirit before freezing. With regard to the second advantage, one has only to compare a paraffin section with a section cut with the freezing microtome to realise that the latter gives a more lifelike picture. In the last place, it cannot be too strongly emphasised that in studying and demonstrating lung diseases the larger the sections are the better.

The carbonic acid freezing microtome permits of a considerable range with regard to the thickness of the sections. I have found it no disadvantage to have them 30–40 μ thick. Indeed, there is this advantage in such sections, that elastic fibre can be followed for much longer distances, and I have had no difficulty in examining such sections even with a $\frac{1}{2}$ oil immersion.

Sections cut in this way may be stored in spirit and stained at any subsequent period.

From the water the sections are taken and stained in ordinary lithium carmine. Specimens cut fresh, or in celloidin, stain in this in a few seconds; sections cut in paraffin require some hours, and even then are apt to be very faintly coloured. They are then transferred at once to spirit containing 1 per cent. of hydrochloric acid; in this they may be left for a few minutes up to several days. The longer they are left the better, and sharper is the differentiation of the nuclei of the cells. From the acid spirit the sections are transferred directly to Weigert's resorcin-fuchsin stain, in which they are left for from twenty minutes up to two hours. They are then removed to absolute alcohol, in which they are differentiated till no more blue colour comes out. If we are dealing with a fresh cut specimen a slide is now introduced under one of the sections, which is carefully spread out with a needle and the slide withdrawn. The section on the slide is then blotted, and a mixture of carbolie acid and xylol (1 to 3) poured over it. In his original article Weigert states that carbol-xylol should not be used, but, as far as the author is able to judge, there is no subsequent fading of the specimen, and there is this advantage, that the section does not tend to shrink so much as when transferred directly from absolute alcohol to pure xylol. After pouring off the excess of carbol-xylol the section is again carefully blotted and pure xylol run over it. The blotting is repeated once more, Canada balsam is dropped on, and the section covered. The blotting is absolutely indispensable, as otherwise extensive shrinking and puckering will occur. By this method the nuclei of the cells are stained red, and the elastic fibres a deep blue. The cartilage of the bronchi is also stained somewhat irregularly blue, but this does not in the least interfere with the method as a means of differentiating the elastic fibres.

Instead of staining with lithium carmine, celloidin or paraffin sections may be stained first in resorcin-fuchsin, and subsequently in hæmatin and van Gieson's fluid; or, if it is desired to bring out the micro-organisms, the section may be stained first in anilin-fuchsin, then differentiated in acid spirit, then placed in the elastic tissue stain for half an hour or more, and subsequently counter-stained in methylene-blue in the way recommended by the author (1904). In such specimens the elastic fibres still stand out in marked contrast to the nuclei of the cells.

For the sake of convenience the following results will be considered under the heads of—(1) Simple Inflammatory Diseases; (2) Tuberculous Diseases; (3) Syphilitic Diseases.

SIMPLE INFLAMMATORY DISEASES.

Under this heading are included inflammatory affections of the lung, which are neither tuberculous nor syphilitic.

(a) *Destructive Changes.*

In inflammatory conditions of the larger air passages, as in diphtheria, there is little that is characteristic as regards changes in the elastic tissue. This is largely due to the extreme thickness and stoutness of the fibres in the walls of the trachea and bronchi. In these air passages the fibres appear to have a distinct influence in preventing the penetration of organisms owing to their thickness and felt arrangement. There is, of course, an infiltration of the walls

with inflammatory cells, and in consequence, in all probability, some separation and weakening of the elastic fibres there, but as a rule no gross lesion. In a case of acute bronchitis, however, due to poisoning with ammonia gas, sloughs were found in the larger air tubes. These, to all appearance, when stained by ordinary methods, were structureless. When stained by the elastic tissue method, however, they were found to represent the first layer of elastic fibres of the mucous coat which lie immediately under the homogeneous basement membrane, and consist of a network of fine elastic fibres passing irregularly in all directions, and usually interlacing with an oblique or longitudinal layer of thick, closely set fibres below. In this case separation of the two layers had occurred, and the fibres in the slough, although well preserved, were degenerating in a manner to be described immediately.

In an ordinary case of acute lobar pneumonia there appears to be no disturbance of the elastic structure of the lung. In the lobular condition, however, especially as it occurs in children, there are important changes in the elastic laminae of the bronchi and bronchioles. Although the bronchi show four distinct layers of elastic fibres, the bronchioles usually show only two, namely, the layer of stout fibres passing obliquely and the fine fibres surrounding the muscularis mucosae, which are circular in direction. The fine layer immediately under the basement membrane becomes less and less marked, and ultimately disappears; the thick layer, uniting and enclosing the cartilage nodules, disappears along with these structures.

In these smaller air passages, usually known as bronchioles, as has just been mentioned, one frequently finds important changes in the broncho-pneumonia of children, consisting in varying degrees of dilatation, and, surrounding these dilated bronchioles, areas of compressed or collapsed lung tissue. Associated with this dilatation, and in all probability the chief factor in its production, is a thinning and ultimate disappearance of the two remaining elastic laminae.

This condition, which has been called bronchiolectasis, or, from its naked-eye appearance when well marked, "Honeycomb lung," is described by Fowler and Godlee (1898) in their text-book on diseases of the lung. According to them it is characterised by—(a) acute peribronchitis; (b) dilatation of the bronchioles; (c) the presence of innumerable small cavities, giving the lung a worm-eaten appearance; (d) the presence on the surface of the lungs of small vesicles containing air.

Sharkey (1892) and Howard Tooth (1897) had previously described the condition; these authors likewise regarded the cavities as dilated bronchioles, but were unable to demonstrate this. Fowler and Godlee also conclude that the pathogenesis is still uncertain. In the article on Bronchiectasis in Allbutt's "System of Medicine" by Ewart (1898), in which the lungs from Sharkey's case are figured, the origin

of the cavities from bronchioles is accepted as proved. By means of the elastic tissue method the pathology of the condition is wonderfully brought out. I have seen one typical case of "Honeycomb lung," and several others more or less closely approximating to it.

Microscopically the earliest stage in the process appears to be an infiltration of the mucous membrane and submucous tissues with inflammatory cells. Then a uniform stretching and thinning of the elastic laminae may be observed. A burst may take place at one particular point, the laminae being to all appearance torn through. Or the process may go on uniformly, the fibres becoming thinner and thinner, and ultimately disappearing altogether (Plate XXIV. Fig. 2). As will be described later, the minute changes to be seen in such degenerating fibres are (*a*) splitting up of the fibres; (*b*) thinning of these, and gradual loss of staining reaction. The dilated bronchioles are usually blocked with plugs of purulent secretion containing occasional micro-organisms. As previously mentioned, the area of lung immediately surrounding the dilated tube is in a state of collapse from direct mechanical pressure.

The factors in the production of this condition are fairly obvious. They are the mechanical pressure of coughing acting on a bronchial wall weakened by inflammation. The question arises as to what are the structures which are chiefly concerned in resisting this dilatation. I have very little doubt that it is, in the case of the smaller tubes at least, the elastic fibres. The muscular fibres in all probability play a part, but they are thin and insignificant, and may be absent altogether in the smallest tubes. Not only, therefore, does the staining of such a lung with the elastic tissue method furnish a means of following the process, but it brings out the structure which resists dilatation longest, and is in consequence essential to the true understanding of the condition.

A further question presents itself, What are the factors in the production of this weakening? There are undoubtedly organisms present, although they are few and far between, and not specially associated with areas of extensive destruction. As a consequence of the presence of these organisms there will doubtless be diffusible poisons. How far these latter may cause destruction of fibres by themselves I am not in a position to say. Microscopically the change most uniformly associated with destruction of elastic fibres is undoubtedly infiltration with inflammatory cells.

Passing to the more acute conditions, such as septic infarction, abscess, and gangrene, one commonly finds a fairly extensive destruction of the elastic fibres. This may be seen both in connection with the walls of vessels and with the lung tissue proper.

Such conditions appear frequently to start in the vasa vasorum of the arteries. This mode of origin is indicated in Plate XXIV. Fig. 1, which is taken from a case of diplococcal meningitis with septic

infarctions in the lung. Here one sees an accumulation of inflammatory cells starting between the elastic laminae of a vessel which is probably a branch of the pulmonary artery, and tearing these laminae apart. Thrombosis has occurred within the lumen of the vessel in connection with the portion of the wall affected. In the same figure a further stage of the process is seen; both laminae have been split and actually ruptured so that the inflammatory cells have escaped into the lumen of the vessel. That the origin in this case has been the same is shown by the incurving of one layer of the elastic lamina at the free extremity. The method by which destruction occurs appears here to be, as before, resolution into the constituent fibrils, the thinning of these and ultimate loss of staining reaction. In such a rapidly destructive process as this, however, the actual tracing of the method is difficult.

In the abscesses in the lung substance in this and several other cases examined a similar process of destruction of elastic fibres was to be observed. The destruction is very marked in places, so that cavities filled with pus are formed. The finer fibres are the first to disappear, leaving the thicker ones which occur at the corners where alveoli open into infundibula more or less intact. In a slough of lung tissue in an abscess in another case, which was to all appearance structureless, and which swarmed with staphylococci, the elastic tissue network was preserved almost in its entirety. As before, it is only where there is infiltration with inflammatory cells that destruction occurs. Apparently if necrosis of a piece of tissue occur without a previous cell infiltration, even although organisms may be present in large numbers, the elastic tissue fibres do not degenerate to the same extent.

Turning to the question of gangrene, of which condition I have examined three cases, several interesting points come out. There is usually considerable destruction of elastic tissue, although it is as usual relatively resistant. As before, the area of most marked destruction is coextensive with the area of cell infiltration. In the actually necrotic areas, which are to all appearance structureless when stained with ordinary methods, the elastic tissue network may be well preserved, so that, although no cell outlines are to be distinguished, elastic fibres, whether of alveoli, bronchi, or vessels, stand out in striking contrast (Plate XXIV. Fig. 3). In preparations suitably stained enormous numbers of bacilli and cocci can be demonstrated in such necrotic areas, even where the elastic fibres are well preserved. Certainly solution of the fibres does eventually occur, but right up to the edge of the gangrenous cavity the fibres can be followed, although somewhat attenuated and pale. In the areas of marked cell infiltration, however, although organisms may be relatively few in numbers, more or less extensive destruction of the elastic fibres can be seen. It seems as though the elastic fibres are subjected to the most severe test at the zone of inflammatory reaction. If they escape entire

destruction here (and the degree of destruction depends upon the acuteness of the process), they may persist for a considerable time in necrotic tissue, even though micro-organisms may be numerous; ultimately, however, they disappear at the margin of abscess or gangrenous cavity.

(b) *Formative Changes.*

In simple inflammatory processes these do not occur to any great extent. In the more acute cases there is no evidence of any new formation of elastic fibres. In the more chronic conditions, such as interstitial pneumonia sometimes observed in children, where there is considerable thickening of the interlobular septa, some new formation of elastic fibres can be seen in this newly formed fibrous tissue. Tuberculous and syphilitic conditions, however, in the author's experience, offer a much better field for the study of these formative changes, and the question will be taken up later in dealing with these conditions.

TUBERCULOUS DISEASES.

The distinction between inflammations of tuberculous and those of other origin is entirely artificial. There is no difference at all in the inflammatory reaction; the difference is in the special nature of the causal parasite in tubercle. The peculiarity of tuberculous inflammatory tissue depends upon the fact that the tubercle bacillus is a slowly growing organism, an organism possessing a resistant envelope, and containing a specific poison which has the property of causing caseation or a peculiar form of cell death. The changes in the elastic fibres, both destructive and formative, are, however, so much better studied in tubercle, largely owing to the slowness of the process, that the author feels justified in discussing them by themselves.

(a) *Destructive Changes.*

Acute Miliary Tubercle.—By this term one usually means a condition of the lungs in which minute tubercles, almost invisible to the naked eye, occur. Microscopically these are found to consist of aggregations of cells, usually mononucleated; in the centre of such aggregations there is a degenerative change commonly termed caseation. Tubercle bacilli, although not numerous, are usually to be found in this area of cell accumulation. The central caseous portion is made up of a more or less homogeneous looking material, into which the cells at the margin appear to be wandering, and within which their nuclei break down to form minute granules of chromatic substance, which ultimately disappear.

Now, in specimens stained by the elastic tissue method one has no difficulty in observing destruction of the elastic fibres in the areas

of cell accumulation, and this is most marked where these cells are commencing to break down. In the centre of such a tubercle elastic fibres are often completely absent. The question now arises: What are the changes which these elastic fibres undergo during the process of destruction? In the first place, there appears to be a splitting up of the fibres into their constituent fibrils. In the second place, there is a thinning of these fibrils, with a gradual loss of staining reaction, so that they become paler and paler, and ultimately pass into a structure which appears to be a continuation of them, but which no longer takes on the specific stain. There is occasional evidence of a sudden loss in continuity in a fibre; there is also some evidence of the breaking up of the fibre into small granules, but the more gradual process appears to be the most common. The thicker fibres are naturally the more resistant, and in larger nodules, where there is a distinct hyalin caseous centre inside the ring where cell destruction is going on, these thicker fibres may preserve, more or less completely, the elastic network of the alveoli (Plate XXV. Fig. 4).

The more chronic forms of miliary tubercle are characterised by the presence of those peculiar cell aggregations known as giant cell systems. Here bacilli are few and far between; indeed, it is exceedingly difficult to demonstrate their presence at all. The cells, instead of breaking down, or before they do so, build up a new formation, and, unless the condition is quiescent, additions are constantly being made to this neoplasm, both from within by cell division and from without by cell aggregation. As a result the impression which one receives is that of a tumour formation pressing aside the elastic fibres, not actually including and destroying them (Plate XXV. Fig. 5). Around such areas the fibres are condensed, and arranged circularly; they seldom pass inside, and when they do they present blunt ends, with no evidence of breaking up into fibrils or of loss of staining reaction. Such tubercles, as is well known, tend to have a distribution along the lymphatic channels, and may be called perivascular, peribronchial, subpleural, etc., according to their position. When situated round bronchi or vessels they may invade these (Plate XXV. Fig. 5), destroying as they do so the elastic laminae. This destruction is associated, as before, with inflammatory infiltration and splitting up of the fibres. When such cell areas abut on one another they exert mutual pressure upon the lung substance between, and doubtless cause a gradual destruction of the elastic network, although the fibres remain well stained up to the last.

It is perhaps needless to say that, associated with these more chronic miliary tubercles, one may find more acute ones with a varying amount of caseation and corresponding destruction of elastic fibres.

Caseous Broncho-pneumonia.—This condition, typically a catarrhal pneumonia which goes on to caseation, is characterised by the presence

of large caseous masses, in which, as a rule, numerous bacilli are to be found, especially at the spreading margins. Here the destructive changes in the elastic fibres may be very extensive. As might be expected, they are existent in proportion to the number of bacilli present. It is not, however, at the spreading margin where the bacilli are present in largest numbers that the destructive changes are most in evidence. One may observe a catarrhal pneumonic process in which bacilli are present in enormous numbers in the catarrhal cells, where the elastic network of the alveolar walls is, to all appearance, intact. The destruction is most marked, as before, at the margin of the caseous area where bacilli may be relatively few, but where cells are breaking down in the early stage of caseation. The degenerative changes which the elastic fibres undergo at this point appear to be the same as before, and this condition affords an excellent opportunity of following the process from beginning to end. The first change to be observed is a splitting up of the fibres into fine fibrils. Then there is a loss in staining reaction, the fibres failing to take on the resorcin-fuchsin stain as deeply as before; they appear, however, to persist as structures which no longer stain as elastic fibres, but which can be followed, when a counter stain such as van Gieson's is used, as yellow strands. I have failed to observe fragmentation of the fibres to any extent. The process appears to be much more a solution than a fragmentation. Should the fibres escape this marginal zone of commencing caseation, they usually persist, so that in the centre of a caseous area which is to all appearance structureless one may often observe the elastic structure of the lung fairly well preserved. As might be expected, however, in the more acute cases where there are large numbers of bacilli present, destruction is more complete, only the thicker bands of fibres escaping, the finer ones having completely disappeared.

A secondary inflammatory change sometimes occurs at the margin of these areas when they have ceased to spread, connected, doubtless, with an attempt on the part of the tissues to shut off the area of dead tissue. Within this zone there is an absence of elastic tissue. This is probably not due directly to destruction of the fibres, but to displacement by the cells of the granulation tissue, which subsequently develop into fibrous tissue. I have seen a large caseous area in the lung of a child, in which the elastic tissue network was almost complete, shut off in this way by a broad band of granulation tissue displacing the normal lung substance.

Not only does destruction of the essential lung substance occur in these conditions, but invasion of bronchi and vessels also takes place (Plate XXV. Fig. 6). The earliest change at such a point consists in the passage of inflammatory cells, usually mononuclear, in between the layers of elastic fibres, splitting them up and causing their gradual disappearance as caseation takes the place of simple cell

accumulation. Again, the zone of destruction corresponds with the zone of commencing caseation or cell fragmentation. I have observed the bursting through of such caseous areas now in two cases into branches of the pulmonary veins; one of these is shown in Plate XXV. Fig. 6. Needless to say, in both those cases there was a condition of acute miliary tuberculosis in such organs as the liver and spleen.

Caseous pneumonia may be lobar in its distribution as well as lobular. In a case of this kind, where the upper lobe of the right lung showed a slowly advancing localised caseous process, the lower lobe was completely consolidated. I found in the lower lobe the most extensive destruction of elastic fibres that I have ever observed. Here, again, the process of destruction appeared to consist, in the first place, in a loss of staining reaction. In specimens stained first by Weigert's method and then counter-stained with van Gieson's stain these fibres could be followed as yellow strands after they had ceased to stain purple with the resorcin-fuchsin. Nevertheless, here again the elastic structure was preserved in areas which were to all appearance structureless. In this case not only were tubercle bacilli present in large numbers, but also diplococci and other organisms, so that one could not regard it as a purely tuberculous process.

Phthisis.—This term is usually applied to tuberculous disease of the lungs in which there is breaking down of the lung substance and cavity formation. It may arise as a diffuse broncho-pneumonic condition, or more commonly as the result of gradual spread from a localised focus. In both cases, however, the result is the formation of more or less extensive areas of caseated lung substance, and it is within these that the process of cavitation commences. In these caseated areas there is a more or less complete preservation of the elastic tissue network, or rather of that part of it which has escaped the advancing inflammatory process, just as we have seen to be the case in chronic miliary tubercle and caseous broncho-pneumonia (Plate XXVI. Fig. 7).

What is the actual cause of the formation of these acute cavities I am not prepared to state. I think it exceedingly probable that it is the invasion of one of the larger air tubes by an advancing caseous area, and the gradual expression of the caseous material during the act of coughing. There appears to be no previous liquefaction, and the elastic network is preserved to the last. Indeed, the elastic fibres must be an important factor in preventing the process from going on more rapidly. It is in such a case that one would find elastic tissue in the sputum. The caseated material comes away piecemeal, containing shreds of the elastic network. As soon as such a cavity has begun to be formed inflammatory cells are again to be found in the caseous material (Plate XXVI. Fig. 8). What is the relationship of micro-organism, whether tubercle bacilli or others, to the process,

I am not prepared at present to state. As soon as such a cavity as is shown in Plate XXVI. Fig. 8 has formed, organisms are usually to be found in the walls, and doubtless they hasten the process of destruction.

The walls of such an acute cavity as is seen in Plate XXVI. Fig. 8 are formed by caseous material which still retains traces of the elastic tissue structure of the consolidated lung area which it represents. The caseous process spreads, more and more lung tissue being included; the cavity also enlarges by the breaking off of portions of this caseated material containing fragments of the coarser elastic tissue fibres which have escaped the primary tuberculous inflammation. The process may, however, be checked by the formation of a bounding wall of granulation tissue. In consequence we find that the more chronic cavities are not lined with caseated lung containing elastic fibres, but by a zone of granulation tissue of varying thickness consisting of young fibrous tissue, young vessels, and inflammatory cells, with an entire absence of elastic tissue, just as we have seen is the case in the zone of granulation tissue shutting off a tuberculous area. The coarsest fibres, such as those of large vessels, may remain, as is seen in Plate XXVII. Fig. 10, but as a rule no elastic fibres are to be found in the walls of these cavities, and therefore none will be found in the sputum.

The relationship of the phthisical process to the vessels is of considerable interest. The spreading caseous process involves in its course vessels as well as all other structures. It is, however, preceded by an inflammatory change which spreads through the vessel walls and causes endarteritis obliterans. I have not observed the bursting through of caseous material into veins such as I have shown to occur in the more acute broncho-pneumonic cases. This is probably explained by the more diffuse and more chronic nature of the process, so that the vessel becomes in the first place enveloped, and then the inflammatory process obliterates the lumen from all sides. Where rapid caseation is taking place with advancing cavity formation, as may be imagined, hæmorrhage is apt to occur, owing to insecure obliteration, or rather to caseation of the thrombus and advancing cavitation. In the more chronic cases, however, as is well seen in Plate XXVII. Fig. 10, a firm fibrous endarteritis obliterans prevents all chance of hæmorrhage, although this obliteration may at first be incomplete (also seen in the figure).

(b) Formative Changes.

As one would expect, formative changes are not a prominent feature in the more acute stages of the tuberculous process. In chronic tuberculous conditions, however, especially in the chronic interstitial changes of phthisis, elastic fibres are unquestionably reproduced.

This increase in elastic tissue may be more apparent than real. For example, one frequently finds large felted masses of elastic fibres thicker and more numerous than in the normal lung in the centre of a caseous and apparently structureless area (Plate XXVI. Fig. 9). This I do not regard as a new formation; it is in the highest degree improbable that new fibres could be produced within a dead and degenerated tissue. In all probability we have here to do with a condensation of elastic fibres, partly from contraction, partly from pressure. It seems not improbable that elastic fibres should show a tendency to shrink as other connective tissues do; possibly they exhibit a special contractibility from their elastic nature. At the same time I have seen no evidence of a tendency in severed fibres to fly apart.

True new formation of fibres does, however, take place, in some cases, to a most extraordinary extent. This may be observed in the greatly thickened pleuras and interlobular septa, so often met with in chronic phthisis. Here the new fibres may be seen passing into the newly formed fibrous tissue along with vessels, of which they form the elastic coats (Plate XXVII. Fig. 12). A similar streaming in of fine fibres, not obviously in connection with new vessels, may be observed. Again, one sometimes comes across places where, among the young fibrous tissue cells of the pleura or interlobular septum, there is a meshwork of the finest of elastic fibrils, and where there is no obvious connection with pre-existing fibres of any kind.

Another interesting new formation of elastic tissue is sometimes seen in connection with vessels. As previously stated, the advancing tuberculous process causes an obliterative change within arteries and veins. This, however, may not be complete. In Plate XXVI. Fig. 8 is seen such a large vessel partially occluded by a simple inflammatory process. But in one corner of it, farthest away from the cavity, is a small vessel within this vessel, surrounded by its own elastic coat of finest fibrils. Following this through a series of sections, one finds that this smaller vessel represents a branch which, by continuing itself within the obliterating artery, has carried on the circulation without fear of bursting into the cavity.

The question now arises: Where do these new elastic fibres come from? Do they arise *de novo* from newly formed cells, or do they spring from pre-existing fibres? I am inclined to think that both processes occur. In the case of the fibres in the walls of new vessels piercing the pleura and invading the newly formed fibrous tissue, a connection with those of the larger vessels from which these smaller ones have sprung can often be seen. Such a connection is, however, much more obvious in the case of solitary fibres passing in from the old pleural fibres. A direct connection between the two can frequently be traced. Plate XXVIII. Fig. 13 shows such a connection; this, however, is taken from a syphilitic not a tuberculous lung. The new fibres

arise from the lateral aspect of the horizontal fibres of the superficial layer of the pleura, they pass perpendicularly into the new fibrous tissue, become thinner and thinner, and finally may be seen to branch into finer fibrils. No direct connection between these new fibres and cells can be made out. Cells are usually to be found in the near neighbourhood, but they are round cells, and do not appear to be connected with the fibres in any way.

On the other hand, in the case of the fine fibres often observed in such enormous numbers in well-formed but fairly cellular fibrous tissue, no direct connection with pre-existing elastic fibres of either vessel or pleura can be seen. They usually occur in special abundance around vessels of some size, but it seems hardly conceivable that they are the result of budding of elastic fibres of the vessel's coat. One is driven to the conclusion that these fine fibrils are formed in some way from these connective tissue cells. As to whether they are formed within the protoplasm of the cell or as the result of some change in an already-formed intercellular structure, it is scarcely possible to dogmatise. I may say that I have seen little or no evidence of the former mode of formation; they appear to be invariably intercellular in position.

Again, with regard to the fibres formed around new vessels of some size, as in Plate XXVII. Fig. 10, nothing very decided can be said. One gets the impression that they are also formed in some way from the cells of the vessel wall. This seems the more probable if what Jores has suggested with regard to the function of such cells be true, namely, the special capability of the cells of the intima to form new elastic fibres.

SYPHILIS.

(a) *Destructive Changes.*

In an acute case of congenital syphilis in a child, where the lungs showed the condition known as white pneumonia, there appeared to be some destruction of the elastic fibres in the consolidated areas. As previously mentioned, in a case of lobar pneumonia, little or no disturbance of elastic tissue is to be seen. In this case, however, one had the distinct impression that there was a destruction of elastic tissue going on, although there were no places where this was so marked as to make one absolutely certain. The lung alveoli were filled with catarrhal cells, polymorpho-nuclear leucocytes, and smaller round cells; they also contained in places large numbers of red blood corpuscles. There was no tendency to caseous change to be seen.

In a case of acquired syphilis in the adult numerous collections of round cells could be seen scattered through the lung, but these were specially numerous in the neighbourhood of a large gumma. Such cell aggregations, which one may call miliary gummata, consisted

chiefly of small round cells. Within these areas there was a distinct destruction of elastic fibres (Plate XXVIII. Fig. 14). They usually occurred in the wall between two alveoli, and there was evidence of solution of continuity in the fibres at that point. These miliary gummata are in all probability analogous to the miliary tubercles.

With the advancing interstitial inflammatory process at the margin of the larger gumma there was evidence of a similar destruction, which, however, could only have been partial as, in a large caseous area, which was apparently structureless, when stained with ordinary methods a fairly well preserved elastic network could be seen. Just as in tubercle also, dense felted masses of elastic fibres could be seen within this caseous area, suggesting new formation; these, however, were probably due to condensation.

In the two cases of acquired syphilis examined the condition was localised to areas of semi-consolidated lung with thickened pleura and interlobular septa and occasional larger and smaller gummata. Owing to these interstitial changes there was, in all probability, considerable compression of lung substance, but this did not appear to cause any great destruction of elastic fibres.

(b) *Formative Changes.*¹

In both cases of acquired syphilis in the localised semi-consolidated areas previously mentioned there appeared to be an increase of elastic tissue. This, however, was probably due partly to compression from interstitial changes with consequent condensation of the lung tissue.

Precisely similar formative changes to those seen in the cases of chronic phthisis were observed in these cases of acquired syphilis. In the thickened pleura and interlobular septa elastic fibres could be seen in direct connection with pre-existing fibres of the pleura. They appeared to arise from the lateral aspect, became thinner as they passed into the thickened pleura, and were frequently observed to branch (Plate XXVIII. Fig. 13). Again, although cells could be seen in the immediate neighbourhood of these fibres, no direct connection between cells and fibres could be made out.

In the fibrous tissue of a large gumma enormous numbers of fine elastic fibres could be seen (Plate XXVIII. Fig. 14). These appeared to be arranged in whorls around medium-sized newly formed vessels. Further, one could also see in the neighbourhood of the above-mentioned gumma fairly large vessels showing endarteritis obliterans; and within the circle formed by the elastic laminae of these larger vessels smaller ones could be observed likewise bounded by a network of fine elastic fibrils.

As regards the mode of formation of these new fibres, one must,

¹ I am indebted to Dr. Douglas Stanley for the three cases of syphilitic disease.

I think, admit the possibility of both methods. To my mind there can be no doubt that the new fibres invading the thickened pleura are apparently developed by a process of lateral budding from the pre-existing elastic tissue. In the case of the fine feltwork of fibres seen in the well-formed connective tissue of the gumma, and also in the case of the fibres of the vessels within vessels, an origin from cells by the laying down of elastic substance in already formed connective tissue fibres seems the more probable explanation.

SUMMARY AND CONCLUSIONS.

As regards the relationship of the inflammatory process to destruction of elastic fibres, my results are, as a whole, in conformity with those of other observers, namely, that this destruction occurs in greatest amount within areas of cell infiltration. The elastic fibres are, however, relatively resistant, and thus afford a means of following the destructive process beyond what is possible in the case of other tissues. Should the fibres partially escape destruction under the action of an advancing zone of inflammation they may persist for a considerable time in the necrosed area left behind.

The area of destruction in tubercle is in the zone between the cellular infiltration and the caseous portion, where the cells are breaking down as the result of their encounter with the tubercle bacilli. In the acute miliary tubercle this is the area in the centre of the cell aggregation, there being often no area of complete caseation. In the larger tubercles and in the caseous broncho-pneumonic areas this line of cell destruction forms a distinct zone, and it is in that zone that the greatest destruction of the elastic fibres occurs. It is probably due to poisons set free from the bacilli by the phagocytic action of the cells upon them affecting cells and intercellular substance. In being set free, however, this poison is fixed by the destroyed cells, so that in the caseous structureless area, though bacilli may be present, their poison does not exist in a free state. A structure like elastic tissue, sufficiently resistant to escape complete destruction in the zone where the poison is being set free, remains intact for apparently an indefinite period within the area of complete caseation. In support of the supposition that caseous material contains no free toxin we have the experiments of Rosa (1897), who failed to produce the symptoms characteristic of tubercle toxin by injection of sterilised caseous material.

In the more chronic tuberculous conditions, where there is a marked formation of giant cell systems, the fibres are not destroyed in the same way. The tubercle in such cases is chiefly a structure of endogenous growth. It therefore pushes aside the fibres, and destruction occurs only by pressure. The remains of elastic fibres may occasionally be observed in tubercles with giant cells, but, like

Katsurada, I have failed to confirm the observations of Soudakewitsch (1889) and Rona (1900) with regard to the formation of giant cells around fragments of elastic tissue.

There is no essential difference, as Schmaus has pointed out, between the acute miliary tubercle and the larger areas of caseous broncho-pneumonia. In the former the area of cell destruction is central; in the latter, which is simply a further stage, it forms a zone outside the caseous area. Between the acute miliary tubercle and the giant cell nodule there is the difference between cell accumulation and cell multiplication. In the former the aggregation is most marked, in the latter the new formation.

Elastic fibres also persist in sloughs of lung tissue and in gangrenous areas. In all probability this persistence is to be ascribed to a similar cause—the fixation of toxin, set free during the encounter of cells and organisms, to the remnants of these cells, thus rendering the poison innocuous. This, of course, would only hold where the toxin is found chiefly in the body of the organism, but we know this to be the case in cocci as well as in tubercle bacilli. The occurrence of large masses of cocci in such sloughs and gangrenous areas in which the elastic structure is more or less completely preserved also supports this idea. The mere existence of the organisms is insufficient to cause destruction so long as the poison is not set free by the action of phagocytic cells.

Turning more particularly to the minute changes to be seen in the elastic fibres while undergoing destruction, my observations are, in general, in agreement with those of Katsurada. The process consists, in the first place, in a splitting up of the fibres, sometimes a separation into constituent fibrils. These fibres take on the Weigert stain with less intensity; they are paler in colour, and ultimately lose the staining reaction altogether. They appear to persist, however, for some time in the form of fibres which do not stain with resorcin-fuchsin, but which may be faintly stained with picric acid; this last point is not described by Katsurada. This method of destruction by a loss of staining reaction, in the first place, is interesting in view of the method of formation of elastic fibres described by Jores. This observer considers that the fibres exist first in a form which does not take on the characteristic stain. It also raises the question as to what this characteristic staining reaction depends upon. Fischer, who has investigated the chemistry of the Weigert method, comes to no conclusion on this point. He considers that everything which retains the stain after treatment with absolute alcohol is of the nature of elastin. Before such treatment, mucin and cartilage stain in a similar way. He finds that the Weigert method bears strict comparison with other tests for elastic tissue, such as resistance to caustic potash and staining with orcein.

As regards the regeneration of elastic fibres, I am inclined to

admit the possibility of both processes, namely, apparent budding from pre-existing fibres, and formation in connection with cells in newly formed tissue.

The former mode of origin was first described by Goldmann (1893) in connection with the development of elastic tissue in scars and around skin grafts. In a later paper (1901) he states that the new fibres formed in the scar tissue of skin arise chiefly from the fibres of the adventitia of vessels, but also from those around hair follicles. Enderlen has confirmed Goldmann's results, and notes the first evidence of regeneration about the twenty-first day; he has also observed regeneration from the remains of the elastic fibres of the skin graft. Both these observers noted the origin of the new fibres, not from the free extremity, but from the lateral aspect of the old ones. Jores confirms these observations; he emphasises the fact that the elastic fibres only commence to form when the tissue has assumed a distinctly fibrous character; it does not occur in what is usually termed granulation tissue.

The above results are confirmed by the author's observations. In simple, in tuberculous, and in syphilitic inflammatory processes I have observed the origin of new fibres from pre-existing ones, both from those of the pleura and from those of the vessel walls. I can also confirm Goldmann and Enderlen's observations that these new fibres appear to arise from the lateral aspect of the older ones. Further, there can be no doubt that it is into well-formed fibrous tissue that they pass, not into cellular or granulation tissue. I have failed to observe any definite connection between these fibres and cells.

This origin of new elastic fibres by a process of budding from old ones seems, on the face of it, improbable. Physiologists, as a matter of fact, do not admit it. There is a possible analogy in the regeneration of nerve fibre, but here the proximal end is still in connection with a living cell, and regeneration from the distal end is not by any means universally admitted. In this connection, however, Enderlen's observations of regeneration from the remains of fibres in the skin graft is interesting; in such a case, of course, the intervention of living cells would be improbable. It may be that connective tissue cells have something to do with the process, that they lay down fibres which subsequently take on the characters of elastic fibres; but, as previously mentioned, the connection is not obvious. The process is continuous, and not interrupted, as it would be in such a case.

The second mode of origin—from cells—is that held by physiologists and embryologists, although there is some difference of opinion among them with regard to the exact way in which the cells are concerned in the process. One idea is that the granules of elastin are developed in the protoplasm of certain cells, which have been called elastoblasts; these granules ultimately fuse to form the fibres. The other idea is that a transformation occurs in the already formed

collagenous fibres, whereby they acquire the properties of elastic fibres. The former view is held by Gardner, who has investigated the question from the embryological standpoint; it is also that supported by Prenant, Bouin, and Maillard in their "*Traité d'histologie*" (1904). Iwanoff, in his investigations on the development of the elastic fibres in the pregnant uterus, describes a similar process. I have never observed anything the least suggestive of this. I have never seen a fibre inside the protoplasm of a cell, or appearing to grow from it. In the area where fibres are being developed one may observe numerous round granules staining characteristically, but these, on altering the focus, are usually found to be fibres cut across.

The other view is held by Jores and Katsurada. The former observer saw elastic fibres staining characteristically passing into fibres which did not stain at all, but which could be followed on account of their highly refractile nature; he also observed that the younger fibres stained less intensely than the older ones. My own observations, so far as they go, appear to bear this out. Even the youngest fibres are intercellular, and in many places they appear to pass into fibres which do not stain with Weigert's method, but which can be followed owing to their high refraction. This is the method by which the elastic fibres, which sometimes occur in such enormous numbers in the thickened pleura and interlobular septa in phthisis, appear to be developed. It also appears to be the mode of origin of the fine fibres formed in the walls of young vessels. It seems probable that Jores is correct in ascribing to the cells of the intima of vessels a special capability for forming elastin.

In the last place this question arises: Is there any reason for the development of elastic fibres in newly formed tissues? Why do they develop in some tissues and not in others? There are those who hold that the fibres are only produced when there is a need for them, when there is some mechanical force, some pressure to be resisted. Such facts as the above-mentioned tendency for the intima to develop new fibres, both physiologically and in cases of sclerosis in arteries, support such an idea. Goldmann, however, concludes that mechanical causes play no part in the process. Jores (1900), while denying that they are the direct causes, considers that under their influence the fibres may tend to become thicker and stronger. Upon this question I do not feel that I can dogmatise. Certainly the formation of elastic fibres in the walls of young blood vessels in scar tissue is in favour of the view that mechanical forces are factors in the production, but the new formation of fibres in thickened pleura and interlobular septa does not appear to require such an explanation. It seems to be the natural tendency of chronic inflammatory tissue under certain unknown conditions, but chiefly in connection with organs and structures rich in elastic tissue, to develop large numbers of elastic fibres.

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DESCRIPTION OF PLATES XXIV.-XXVIII.

PLATE XXIV.

- FIG. 1.—*Septic infarction from case of pneumococcal meningitis*.—To the left is seen a vessel in whose wall a small abscess has developed between the layers of the elastic coat, suggesting an origin from a septic embolus of one of the vasa vasorum. Thrombosis has occurred within the lumen. To the right is seen a further stage in the process, where the abscess has destroyed the inner elastic lamina and has burst into the lumen of the vessel. ($\times 30$.)
- FIG. 2.—*Acute bronchiolectasis (lung of child)*.—A much dilated bronchiole is seen in the centre of the field. Its elastic lamina is much thinned, and in places completely destroyed. The surrounding lung substance is partially collapsed and consolidated. Small portions of two other bronchioles, showing similar changes, are also seen. ($\times 30$.)
- FIG. 3.—*Gangrene (lung of child)*.—Shows gangrenous area with complete absence of cellular structure, but at the same time almost complete retention of elastic network. ($\times 30$.)

PLATE XXV.

- FIG. 4.—*Acute miliary tubercle (lung of child)*.—The centre of one of the miliary tubercles is seen. To the right is zone of cell infiltration, where destruction of the elastic fibres is going on. In the centre of the field, and to the left, is the area of complete caseation, showing some of the coarser fibres which have escaped destruction well preserved. ($\times 570$.)
- FIG. 5.—*Chronic miliary tubercle (lung of child)*.—Shows perivascular development of typical tubercles, with compression of surrounding lung substance. To the left is seen a bronchus, whose wall at one point is in process of invasion by a tubercle nodule. The elastic lamina is seen destroyed at this point. ($\times 30$.)
- FIG. 6.—*Caseous broncho-pneumonia (lung of child)*.—The process of invasion of the wall of a pulmonary vein is well seen here. Note the separation of the elastic fibres by the inflammatory cells, which have actually burst through at one point, the tuberculous material escaping into the lumen. The structure of a caseous broncho-pneumonic area is also well seen. Note the zone of cell infiltration where elastic fibres are in process of destruction, also the central caseous area where the coarser fibres which have escaped destruction are still to be seen. ($\times 30$.)

PLATE XXVI.

- FIG. 7.—*Caseous nodule in apex of lung of diabetic*.—A portion of this nodule, which appeared structureless when stained with ordinary methods, is seen. Note fairly complete preservation of elastic network. ($\times 30$.)
- FIG. 8.—*Acute phthisis (lung of adult)*.—Caseous area breaking down to form acute cavity. Wall of cavity consists of caseous material, in which portions of elastic fibres are still to be seen. ($\times 30$.)
- FIG. 9.—*Chronic phthisis (lung of adult)*.—Apparent increase in the amount of elastic tissue in a caseous, structureless area of the lung, probably due to condensation. ($\times 30$.)

PLATE XXVII.

- FIG. 10.—*Chronic phthisis (lung of adult)*.—Margin of chronic cavity, with vessel showing endarteritis obliterans. Portion of lumen which represents the continuation of a branch, seen separate in other sections, still patent and surrounded with circle of fine elastic fibres. Granulating margin of cavity seen with absence of elastic structure. ($\times 30$.)
- FIG. 11.—*Chronic phthisis (lung of adult)*.—Portion of thickened interlobular septum, showing enormous new formation of elastic fibres. Note that the tissue is not very cellular, also that there appears to be no connection with cells and elastic fibres. ($\times 570$.)
- FIG. 12.—*Chronic phthisis (lung of adult)*.—Greatly thickened pleura, with new development of elastic fibres around the young blood vessel. ($\times 30$.)

PLATE XXVIII.

- FIG. 13.—*Acquired syphilis (lung of adult)*.—Margin of thickened pleura, with numerous fine elastic fibres arising apparently from the lateral aspect of the pre-existing fibres, and streaming into the newly formed tissue. Several large cells filled with pigment can be seen. ($\times 570$.)
- FIG. 14.—*Acquired syphilis (lung of adult)*.—Margin of gumma showing fibrosis, with new development of elastic tissue, seen as fine shading around young blood vessels. Two small miliary gummata are seen in the substance of the lung, consisting of accumulations of small round cells, in which the elastic fibres have to some extent been destroyed. Rest of lung substance shows marked condensation. ($\times 30$.)

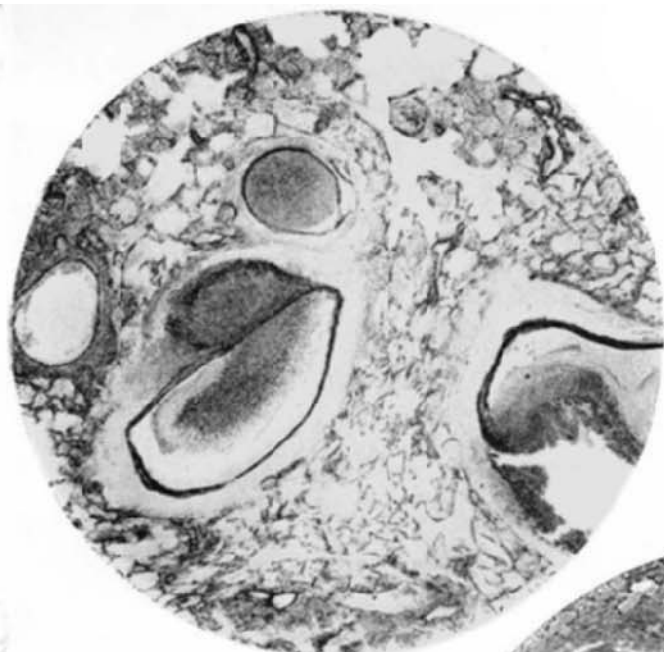


FIG. 1.

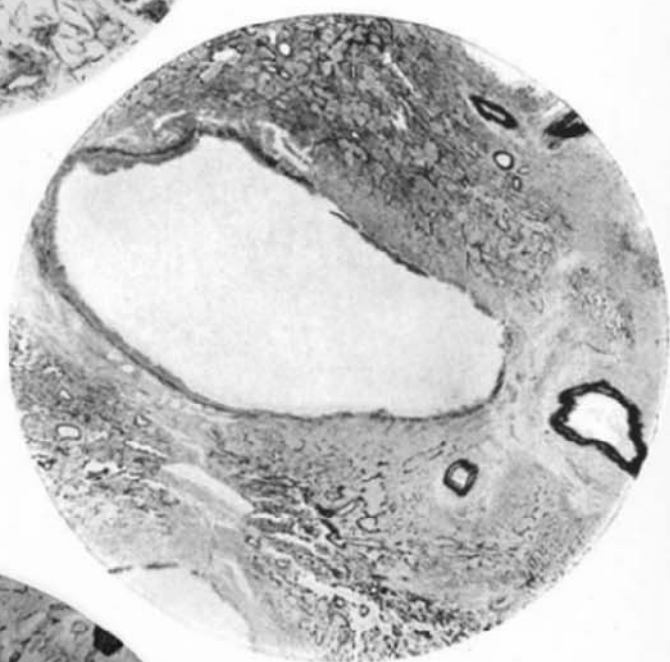


FIG. 2.

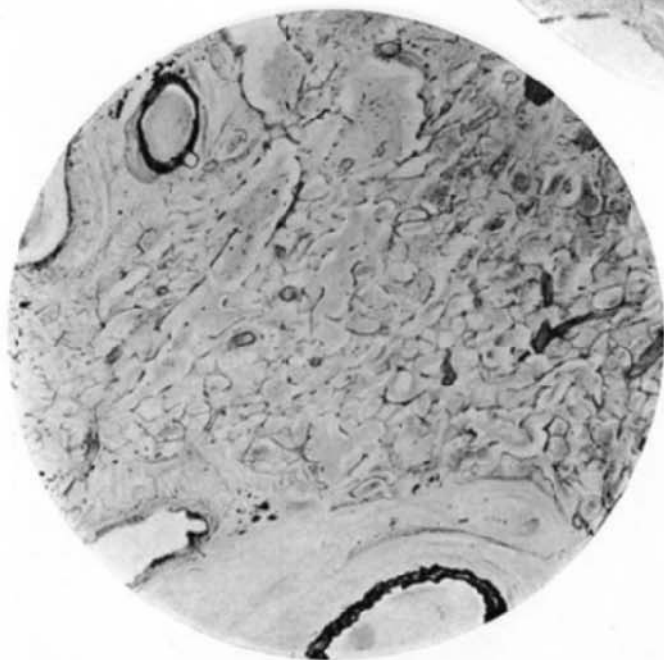


FIG. 3.

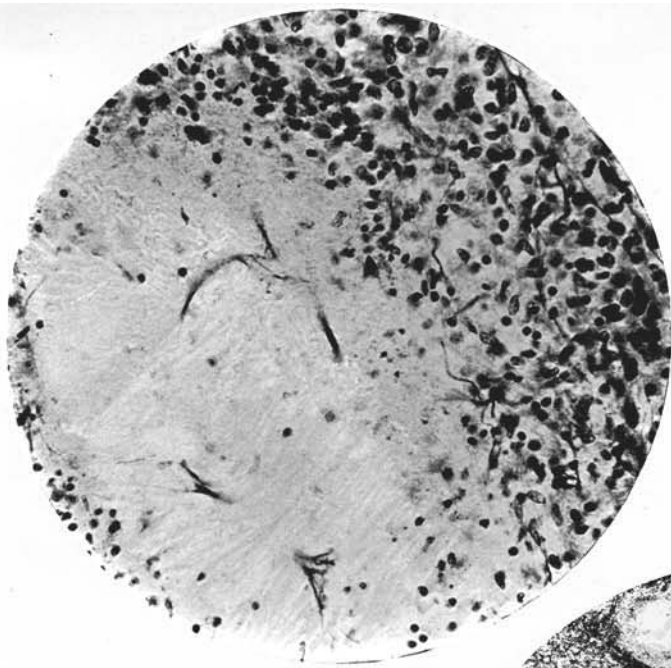


FIG. 4.



FIG. 5.

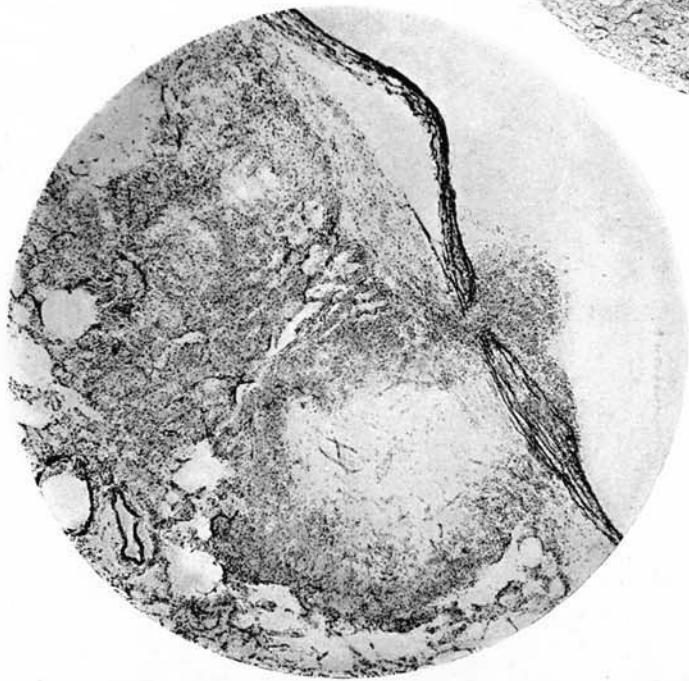


FIG. 6.

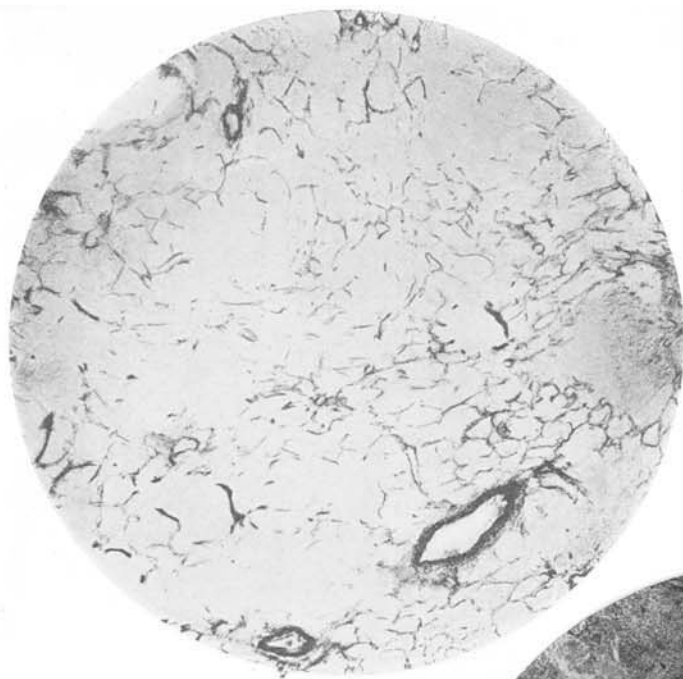


FIG. 7.

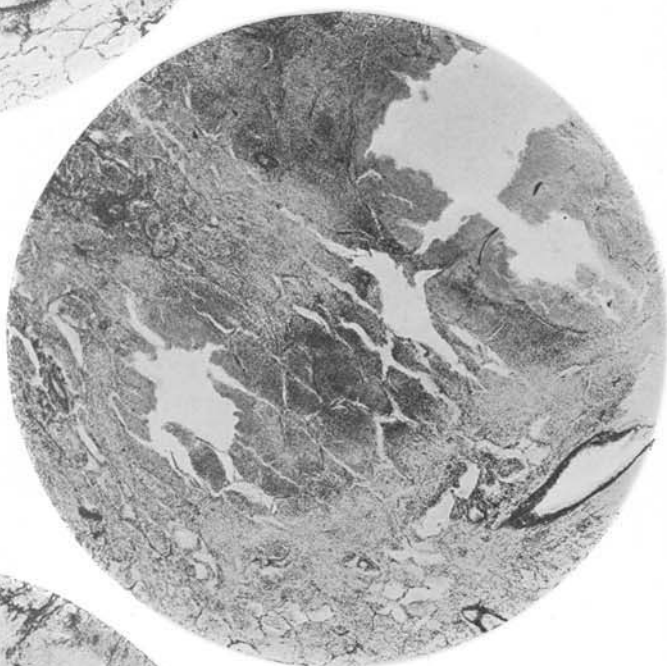


FIG. 8.

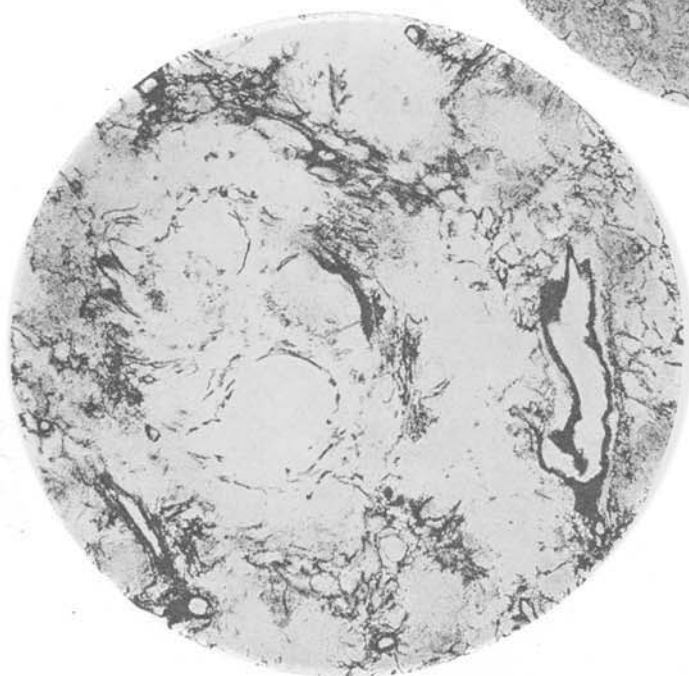


FIG. 9.

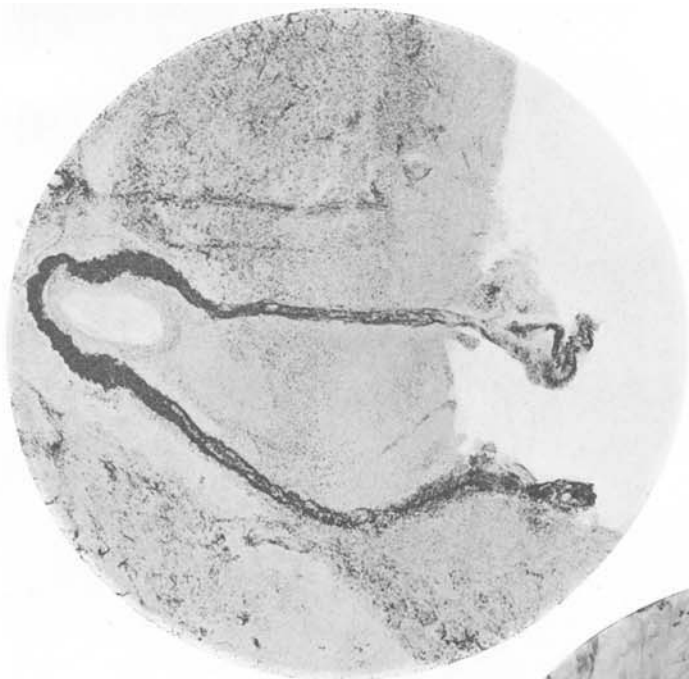


FIG. 10.

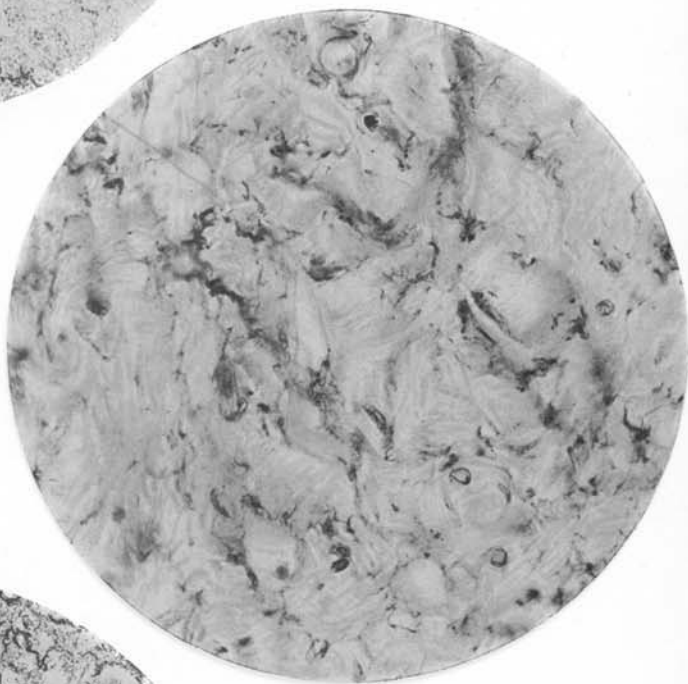


FIG. 11

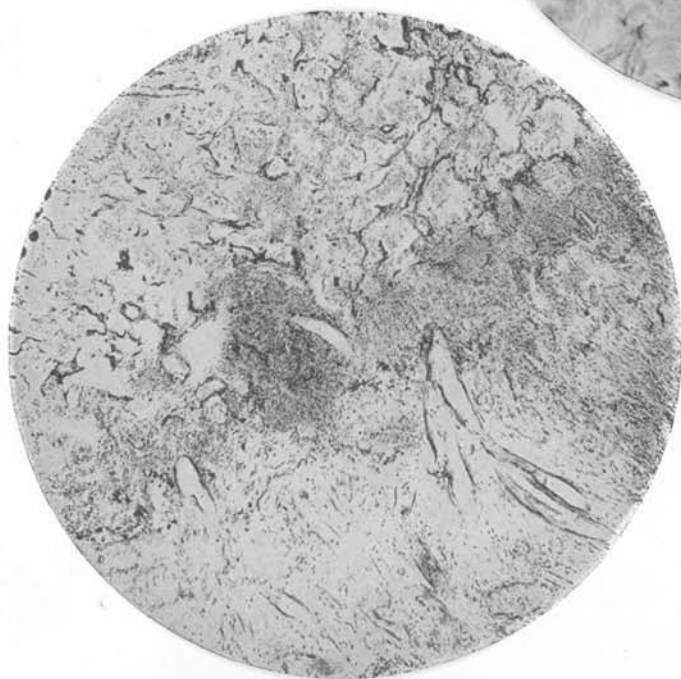


FIG. 12.

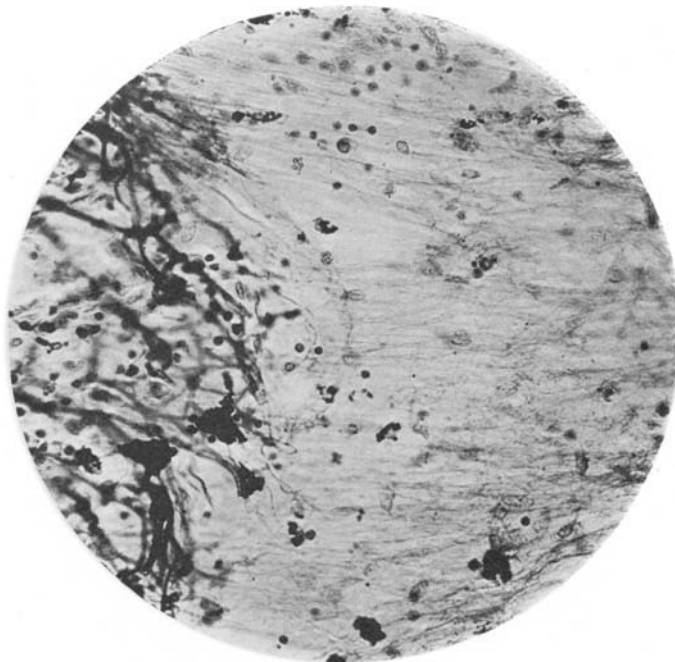


FIG. 13.



FIG. 14.