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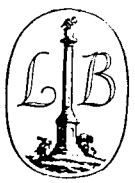


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CHAPTER 2

# THE PATHOLOGY OF THE PNEUMOCONIOSES

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In discussing the pathology of the pneumoconioses it is essential to distinguish asbestosis, a variety which is caused by minerals with a fibrous structure, from those varieties due to particulate, non-fibrous minerals, such as silica, coal and hæmatite. Numerically the second group is the more important and will be considered first, taking as types classical silicosis and coalworkers' pneumoconiosis, each of which assumes a simple and a massive form.

## Simple Pneumoconiosis

By simple pneumoconiosis is meant the pulmonary reaction to dust uncomplicated by any other factor and the term thus refers to the essential manifestation of the disease. Characteristically it takes the form of numerous, small, focal lesions composed basically of dust and fibrous tissue in various proportions. These lesions are discrete and measure up to about 5 mm. in diameter; they are more or less evenly scattered throughout the lung substance, but may be somewhat larger and more numerous in the upper than in the lower parts. To appreciate the mode of development of dust lesions reference must be made to the normal anatomy of the respiratory portion of the bronchiolar tree. The terminal bronchiole, that is the last order of nonrespiratory bronchiole, gives rise to three successive orders of respiratory bronchiole (i.e. those bearing alveoli) before the single order of alveolar duct is reached; the alveolar ducts then lead to atria and alveolar sacs (Heppleston, 1953). Dust deposited in the alveoli is ingested by phagocytes which attempt to eliminate the dust up the bronchiolar tree or to transport it to the lymphatic system. Dust may also move along airways and into the interstices of the lung as free particles, but evidence of this is not easily obtained. Small accumulations of dust are found in relation to the

intrapulmonary lymphoid tissue, situated along the peribronchial, periarterial and perivenous lymphatic channels, but a considerable concentration of dust occurs in the hilar lymph glands. It is sometimes contended that dust accumulation, with its associated fibrosis, in the hilar glands causes lymph stasis and thus leads to retrograde parenchymal accumulation of dust, but the evidence from both man (Simson, Strachan and Irvine, 1931) and animals (Heppleston, 1954b, 1958) contradicts this view. The typical dust foci, however, are situated in relation to respiratory air passages and they develop, both in man and in animals, because there are too many phagocytes to be evicted by the bronchial route and they therefore become trapped in the alveoli opening into and surrounding respiratory bronchioles (Heppleston, 1954a, 1954b). A physiological block evidently exists where respiratory bronchioles, i.e. alveolated air passages, join the nonrespiratory bronchiole. The subsequent course of events is determined by the nature of the dust, those containing a high proportion of free silica leading to the development of a specific lesion, the classical silicotic nodule, and dusts which contain little free silica, such as coal, to the formation of a quite distinct but equally characteristic dust lesion.

### Simple Silicosis

The simple silicotic nodule develops in relation to the respiratory bronchioles. At an early stage a fibroblastic reaction appears in the dust cell aggregates and eventually progresses to the formation of one or more islets of acellular fibrous tissue, which is often hyaline and arranged in a whorled fashion. In the fully developed classical silicotic nodule, these islets are enclosed by a zone of concentrically arranged and rather cellular fibrous tissue, around which there is an external zone of irregularly disposed connective tissue (Simson, 1935; Belt, 1939). Incinerated preparations, seen by dark-field illumination, show a typical ash pattern. The central islets contain a variable amount of finely dispersed dust, but the concentric zone is totally or largely devoid of particles, while a distinctive halo of dust lies in the external zone (Belt, 1939). Increasing exposure to siliceous dust results in the enlargement of existing nodules and the development of new ones. Thus, in the simple silicotic nodule the amount of dust is overshadowed by the large amount of fibrous tissue, which possesses a characteristic disposition. It is important to note that the air spaces surrounding the fully developed nodule are often of



normal size (Heppleston, 1947, 1951). The question of emphysema in simple silicosis is discussed later.

The proximate mechanism by which free silica induces fibrosis is still undecided, though some surface property is probably involved. For many years the silica solubility theory has been in vogue, but the idea that solution of silica in body fluids mediated the fibrosis was called in question by Gardner over twenty years ago when he pointed out that certain silicates, though more soluble than quartz, were not so fibrogenic (Gardner, 1934). King, Zaidi and Nagelschmidt (1956) have lately drawn attention to the inconsistencies of the silica solubility theory with the pathogenesis of silicosis. Once silicotic fibrosis has developed, hyalinization often follows and for this secondary process of hyalinization an immunological mechanism has been suggested. Pernis has demonstrated that silicotic hyaline tissue differs in its chemical constitution from other hyaline connective tissues of physiological or pathological origin. These true hyaline connective tissues are composed of approximately 80% collagen and 20% globulin, whereas silicotic hyaline contains only 40% collagen, the remaining protein being a globulin with a position between the serum $\beta$- and $\gamma$-globulins. Silicotic hyaline also contains more carbohydrate and much more lipid than ordinary hyaline connective tissue. In all these respects silicotic hyaline resembles amyloid (Vigliani and Pernis, 1958). There is presumptive evidence of an immunological mechanism in the genesis of amyloid (Vazquez and Dixon, 1956), and Pernis *et al.* (1957) have now demonstrated immunologically the presence of a serum globulin lying in the $\beta$–$\gamma$ zone in the hyaline tissue of silicosis. These observations emphasise the role of the host in the genesis of silicosis and raise the possibility of a relationship to the so-called collagen diseases.

### Simple Pneumoconiosis in Coalworkers

The simple dust lesion of coalworkers has three distinguishing features, a large amount of dust, a small amount of irregularly disposed fibrous tissue and frequently the presence of enlarged air spaces in and around the dust foci, that is focal emphysema (Gough, 1940, 1947; Heppleston, 1947, 1951). In all these regards the dust lesion of coalworkers contrasts with the silicotic nodule. To understand the precise structural changes in coalworkers' simple pneumoconiosis recourse must be made to serial sections. These clearly show (*a*) that the lesion is in effect a fairly wide sleeve of vesicular

tissue consolidated by dust and a little fibrosis disposed around the respiratory bronchioles, especially those of the second order, and (*b*) that it is these same respiratory bronchioles which dilate to produce the state known as focal emphysema (Heppleston, 1953). The appearance of these dust lesions in random histological preparations varies according to the plane of section. When this is transverse the lesion has a typically stellate outline with dilated air passages running through and surrounding the dust, whereas in longitudinal section the respiratory bronchioles are outlined in their tree-like form. By cinephotography of serial sections it is possible to trace the continuity of air passages in transverse, oblique and longitudinal planes, so reconciling the different appearances as manifestations of the same fundamental structure (Heppleston, 1955). The degree of focal emphysema varies widely from case to case and is sometimes so severe that alveolar ducts and sacs are compressed by the grossly dilated respiratory bronchioles. It is, however, important to recognize that the radiological features of simple pneumoconiosis in coalworkers are due to the dust itself plus the small amount of fibrous tissue and that chest X-rays reveal neither the existence nor the degree of focal emphysema (Gough, James and Wentworth, 1949).

The composition of the dust generated in the various operations entailed in mining coal must vary considerably. Hicks and Nagelschmidt (1943), for instance, found that in the rock strata adjacent to and sometimes dividing the coal seams in certain Welsh collieries the quartz content varied from 8% to 46% of the total minerals, yet in our experience all coal-face workers develop the same focal type of lesion. Moreover, simple pneumoconiosis in coalworkers shows identical features irrespective of (*a*) the rank of coal worked, whether anthracite, carbonaceous or bituminous and (*b*) the coalfield, whether British or American (Heppleston, 1947, 1951). Because airborne coal dust contains a little free silica, with a mean value less than 2% in South Wales (Nagelschmidt, 1943), this fraction has been regarded as the essential cause. If this were so the pure dust lesion of coalworkers would be expected to show some morphological resemblance to the classical silicotic nodule, that is the specific lesion caused by free silica. But, as already indicated, no such resemblance exists and we therefore believe that the simple dust lesion of coalworkers is a nonspecific reaction to the major fraction of the dust which is devoid of free silica and whatever the



free silica contributes is inconspicuous and non-specific (Heppleston, 1951). Crucial evidence supporting this conclusion was provided by a woman exposed for five years to carbon black, a highly purified form of carbon, and a man employed for 18 years in the manufacture of carbon electrodes. The simple dust lesions in these two individuals in no way differed from those in coalworkers, as Rüttner, Bovet and Aufdermaur (1952) also found in the case of a graphite miller, who had been exposed to a dust with the remarkably low ash content of 0·085% and whose lung ash contained no quartz. From this it may be concluded that free silica is not necessary for the development of the pure dust lesion in coalworkers and that this form of pneumoconiosis represents the effects of simple mechanical accumulation of a sufficient amount of dust irrespective of its nature.

The mechanics of focal emphysema is most easily interpreted on the basis of imbalance between the forces of inspiration and expiration (Heppleston, 1954a). As already shown, the simple dust lesion of coalworkers is in effect a fairly wide cylinder of vesicular tissue consolidated by dust and a little fibrous tissue, disposed around the respiratory bronchioles. Dust consolidation prevents expansion of this vesicular tissue under the traction of inspiration and the tension normally expended on these alveoli is evidently transmitted to the respiratory bronchioles as an addition to the inspiratory force to which they are normally subjected. A more important consequence of dust consolidation appears to be atrophy of the bronchiolar smooth muscle upon which expiratory contraction and shortening of respiratory bronchioles depend. These movements will therefore be diminished or abolished. Such interferences with the bronchiolar movements, both inspiratory and expiratory, will combine to produce the same effect, namely permanent dilatation, that is focal emphysema. The simple silicotic nodule, although it develops in the same situation as the focal dust lesion of coalworkers, does not lead to focal emphysema as defined above because it is a progressively expanding lesion, which indents and actually narrows respiratory bronchioles and at the same time counteracts the increased inspiratory traction produced by simple consolidation of vesicular tissue around respiratory bronchioles. Sometimes, however, the air spaces around silicotic nodules are emphysematous, but this enlargement is distinct from focal emphysema in that it affects any air space adjacent to the nodule and not particular segments of the airway. Emphysema with this irregular distribution may be attributed to

fibrous retraction after growth of the nodule ceases, which may not be for years after cessation of exposure to siliceous dust.

Lesions fundamentally similar to those occurring in coalworkers are found in hæmatite miners, coke workers, graphite workers (Gloyne, Marshall and Hoyle, 1949) and boiler scalers (Harding and Massie, 1951). In all these occupations the dust, like coal, has a low free silica content and it is therefore reasonable to conclude that they share a common pathogenesis. Comparable lesions also occur in some foundry workers (McLaughlin, 1950).

### Massive Pneumoconiosis

Massive lesions in coalworkers (Gough, 1940, 1947; Heppleston, 1951) consist of dust irregularly mingled with bundles of coarse, hyaline collagen fibres and tend to occur mainly in the upper parts of the lung. Blood vessels and air passages are inconspicuous, but the previous existence of arteries and arterioles in massive lesions is shown by the persistence of internal elastic lamellæ after the lumina have been partially or totally obliterated by an invasion of fibrous tissue accompanied by dust-laden cells. The massive lesions of silicosis are distinguished by the typically nodular arrangement of the connective tissue, numerous nodules being matted together by fibrosis. Caseous areas may be found in massive fibrosis but they do not always show conclusive histological evidence of tuberculosis.

A tuberculous element is often recognized to participate in the production of silicotic massive fibrosis (Simson and Strachan, 1935; Gardner, 1940; Strachan, 1947) but the ætiology of massive lesions in coalworkers has long formed a matter for dispute. It has been maintained that dust alone is sufficient for this purpose but James (1954) adduced several reasons which render this view most unlikely. Simple pneumoconiosis is symmetrical and, if massive fibrosis was due only to dust, both lungs should be equally affected, but this is often not the case. Numerous, large dust foci may occur without massive disease, which, on the other hand, is sometimes seen in young men with short dust exposures and relatively little dust in the non-fibrosed parts of the lung. Furthermore, coal-dust acting alone is inadequate to account for the excessive fibrosis. For this same reason collapse with coalescence of simple dust lesions is also an inadequate explanation for the genesis of massive fibrosis, quite apart from the fact that no evidence for collapse can be made out. In the genesis of massive fibrosis, therefore, a factor additional to the



dust must operate and for well over 100 years tuberculosis has repeatedly been advanced as the complicating element. This concept was thoroughly tested by James (1954), who found bacteriological or histological evidence of tuberculosis in 40% of massive lesions from 365 South Wales coalworkers. Although the remaining 60% of these massive lesions showed no clear evidence of tuberculosis, they may well represent healed lesions, since the general pathological features of massive fibrosis are always similar. James' analysis supports this interpretation, since 88% of massive lesions from men under 40 showed tuberculosis, which was evident in only 29% of lesions from men of 60 or over. We therefore interpret these findings as indicating the tuberculous origin of massive fibrosis and believe that with increasing age the infection dies out. It is difficult to conceive of tubercle bacilli penetrating into existing massive lesions. Tubercle bacilli only appear in the sputum when tuberculous foci communicate with bronchi, many of which however are obliterated in massive lesions. This probably explains why during life tubercle bacilli are present in the sputum of less than 2% of men with massive fibrosis (Cochrane *et al.*, 1952; Carpenter *et al.*, 1956). A tuberculous element therefore exists in the massive fibrosis of coalworkers just as in classical silicosis, but in coalworkers it is largely concealed, except in the younger men, many of whom are hewers and getters. Why tuberculosis should be less apparent in coalworkers than in silicotics is not clear, but Cummins and his collaborators (1931, 1938) showed that coal-dust adsorbed tuberculin and abolished the Mantoux reaction, but quartz did not do so. Coal-dust might therefore alter the reaction of the tissues to the toxin of the tubercle bacillus so as to restrict the extent and the progression of the disease. The tuberculous element clearly occurs in a modified form and the pathological features also suggest that it is limited in its extension and retarded in its rate of progression. The epidemiological observations of Mann (1951) and Cochrane (1954) accord with this view. The study of human material has provided no satisfactory alternative to the view that tuberculosis is the complicating factor in the production of massive fibrosis. Those who do not accept the tuberculous origin of all cases of massive fibrosis may suggest that bronchial infection is the cause, but such infections have the reverse effect and cause dust to be discharged from the lung and not accumulated in it (Gough, 1957). Moreover, animal experiments show that tuberculous infection of the lungs combined

with the inhalation or intratracheal injection of various dusts, including free silica (Gardner, 1937, 1938) and coal (Zaidi *et al.*, 1955), can induce extensive fibrosis, but non-tuberculous infection of the lungs of silicotic rabbits failed to do so (Vorwald, Delahant and Dworski, 1940).

Massive fibrosis in coalworkers often leads to death, sometimes from overt pulmonary tuberculosis but much more frequently from pulmonary heart disease due to vascular obliteration and emphysema (Gough and Heppleston, 1955), whereas the reverse obtained in classical silicosis (Strachan, 1947). On the basis of the above evidence, it can, however, be said that indirectly tuberculosis plays a large part in the mortality of coalworkers.

Cavitation is frequently seen in the massive lesions of coalworkers and it develops as the consequence of two distinct pathological processes, ischæmia and tuberculosis (Kilpatrick, Heppleston and Fletcher, 1954). Vascular occlusion leads to colliquative necrosis and, if a patent bronchus is involved, to cavitation. Cavitation also results when softening occurs in areas of caseous tuberculosis enclosed by massive fibrosis and a bronchus is eroded. Closely similar types of cavitation are recognized in silicotic massive fibrosis (Vorwald, 1941).

### 'Rheumatoid' Pneumoconiosis

A condition recently recognized by Caplan (1953) is the so-called rheumatoid pneumoconiosis. Caplan drew attention to the greatly increased prevalence of massive fibrosis in Welsh coal-miners with rheumatoid arthritis and to the fact that about a quarter of these men also had peculiar, rounded opacities in their lung radiographs. These discrete opacities are now known to represent rheumatoid nodules, which may coalesce into massive lesions. Characteristically, the nodules appear in crops and develop much more rapidly than the areas of massive fibrosis in non-arthritic miners. The radiological severity of the lung changes does not necessarily parallel the degree of arthritis. Pulmonary lesions usually develop contemporaneously with the arthritis but either manifestation may precede the other by several years (Miall *et al.*, 1953).

Rheumatoid nodules are usually bigger than silicotic nodules and when fully developed show wide concentric bands of necrotic collagen separated by lines of dust. In addition rheumatoid nodules show peripheral zones of active inflammation in relation to necrotic collagen and this feature occurs in some nodules from which tubercle



bacilli cannot be recovered by culture or guinea pig inoculation. Rheumatoid disease is regarded by Kellgren (1952) as being essentially an inflammatory reaction to necrosis of normal or pathologically produced collagen. It is therefore suggested that coalworkers with rheumatoid disease react abnormally to the collagen produced in infective pneumoconiosis and the inflammatory reaction, occurring in the absence of tubercle bacilli, is believed to be the rheumatoid component of these peculiar nodules (Gough *et al.*, 1955).

The subsequent course of rheumatoid nodules varies. Sometimes the central necrosis involves an air passage and the necrotic material is expectorated so leaving one or more thin-walled cavities. In some such cases the sputum has been free from tubercle bacilli. Other rheumatoid nodules calcify and still others enter a stationary or quiescent stage.

### Asbestosis

The term asbestos derives from the Greek meaning 'unquenchable,' in the sense of being indestructible, and refers to certain fibrous silicates, which have been in use for over 2,000 years. These silicates belong to two groups of minerals, serpentine and amphibole, the latter also being known as hornblende. The serpentine group is represented by the particular mineral chrysotile or white asbestos, which is a hydrated magnesium silicate containing a small amount of iron. The amphibole group includes crocidolite or blue asbestos and amosite, both of which are iron silicates, together with tremolite, a magnesium calcium silicate. These minerals occur in Canada, Italy and South Africa, crocidolite coming almost exclusively from South Africa. They are mined by blasting and quarrying and then processed by crushing, carding and spinning for use in the manufacture of textiles, paper and board, brake linings, asbestos cement and as fillers in paint and plaster. It is in mining and processing that fibres are produced and many of them are of a size that can penetrate the depths of the respiratory tract. In Britain asbestos is processed for industrial use but, since the introduction of the Asbestos Industry Regulations in 1931, the risks attending exposure to the inhalation of asbestos fibres have greatly diminished.

Despite its ancient usage, the recognition of asbestos as a cause of industrial pulmonary disease is relatively recent and it was only 31 years ago that Cooke (1927) and McDonald (1927) first designated the condition as asbestosis. The pathological reaction in asbestosis has three main features.

**1. Formation of asbestosis bodies.** These are found only within the host and, judging by their rate of appearance in the sputum, they develop fairly rapidly after exposure. The body is composed of a central fibre, which is encased by a deposition of protein, evidently derived from tissue fluids. The protein sheath possesses a brown colour due to the presence of iron and often assumes a beaded or segmented appearance with bulbous extremities, which may also show cleavages. These fissures evidently represent a process of disintegration (Gloyne, 1938) and in long-standing or severe cases of asbestosis, the proportion of smaller bodies increases (Gloyne, 1951; Knox and Beattie, 1954a, 1954b). Histological preparations show that asbestosis bodies lie in the respiratory portion of the bronchial tree and occur singly or in groups. Their presence means only that a tissue reaction to the fibre has occurred. The formation of asbestosis bodies appears to render them innocuous, since bodies extracted from human lungs are unable to induce fibrosis in the guinea pig lung, whereas asbestos fibres themselves are active (Vorwald *et al.*, 1951). Thus the reaction to the fibre does not necessarily parallel the production of pulmonary fibrosis.

**2. Macrophage reaction.** The presence in the lung parenchyma of asbestos fibres leads to a pronounced proliferation of macrophages which surround and attempt to engulf the fibres in the air spaces. Not infrequently foreign-body giant cells are formed, but even these are sometimes too small to ingest the longest fibres completely.

**3. Fibrosis.** In man several forms of fibrosis are seen and tend to affect the lower parts of the lung predominantly. A widespread *fine* fibrosis is common around respiratory bronchioles, alveolar ducts and sacs, that is in relation to the sites where asbestos fibres lodge. Fibrosis also occurs in the pleura, where it may be pronounced, and in the lung septa. In consequence of these changes the lung structure tends to be obliterated, but it is most likely that the *massive* fibrosis of human asbestosis is the result of secondary infection. Gardner (1938) failed to produce massive fibrosis in guinea pigs by exposure to asbestos alone but fibrous foci were formed after tuberculous or nontuberculous infection in animals with asbestosis. If, in human disease, the fibrosis has a patchy distribution, *cystic* change may develop in adjacent non-fibrosed areas of lung, so giving rise to a honeycomb appearance in a manner analogous to that seen in other pulmonary conditions (Heppleston, 1956).

**Complications.** Hyperplasia of bronchiolar epithelium, which may also show squamous metaplasia, is not uncommonly associated with the fibrotic or fibrocystic changes of asbestosis, and the epithelial proliferation may progress to frank malignancy. When pulmonary carcinoma supervenes in asbestosis, it is usually of squamous type and, in contrast to the general population, predominantly arises in the lower lobes, which are also the site of maximum involvement by asbestosis. Isselbacher *et al.* (1953) summarized the published evidence and concluded that the association of bronchogenic carcinoma with asbestosis was more than coincidence. Doll (1955) stated that lung cancer was a specific industrial hazard of certain asbestos workers, and that the average risk among employees exposed for 20 or more years has been of the order of ten times that experienced by the general population. This risk has, however, progressively diminished since the working environment was improved by the introduction of the 1931 regulations. Endothelioma may develop in the greatly thickened pleura of asbestosis. In contrast to asbestosis, there is no evidence that silicosis (Irvine, 1935–38; Vorwald and Karr, 1938) or coalworkers' pneumoconiosis (James, 1955) is associated with an increased liability to carcinoma of the lung.

Although it is possible that an increased risk of developing pulmonary tuberculosis exists in asbestosis, the evidence is too fragmentary to be dogmatic. The figures, though small, do suggest a lesser incidence of tuberculosis in asbestos workers than in silicotics (Merewether, 1933–34). In guinea pigs, asbestos inhalation causes a restricted and temporary spread of pulmonary tuberculosis (Vorwald *et al.*, 1951).

**Ætiology.** Two views have been expressed. The *chemical* hypothesis assumes that on disintegration of the fibres, the asbestos minerals are liberated and dissolve in the body fluids, so leading to fibrosis (Gloyne, 1951; Knox and Beattie, 1954a, 1954b). Because chrysotile and hornblende occurred in the dusts to which workers were exposed but only hornblende in the lung residues, Kühn (1941) thought that chrysotile was broken down to produce the lung changes whereas hornblende persisted and led to the formation of asbestosis bodies. The experimental evidence cited by Vorwald *et al.* (1951) is, however, opposed to the chemical hypothesis. Brucite ($Mg(OH)_2$) fibres, containing very little silica, cause a similar fibrotic reaction to asbestos on intratracheal injection. The potency of free silica increases with diminishing particle sizes, but asbestos fibres less than

10–20 $\mu$ long are practically innocuous. Aluminium hydroxide neutralizes the effect of quartz but not asbestos. Nonfibrous serpentine is inert in the tissues, but has the same chemical composition as the active fibrous chrysotile. Although the minerals causing asbestosis vary widely in their chemical composition they are all fibrous in form and hence the hypothesis of *mechanical* irritation is now favoured. The fibres, it seems, must be both long and flexible, since, according to Vorwald *et al.*, a minimum length of 20–50 $\mu$ is required to produce fibrosis in the guinea pig and the inflexible fibres of glass wool are non-fibrogenic. Furthermore, the flexible fibres only appear to act in the lung and the peritoneum, that is in sites normally subjected to regular movement. It is clear from these considerations that the pathogenesis of asbestosis cannot be regarded as settled.

### Talc Pneumoconiosis

Pure talc is a hydrated magnesium silicate, which occurs in foliated or compact masses or as plates, but commercial talc may also contain minerals of the serpentine and amphibole groups. Talc is mined in North America, Europe, Scandinavia, Egypt, India and China. The ore is first milled and then separated by air for industrial use as a filler, dusting powder and absorbent. Relatively few cases of talc pneumoconiosis have come to autopsy, but more have been diagnosed clinically.

According to the accounts given by Porro *et al.* (1942), McLaughlin *et al.* (1949), di Biasi (1951), Schepers and Durkan (1955) and by Hunt (1956) talc pneumoconiosis is characterized by diffuse and nodular fibrosis, but the pattern does not suggest silicosis. The nodules contain numerous birefringent particles resembling short needles and scattered asbestosis-like bodies are also present. X-ray analysis of the lung ash from the case of McLaughlin *et al.* (1949) showed that there was probably less than 0·06% of free silica in the dried lung, whilst in di Biasi's case no quartz was present in the lung on chemical or X-ray diffraction analysis. The X-ray diffraction pattern of the lung residues in Hunt's case indicated less than 0·5% quartz.

There is a certain histological similarity between asbestosis and talc pneumoconiosis, which may depend on the similar physical form or chemical constitution of the minerals responsible. The resemblance is strengthened by the occurrence of asbestosis-like bodies in both conditions.



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CHAPTER 3

# REACTION OF THE LUNG TO DUST

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THE following account attempts to show by description and photomicrograph how the lung reacts to different dusts under the simplified circumstances of animal experiment before going on to consider the reactions of the human lung under the more complicated conditions that obtain during a worker's lifetime.

The dusts we have studied most are coal and quartz, and in most of our experiments the dust has been given as a single intratracheal injection. This is a rather artificial method, but it has the advantage of allowing us to observe the reactions at known time intervals after the application of the dust.

## The Reaction of the Lung to Coal

In this experiment rats were given a single intratracheal injection of 100 mg. of finely powdered coal-mine dust in the same range of particle size as respirable dust. (Nearly all the particles were less than 5 $\mu$ and 20% were less than 2 $\mu$ diameter.) The dust reaches the alveoli over a wide area of lung, but at first lies free. Within 30 days (Fig. 1*a*) it is nearly all picked up by alveolar phagocytes and these begin to collect into clusters, mainly around the vessels and respiratory bronchioles. A proportion of these dust cells migrate to the hilar lymph nodes. The residual dust cells remain *in situ* and in due course are surrounded by a minimal network of fine reticulin fibres (Fig 1*b*). In a word this dust occupies space within the lung, but does not excite fibrosis.

## The Reaction of the Lung to Quartz

With a fibrogenic dust like quartz the effects are quite different. The dust is given in the same way as coal, but the dose was only 50 mg. per rat. It is rapidly phagocytosed and the dust cells collect into clusters. This occurs rather more quickly than with coal;