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PNEUMOCONIOSIS OF COAL-MINERS*

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[WITH PHOTOGRAVURE PLATE]†

In South Wales during the past 15 years rather more than 17,000 men have been certified by the Silicosis Medical Boards to be suffering from silicosis or pneumoconiosis and have been suspended from their underground work. More than 10,000 of them have been certified in the past three years. There were two mines in South Wales which lost one in every three of their underground workers owing to these diseases in the one year 1945. These bare figures need no embellishment to reveal the seriousness of the problem presented to the mining industry or to convey the extent of human suffering occasioned by pneumoconiosis in this region. Elsewhere in Great Britain the problem is proportionately less serious, but even here the certification of nearly 3,000 men in 15 years presents a problem that is serious enough.

In 1943 a committee was set up by the Minister of Fuel and Power to consider the rehabilitation and treatment of miners in South Wales suffering from silicosis and pneumoconiosis. Among the recommendations of this committee (Ministry of Fuel and Power, 1944) was that more research into the problem was needed. The Medical Research Council was approached, and in 1945 it established in South Wales a Pneumoconiosis Research Unit to carry out investigations into every aspect of the problem of coal-miners' pneumoconiosis. Since then it has been my concern to organize and carry out research with a growing team of medical and other scientists in this Unit.

I propose, first, to consider briefly how the present disastrous situation has arisen in a century remarkable for the important advances in industrial health which have been achieved in almost every industry, then to discuss the former investigations of the Medical Research Council into the problem and the developments that have taken place since their publication. Finally, I shall describe some of the recent investigations undertaken by the Pneumoconiosis Research Unit and others in South Wales.

History

The early history of coal-miners' pneumoconiosis is rather obscure. The pathology of the disease was described in this country over 100 years ago in Scottish coal-miners by Gregory (1831), Marshall (1834), and Thomson (1836), and the associated clinical descriptions of the breathlessness,

which was called miners' asthma, and the black spit of such cases exactly match the clinical picture as we see it to-day. Greenhow's demonstration of the siliceous residues in the lungs of such cases in 1869 carried knowledge a step further, but thereafter the subject lapsed into obscurity, with a general consensus of opinion developing in the first two decades of this century that, owing to the improved conditions in the pits, the disease no longer existed among coal-miners (Oliver, 1908). This opinion was expressed by two successive Milroy lecturers. Thus Shufflebotham in 1914 said, "At the present time in Great Britain fibrosis of the lungs among miners can be said to be practically non-existent"; and in 1915 Collis said, "Miners' asthma, common though it used to be, has passed unobserved from our midst, and conjectures as to its character and causation are idle."

Whether these opinions were correct or not we cannot now be sure, but some doubt is thrown on them by a consideration of the Registrar-General's returns in the first four decennial supplements of this century. Unfortunately, we cannot go further back than this because of the unsatisfactory occupational classifications previously in use. However, for these four periods Mr. Oldham, our statistician, has calculated mortality rates (standardized on the population of all occupied and retired males in England and Wales, 1901) from all respiratory diseases other than tuberculosis and from pulmonary tuberculosis for coal-miners over and under the age of 55; for it is in the older coal-miners that deaths from pneumoconiosis are most likely to occur. These standardized rates are given in Table I, together with the rates from the same causes for

TABLE I.—Standardized Death Rates of Coal-miners and All Occupied and Retired Males in England and Wales, per 1,000

Period:	All Respiratory Diseases except Tuberculosis				Pulmonary Tuberculosis			
	1900-2	10-12	21-3	30-2	1900-2	10-12	21-3	30-2
Over 55 { Coal-miners All occ. and ret. males, E. & W.	21.33 14.24	14.21 9.91	13.60 8.96	7.02 5.16	1.82 2.17	1.27 1.85	1.14 1.26	0.86 1.04
Under 55 { Coal-miners All occ. and ret. males, E. & W.	1.57 1.93	1.05 1.14	1.00 1.00	0.90 0.76	1.14 2.64	1.01 1.96	1.06 1.50	0.95 1.24

*The first of the two Goulstonian Lectures delivered at the Royal College of Physicians of London on Jan. 13 and 15.

†The Photogravure Plate will appear in next week's issue, with Lecture II.

all occupied and retired males. Coal-miners over 55 have throughout this period consistently shown a relatively high death rate from all respiratory diseases other than

tuberculosis. Although Oliver's (1908) evidence of a diminishing incidence of pulmonary fibrosis among coal-miners towards the end of the last century is convincing, I suspect that considerable numbers of these deaths have always been due to dust diseases of the lung, and that the supposed disappearance of the disease was in part due to incorrect diagnoses.

The relatively low death rates of coal-miners from tuberculosis are also shown in Table I. It was perhaps this fact more than anything else which led to the widespread and persistent acceptance of the view that silicosis was rare among coal-miners; for the particular liability of the silicotic to die from tuberculosis had become established in this century, especially as a result of J. S. Haldane's important contributions to the subject. It was Haldane (1934) who defined silicosis as "a disease of the lungs brought about by the inhalation of siliceous dust and leading to tubercular infection of the lungs accompanied by a great development of fibrosis in them." From this definition the reverse conclusion was derived that when in any industry there was no excessive tuberculous mortality there was no silicosis. Haldane's (1923) declaration that "the inhalation of coal dust causes no danger to life but on the contrary gives even protection against the development of tuberculosis" was largely responsible for the fact that mining engineers made no attempt to reduce the concentrations of air-borne coal dust in the mines at a time when, owing to the introduction of mechanical methods of mining, these concentrations were in general becoming more intense. It must be admitted that medical men by their ill-informed complacency have a heavy load of responsibility to bear for the present high incidence of pneumoconiosis among coal-miners.

This period of complacency was closed chiefly by the increasing use of radiography in the diagnosis of chest disease. Cases of definite silicosis in coal-miners who had carried out drilling in rock were first reported in South Wales in 1926 by Tattersall. Soon after this, in South Wales, tuberculosis officers of the Welsh National Memorial Association (1931) and private radiologists, in particular Harper (1934) in Ammanford, began to observe radiological pictures similar to silicosis in coal-miners who would have been diagnosed clinically as cases of chronic bronchitis, and even in apparently healthy miners. In 1930 Cummins and Sladden in a classical paper published a detailed account of the pathology of such cases, showing that they had a kind of silicosis modified by what was regarded as an accumulation of coal dust due to lymphatic blockage by silicotic fibrosis.

The South Wales Miners' Federation had naturally been claiming compensation for men such as these for some years, but it was not until 1929 that a scheme of compensation was started. Initially, the scheme was confined to men who could prove that they had worked in silica rock, but in 1934 it was opened to all men working in coal. The rising number of certified cases in South Wales soon showed that pneumoconiosis was a serious problem, at least in the anthracite mines in this coalfield. At the same time, in Sweden (Edling, 1926), Germany (Boehme, 1925), Belgium (Langelez, 1938), France (Magnin, 1935), and also in Australia (Badham and Taylor, 1933) reports of silicosis among coal-miners were appearing. In America (Bloomfield *et al.*, 1935; Flinn *et al.*, 1941; Jones, 1942), and later in the Soviet Union (Moshkovsky, 1941), the disease was also shown to exist, chiefly among anthracite miners.

In England, however, uncertainty concerning the nature of the disease among coal-miners persisted. Haldane's (1935) view was that coal-miners developed bronchitis because of the excessive pulmonary ventilation occasioned

by their strenuous work, and that consequently inhaled coal dust was not normally eliminated from their lungs and accumulated to cause a benign type of fibrosis which was not silicotic. Jones (1936) added the suggestion that bronchitis was especially common among anthracite miners because they become chilled after their day's work by being brought to the surface in special open cars or "spakes," whose use is almost entirely confined to this part of the coalfield.

M.R.C. Inquiries—Medical Studies

It was against this background of increasing awareness of the prevalence of some form of pulmonary fibrosis among coal-miners that the Industrial Pulmonary Diseases Committee of the Medical Research Council undertook to investigate the problem in South Wales. These investigations began in 1937, and their results were published in three reports appearing in 1942, 1943, and 1945.

Between 1938 and 1940 Hart and Aslett carried out a radiological survey of working colliers at 16 pits distributed throughout the South Wales coalfield. Their main conclusions were:

First, that there was a serious incidence of radiological abnormalities among coal-face workers, similar to those seen in cases of silicosis, which must be attributed to the inhalation of coal dust. Although men exposed to the inhalation of rock dust were more prone to develop these abnormalities it was among the numerically predominant coal-getters that the greatest number of cases occurred. The part played by coal dust was further illustrated by confirming the presence of similar abnormalities in the lungs of coal-trimmers exposed to dense clouds of coal dust, but to no rock dust, in the bunkers of ships in South Wales ports, thus confirming the findings of Collis and Gilchrist (1928).

Secondly, that the incidence of the disease appeared to be related to the type of coal in which the men worked. They confirmed the evidence provided by figures of certification that hewers of anthracite in the western part of the coalfield were most seriously affected, that hewers of soft or bituminous coal were much less affected, and that hewers of steam coal with its intermediate rank showed an intermediate incidence. This observation gave rise to what may be called the "rank of coal" hypothesis, which relates incidence of pneumoconiosis to rank of coal. The "rank" of a coal is measured by the proportions of carbon and hydrogen in the coal substance. A high rank, or hard, coal has a high proportion of carbon (as in anthracite), while in softer coals the proportion of hydrogen increases and that of carbon diminishes. There were a few anthracite (high rank) pits which did not show a high incidence, but these exceptions were explained by the fact that they were shallow pits in which the coal was naturally damp and therefore less dusty.

Thirdly, they described an appearance in the abnormal radiographs of a "fine network, sometimes sharp and lacelike in pattern, but much more often blurred in appearance," which they called *reticulation*. This condition was clearly occupational in origin and might be associated with respiratory disability, but, not being nodular in appearance, did not conform to the criteria of silicosis required for compensation purposes. The Industrial Pulmonary Diseases Committee consequently recommended that for the purposes of compensation the radiological standard required for the diagnosis of "pneumoconiosis of coal-miners" should include reticulation. Subsequently an order was issued to this effect, and on and after July 1, 1943, the radiological condition of reticulation was made certifiable.

"Reticulation"

I want at this point to make a few comments on the introduction of the term "reticulation," for some confusion has arisen from its use and from the description of its appearance as being that of a network. Hart and Aslett admitted in their full discussion of this question that a

reticular pattern, or an increase of linear lung markings, had been described by other observers (e.g., Steuart, 1923; Edling, 1926) in the early stages of silicosis which precede the formation of definite nodular shadows and which were considered by many of them to be non-specific changes that might be seen in cases without any dust exposure, particularly in patients with chronic bronchitis. Hart and Aslett considered that reticulation was distinct from the appearance of exaggerated lung markings in that it was a finer pattern and did not fade at the periphery of the lung fields. Confusion has, however, persisted. For instance, in France, where periodical x-ray examinations of all underground workers in coal-mines have recently been instituted, the term reticulation is used to describe non-specific changes (Croizier, 1947). In South Wales many men are referred by their doctors to the Silicosis Medical Boards with a radiological opinion that they have reticulation when their radiographs show only an increase in lung markings. Moreover, "reticulation" has come to be used, even in this country, to describe the earliest stages of classical silicosis (Hale, 1946) and other occupational lung diseases (Perry, 1947). Whatever may be the merits of the word "reticulation" to describe the characteristic pattern of early coal-miners' pneumoconiosis, there is no doubt that in practice its use may give rise to some misunderstanding.

Hart and Aslett were forced by circumstances to use a portable x-ray set for their radiography and were therefore unable to achieve a high degree of definition in their films. In the Pneumoconiosis Research Unit we have been fortunate in having a fine-focus rotating anode tube, and we have used ordinary films and high-definition screens. With this technique we find that the most characteristic and almost universal change in the disease is a fine mottling whose main components are usually less than 1 mm. in diameter but may reach twice that size. For this appearance we have, for the time being, used the term "pin-head mottling." In the earliest stages it appears alongside and between exaggerated lung markings, but later it may become so intense that it obscures the normal markings completely (Plate, Fig. 1). The appearance is similar to that described by Caplan (1947) in silicosis in the Kolar gold-mines. It is uncommon for this pin-head mottling to remain in a pure form. Frequently it is associated with a coarser mottling, through which it can still be distinguished, so that a film is often seen which appears nodular when viewed at a distance of a few feet but in which, on closer scrutiny, the nodules can be seen to be composed of aggregates of pin-head mottling (Fig. 2). These granular nodules may be distinguished from a more homogeneous type of nodule which we see particularly in cases resembling classical silicosis with a history of heavy exposure to rock dust or in cases where we suspect a complicating tuberculosis. The commonest type of film is one in which there is a mixture of pin-head mottling with rather coarser nodular shadows of irregular shape and size (Fig. 3). We are not inclined to use the word "network" to describe any of these appearances. We do not suggest that at present the term "reticulation" should be abandoned. It has proved useful in emphasizing the differences between the early stages of coal-miners' pneumoconiosis and those of classical silicosis, and it can only be supplanted by some better term as a result of wide agreement among workers in the field of pneumoconiosis. Moreover, it may be that, with further advances in radiographic technique, further modifications in terminology may become necessary.

Verbal descriptions of radiological appearances, however, will always be confusing. We think they should be forsaken and that in their place should be built up a national (perhaps ultimately international) collection of type films. These films, or good reproductions of them, should be

made available to all medical men concerned with the study of pneumoconiosis. Any radiological appearance could then be described without risk of misunderstanding as being similar to a particular area of a given standard film.

A more serious practical difficulty than that of terminology arises from the fact that reticulation has to be considered as a definable condition for the purpose of decisions concerning compensation. It is obvious that the condition must in fact gradually develop from normality, but, unlike nodulation, in which it may be possible to define a minimum number and size of nodules for such purposes, reticulation cannot be assessed numerically, and it appears to develop only by a gradual increase in intensity. Hart and Aslett gave no guide to the degree of abnormality required for a confident diagnosis of reticulation to be made.

I have recently explored this question experimentally by presenting x-ray films showing various degrees of reticulation to a number of experienced observers, and have found remarkable differences in their opinions concerning the minimal degree of abnormality required to justify a diagnosis of reticulation.

This quantitative aspect of diagnosis is an artificial one resulting from the requirements of compensation legislation. The difficulty might be resolved by the use of standard films (taken, of course, with standard technique) for comparison with any film that is under consideration. I propose to repeat my experiment on diagnosis using such standards, in order to see what increase in consistency of opinion can be obtained with their assistance.

To return now to Hart and Aslett's conclusions: In the fourth place, they described a sequence of radiological abnormalities beginning with reticulation and proceeding through nodulation (consisting of localized or generalized multiple discrete shadows 2 to 5 mm. in diameter) to coalescent nodulation in which the nodular shadows begin to fuse, and on to the late stages of multiple fluffy shadows consisting of larger, less well-defined shadows than those of nodulation, and finally to large, well-defined, and dense massive shadows. From a consideration of the varying incidence of these abnormalities in men with increasing exposure to coal dust they postulated that with such continued exposure, at least in the mines with higher incidence, reticulation tended to develop into nodulation and thence by coalescence to fluffy and massive shadows. Consideration of the underlying pathology of these radiological appearances led to the conclusion that reticulation and the later more advanced abnormalities were "related in pathological development as well as being connected in time sequence." They carefully considered the part that tuberculosis might play, but concluded that it was so modified by pneumoconiosis that its presence could not be identified confidently in life and that it played an associated rather than a causative part. This view that a modified tuberculosis might play an adjuvant rather than an essential part in the development of massive fibrosis was similar to the views of Cummins (1936), Sen (1937), and Jones (1938) in South Wales. It differed slightly from the American view (Sokoloff, 1936; Bloomfield *et al.*, 1935; Gardner, 1940), by which tuberculosis appeared to be regarded as entering into and modifying the majority of the cases of advanced fibrosis. It was opposed to the view of Policard (Policard *et al.*, 1939), in France, who has always maintained that tuberculosis is the main cause of fibrosis in pneumoconiosis.

Lastly, finding no particular method of mining to which the high incidence of the disease might be attributed, Hart and Aslett emphasized the urgent need for suppression of all air-borne dust in coal-mines.

M.R.C. Studies of Pathology and Pathogenesis

In the same report there appeared an account by Belt and Ferris (1942) of the pathology underlying the x-ray changes described by Hart and Aslett. They were not able to add much to existing accounts of the disease

(Cummins and Sladden, 1930; Gough, 1940), but they laid emphasis on a basic pathological change underlying the radiological reticulation which they described as a diffuse network of reticulin fibrosis enmeshing, without redundancy, the deposits of coal dust in the lungs. To this condition they gave the name "dust reticulation." After ashing, dust reticulation left a highly siliceous residue. It provided a constant background, as does radiological reticulation, to the more advanced collagenous fibrosis corresponding to radiological appearances ranging from nodulation to massive shadows. Belt and Ferris suggested that the dust reticulation was due solely to the presence of silica in the coal dust, but that the development, in certain cases only, of collagenous fibrosis was due to the sporadic influence of an additional factor. This factor was not identified, but it was suggested that it might often, though not necessarily always, be the tubercle bacillus. This suggestion was based on the histological similarity between many of the fibrotic lesions in which tubercle bacilli could be identified and others in which they were not to be found but might none the less have been present at an earlier stage in the development of the lesion.

The pathogenesis of the disease was investigated along three main lines in addition to that of morbid histology.

A. By studies of air-borne dust underground in the mines at which radiological surveys had been carried out (Medical Research Council, 1943). It was shown that there was a relationship between disease incidence and the concentration both of the total dust and of its ash (or non-coal) component. It was not possible to distinguish between the quantitative and qualitative effects of the various dusts, but in their summary of the findings the Industrial Pulmonary Diseases Committee concluded that "the dust in anthracite mines is more dangerous than in the bituminous mines," thus supporting, but not explaining, the rank-of-coal hypothesis.

B. By chemical and mineralogical studies of the residues obtained by incineration of lung specimens an attempt was made by King and Nagelschmidt (1945) to see whether the degree or type of fibrosis could be correlated with any particular component of the dust in the lungs. In the lungs of men who had worked predominantly in rock and who had developed the classical type of silicotic nodulation there was a significantly greater amount of quartz and mica than in lungs showing the other types of fibrosis, but amongst the latter group, while there was rather more quartz and mica in the more advanced cases of fibrosis, the difference from the earlier cases was not statistically significant. No correlation was found between the amount of fibrosis and the amount of coal, which led to the conclusion that coal itself was not fibrogenic.

C. By the intratracheal inoculation of rats with suspensions of various air-borne dusts and of dusts obtained by the grinding of certain rock strata encountered in the South Wales coal-measures Belt and King (1945) showed that dusts containing high proportions of quartz and mica were the most fibrogenic. Air-borne dusts in general gave little fibrosis. The most fibrogenic air-borne dust was, curiously enough, derived from a low-incidence bituminous mine.

On the other hand, Campbell (1944) exposed mice to the inhalation of anthracite and bituminous dust and found that a greater increase of reticular tissue was produced in the lungs with the former than with the latter dust.

The state of knowledge concerning coal-miners' pneumoconiosis as it was left after the publication of the Medical Research Council's Reports may be very briefly summarized as follows: There was now no doubt that pulmonary disease attributable to the inhalation of coal dust was a serious problem among the coal-miners of South Wales; that the frequency of its occurrence appeared to be related to the rank of coal, being higher in the higher-rank coal-mines, but whether this was due to quantitative or qualitative differences in the air-borne dust clouds could not be decided; and, lastly, that both silica and some unspecified

agent, possibly tuberculosis, were chiefly responsible for the development of fibrosis.

On the scientific aspect of the problem, the chief developments after the completion of the Medical Research Council's earlier investigation were in the field of pathology, which I shall discuss later.

In the field of practical affairs, two developments need consideration: dust suppression, and an increase in the incidence of certified disease.

Dust Suppression

After the passing of the Coal Mines Act in 1911 the use of some device to prevent the escape of rock dust into the air during drilling became obligatory, but no attempts were made to suppress coal dust. In 1938 the Royal Commission for Safety in Coal Mines discussed suppression of coal dust only as a means of reducing the danger from explosions. Research into the problem was, however, advised, and the British Coalowners' Research Associations and the Safety in Mines Research Board began to investigate the problem. In South Wales, as the results of the Medical Research Council's investigations came to be known, serious attention began to be paid to the prevention and suppression of coal dust underground, both by the Mines Inspectorate, the Monmouthshire and South Wales Coal Owners' Association, and by the Amalgamated Anthracite Company, who set up their own Silicosis Research Committee.

The result has been the development of various methods of dust suppression, of which the most important are the following.

1. *Improvements in Ventilation.*—This has been of importance particularly in anthracite mines, where, owing to the methods of working the coal in common use, and owing to the rather haphazard development of the mines from shallow surface workings, poor ventilation was formerly one of the main reasons for the high dust concentrations in this part of the coalfield.

2. *Water Infusion.*—By this method water is introduced under pressure into the coal seam in advance of the working face, so that the coal is already damp when it is cut. It is a most effective method, but is not free from technical difficulties, particularly if the water leaks out from the coal seam into the adjacent strata, which it may soften and thus cause difficulties in the control of the roof.

3. *Wet Cutting.*—The mechanical cutting of coal has since its introduction been one of the most prolific sources of dust. A chain of picks is carried by a jib into the coal seam and undercuts or overcuts it, so that the coal is more easily won. The cutting of coal produces a mass of finely ground coal, much of which subsequently becomes air-borne, particularly when it is shovelled on to a conveyor. The introduction of water or foam with the picks damps the finely ground coal and largely prevents it from becoming air-borne, while percolation of the water into the coal adjacent to the cut and the dampness of the floor reduces much of the dust caused by working the overhanging coal.

4. *Water Sprays.*—Where water infusion or wet cutting is impracticable, water sprays are used to wet the coal-face before the coal is pulled down and the loose coal before it is loaded or before it is transferred from one conveyor to another or from a conveyor into trams. They have also recently been applied to pneumatic picks, which are another important source of dust.

The magnitude of the task achieved in the field of dust suppression in South Wales is shown by Table II, which gives the

TABLE II.—*Extent of Dust Suppression in Coal-mines in Great Britain in November, 1947*

	South Wales		Rest of Gt. Britain	
	Miles	% of Total	Miles	% of Total
Total length of coal-faces worked ..	80.51	100	306	100
Total length of faces with dust suppression in operation ..	42.6	53	12.5	4
Length machine-cut wet ..	14.6	18	8.6	2.7
Length water-infused ..	17.3	21.5	0.2	0.1
Length treated with hand-sprays ..	10.7	13.5	3.7	1.2

position of dust suppression in November, 1947. In South Wales half of all the coal-faces were treated with some means of dust suppression, and this is claimed to represent nearly all the places at which dust concentrations rise above the

provisional standards of safety that have been adopted. It will be seen that dust suppression in the rest of England is still in its infancy. Dust Prevention Committees have recently been set up in every division of the British coalfields, and the fruit of their labours should soon become apparent.

In this field, however, it is the doctor's role not to ask over how many miles of coal-face measures of dust prevention are officially being applied; he must ask, rather, how far dust levels are in fact being reduced. There is good evidence that in many places dust levels have been reduced to as little as 10% of their former high level, although all too often this degree of success has not been achieved (Monmouthshire and South Wales Coal Owners' Association, 1945). Whether this reduction is sufficient to remove the risk of pneumoconiosis is not yet established; nor can it be until, in the course of years, it can be shown that new cases are no longer arising.

A further role for the doctor as a human biologist is to insist that dust-suppression measures should not only be mechanically and physically effective but that the men who have to operate them should find them convenient and acceptable in use, and that they should by a policy of education come fully to appreciate their need. Sprays that are ill-adjusted may wet the men more than the coal and will be turned off. Excessive use of water in any method may cause unpleasant working conditions. Men are always unwilling to accept measures for their own safety that are inconvenient and require care and attention. Perhaps the most urgent needs to-day in the field of dust suppression are that more attention should be paid to the human factor, that in every piece of mining machinery automatic dust-suppression devices should be incorporated by the manufacturers, and that there should be *fully trained* dust-suppression officers in every pit.

There may always be certain mining methods in which the production of heavy dust clouds will be unavoidable—for instance, shot-firing. Under these circumstances it may be necessary for men to wear respirators. Unfortunately, no efficient respirator has yet been devised which men are willing to wear consistently. In the design of respirators filtration efficiency has been given priority over wearability, despite the obvious fact that an efficient mask in the pocket is of much less use than an inefficient mask on the face. In this field of investigation the biological approach is needed, giving first attention to the convenience of the man, if necessary at the expense of perfect filtration efficiency.

Increase in Certification Rates

The second important development since the publication of the first reports of the Medical Research Council has been an increase in the incidence of certified disease, which, in point of time, followed the acceptance of the radiological condition of reticulation for purposes of compensation. Hart and Aslett considered the possible consequences of such a change in legislation, but concluded that a large increase in numbers of certified cases should not be anticipated, chiefly because respiratory disability, in the absence of which compensation is

not granted, was infrequent in cases of reticulation except in the later age groups.

Unfortunately, this forecast was not correct, as may be seen in Chart I, which shows the number of men certified as totally or partially disabled in each year from 1931 to 1946. After the introduction of the Coal Miners' Pneumoconiosis Order in 1943, applications to the Board rapidly increased. At first the Medical Boards were overwhelmed in South Wales, and a large waiting-list was built up. More doctors were appointed in 1944, and the number of men certified rose to over 5,000 in 1945, to fall again in 1946. Provisional figures for 1947 show a further fall to just under 3,000. It is to be noted that certifications have continued to rise in the other coalfields of Great Britain, and provisional figures for 1947 show a further rise to just under 1,000.

The mean rate of certification since 1942 has risen to four or five times the rate in that year. There are no precise figures available to show what proportion of this increase was caused by the inclusion of cases of reticulation, but Dr. N. Keating and Dr. J. C. McVittie, of the Cardiff and Swansea Silicosis Boards, estimate that of the men certified since July, 1943, approximately 50% have been cases of reticulation that would previously have been rejected. Thus, since only half of the increase can be accounted for on this basis, there must have been a considerable increase in the number of applicants to the Board with more advanced disease than reticulation. It is important to consider why this increase has occurred.

There is no doubt that men with quite advanced pneumoconiosis can continue to work for many years underground. At first they may have no symptoms; later, with increasing symptoms, economic pressure and fear of unemployment may

CHART I.—Number of men certified by the Silicosis Medical Boards as partially and totally disabled by pneumoconiosis and silicosis in each year from 1931 to 1946. Above: South Wales. Below: Rest of Great Britain. The population at risk is about six times greater in the rest of Great Britain than in South Wales. The percentage of applicants rejected by the Medical Boards in each year in South Wales is also shown.

keep them at work. Any influence which will lead men to apply with greater readiness to the Silicosis Boards will therefore give rise to an apparent increase in the incidence of all stages of the disease as judged by certification rates. Two such influences have recently been of importance, at least in South Wales.

The first has been the operation of the Essential Works Order, under whose provisions during and since the war men could leave coal-mining on medical grounds only. In South Wales before the war there was little alternative employment for a coal-miner, but by 1942 war industries were in full operation, so that there was actually a labour shortage. Wages were high in these factories and conditions good. If after a day's toil at the coal-face a man comes home tired and dirty to find that his daughter, fresh from a day of light bench work, has earned more money than he has, he may begin to think of following her example. Many men found an application to the Silicosis Medical Boards a means of escape from mining to easier and more remunerative work. The second influence, in South Wales at least, has been increasing awareness among miners of the risk of pneumoconiosis. Miners are well-educated men, and in many a workman's club library the Medical Research Council's Reports on Chronic Pulmonary Disease Among Coal-miners are well thumbed and well understood. In every mining village in South Wales patients certified as suffering from silicosis can be seen pausing for breath on the hills. In a recent study undertaken by the Social Survey (1947) to investigate the problem of recruitment to coal-mining 68% of mining men in South Wales gave danger to health and dustiness as the chief objection to mining, whereas in other mining areas this objection was not raised by more than 40% of those questioned. The weight of these influences is shown by the large number of unsuccessful applications to the Boards. It might have been expected that the adoption of reticulation as a basis for compensation would have resulted in an abrupt fall in the percentage of cases rejected. In fact, as may be seen in Chart I,

no such fall occurred because of a rise in the number of applicants with insufficient disease for certification.

It also will be seen in Chart I that during the past five years there has been a slight but definite rise in the number of cases certified as totally disabled. These men have such severe symptoms that they would have applied to the Board regardless of any outside influence. This increase in numbers of advanced cases suggests that there has been a true increase in incidence recently.

Further evidence for such an increase may be derived from an analysis of the geographical distribution of certified cases which I have made with the help of my colleague, Mr. H. H. Watson, by calculating the annual certified incidence per 1,000 underground workers in all South Wales mines employing more than 100 men underground. These incidence rates were calculated for two periods, 1931-8 and 1940-5. The mines were then classified into groups showing, in the first period, annual rates per 1,000 of less than 1, 1-3, 3-5, 5-7, and over 7; and in the second period into groups showing annual rates per 1,000 of under 1, 1-10, 10-30, 30-50, 50-70, and over 70. When these rates are plotted on a map of the mines in the South Wales coal-field (see accompanying Maps) it is possible to draw "contour" lines enclosing those pits which fall within the same incidence groups. It is interesting to note that while pits with widely differing incidences may adjoin one another, areas of high incidence, in general, are surrounded in turn by areas of medium and low incidence. I cannot enter here into the complex factors which determine the disposition and shape of these contours, but will only state that the incidence of certifications is probably closely related to actual disease incidence. In the first period the groups of high-incidence mines in the anthracite area are clearly seen: there is a long irregular tongue of medium incidence extending into the steam-coal area, and there is another small but sharp peak of high incidence in the bituminous area. Elsewhere the annual rate is less than 1 per 1,000.

In the second period, in which the incidence levels at which contours have been drawn are ten times as great as those in the first period, the anthracite peaks remain, the bituminous peak is but a relatively low mound, but the striking change is the high peak that has developed in the steam-coal area, especially in the Rhondda Valley, which now rises to match the western heights. Only a small area in Monmouthshire has retained an annual incidence of less than 1 per 1,000.

The outstanding increase of incidence in East Glamorgan is brought out again in Table III, in which the pits have been grouped geographically into four main areas and the ratio between the average incidence in the two periods throughout these areas is shown. In the anthracite area, in West Glamorgan and in Monmouthshire, the average increase of incidence lies between sixfold and sevenfold. In East Glamorgan, however, the increase is nearly three times as great. A fallacy in these ratios might be caused by a disproportionate decrease in underground man-power in this area, but the percentage decreases in underground man-power (also shown in Table III) are similar in all the areas.

We must also consider the possibility that the high ratio in East Glamorgan might be due not to a real increase in incidence but rather to a later development of awareness of the disease in this area. In this case the disproportionate increase in certifications might be due to a flood of applicants whose disease originated in the earlier period but who had for some reason delayed applying to the Board until the later period. If this

Maps of the South Wales Coalfield showing the incidence of certified silicosis and pneumoconiosis in 1931-8 and 1940-5 in all mines normally employing more than 100 underground workers. The small black circles each represent a single mine. "Contours" have been drawn enclosing mines at which the incidence of certified disease per 1,000 underground workers per annum falls into the same group. These incidence groups are shown in the Map. U.G.W.=Underground workers.

TABLE III.—*Certification Rates in South Wales by Counties and Class of Coal, and in Rest of Great Britain, 1931-8 and 1940-5*

	Certification Rate Per 1,000 U.G.W.		Ratio of Rate 1940-5 Rate 1931-8	Ratio of U.G.W. 1931-8 U.G.W. 1940-5
	1931-8	1940-5		
South Wales (Pit employing > 100 U.G.)				
Anthracite	5.14	34.7	6.75	0.95
Non-anthracite :				
W. Glamorgan ..	1.14	7.69	6.75	0.84
E. Glamorgan ..	1.00	18.27	18.27	0.85
Monmouthshire ..	0.82	5.18	6.32	0.87
Rest of Great Britain (all pits)	0.0535	0.467	8.72	0.90

Figures for South Wales derived from all mines normally employing more than 100 men underground. Figures for rest of Great Britain derived from all mines. U.G.W. = Underground workers.

were so we should find that the cases coming from the high-incidence steam-coal pits were older men than those coming from the other pits. Figures for the age distribution of certified cases are available for only ten pits in the anthracite area and six high-incidence pits in the East Glamorgan steam-coal area, but these should be representative figures, and it will be seen from Chart II, which shows the age distribution of certified

CHART II.—Age distribution of all cases certified with silicosis and pneumoconiosis between 1940 and 1947 at ten anthracite mines and six high-incidence steam-coal mines in East Glamorgan. The height of the vertical columns represents the percentages of all cases falling into 10-year age groups.

cases during the second period from these two areas, that on the whole the East Glamorgan cases are the younger men. This finding is inconsistent with delayed awareness of disease in this area and is consistent with a real increase in incidence.

To sum up, we may conclude from these certification figures that the change in legislation in 1943 and the tendency for men to seek employment outside coal-mining may account for the general increase in the certification rate during the past six years, but that some additional factor must have operated in the East Glamorgan steam-coal pits, especially in the Rhondda Valley, to produce a real increase in disease incidence.

What, then, may this factor have been? The rank-of-coal hypothesis would demand that dust concentrations must have been much higher in steam-coal pits than in anthracite pits in order to give as high an incidence. There must then have been some relatively recent rise in dust concentrations in the East

Glamorgan steam-coal pits to account for the big increase in certified incidence there. It was in these pits that intensive mechanized mining was first adopted in South Wales, and there is general agreement among mining men that these methods gave rise to an enormous increase in dustiness. These mechanical methods of mining were mostly introduced in the early nineteen-thirties and would have been expected to produce a rise in certification rate beginning seven to ten years later, which in fact we find; for this is the minimum period necessary for the development of a certifiable degree of pneumoconiosis in most cases (Hart and Aslett, 1942).

Unfortunately, quantitative information concerning dust concentrations in South Wales pits before the institution of dust suppression is scanty. However, Briscoe *et al.* (1943) give figures for the mass concentration of air-borne dust in the pits at which colliers had been examined by Hart and Aslett (1942). Unfortunately, they did not include any high-incidence steam-coal pits. However, rather scanty figures are given for mass concentrations of air-borne dust at coal-faces in some of these pits before dust suppression in the 15th Report of the Coal Dust Research Committee of the Monmouthshire and South Wales Coal Owners' Association. In Chart III the annual certified incidence at various pits between 1940 and 1945 per 1,000 underground workers is plotted against the total mass concentrations of air-borne dust derived from these two sources. The figures

CHART III.—Relationship between annual certified incidence per 1,000 underground workers (horizontal axis) and air-borne dust concentrations expressed as mg./cu.m. (vertical axis) at seven South Wales coal-mines. Circles representing mines for which figures are available from both sources are joined by a dotted line.

for the pits surveyed by both investigators are joined by a dotted line in the chart. There is a fairly direct relationship between certified incidence and total mass concentration of dust, but there appears to be a systematic shift in the dust levels between the two sets of estimations which may be due to the difference in the methods of sampling employed. However, if allowance may be made for this shift by bringing the figures from the pits surveyed by both investigators to the same level, it appears that dust concentrations in anthracite and steam-coal pits of equivalent certified incidence were similar and not much greater in the steam-coal pits, as would have been demanded by the rank-of-coal hypothesis, upon which some doubt is thus thrown.

Too much weight must not be placed upon this rather unsatisfactory evidence, and it must be admitted that there are a few

figures recorded for dust concentrations under exceptional circumstances in steam-coal pits (for instance, at loading points) which are higher than any figures recorded by the Medical Research Council's investigators in anthracite pits. But it is fair to say that at present there is no good evidence that conflicts with the hypothesis that differences in the concentrations of air-borne dusts rather than differences in the constitution of the dusts chiefly account for the differing incidence of the disease among the coal-miners of South Wales.

This does not mean that qualitative differences in the dust clouds are of no importance. That they are important is indicated by Hart and Aslett's demonstration that rock workers have a greater tendency than colliers to develop radiological abnormalities. Since, however, there is in South Wales at least a hundredfold variation in the concentration of air-borne dust at the coal-face from mine to mine, while the variation in silica content, for instance, is less than tenfold, any effect of the qualitative differences in the dusts is concealed by the far greater quantitative differences.

I suggest, therefore, that the earlier development of a high incidence of pneumoconiosis in anthracite mines was due to high dust concentrations resulting mainly from poor ventilation, especially during the nineteen-twenties; and that its late development in steam-coal mines was due to high dust concentrations resulting from the introduction of intensive mechanical methods of mining in the dusty coal seams of East Glamorgan during the next decade.

This problem of the differing and changing incidence of the disease in South Wales pits is one to which we are devoting considerable attention in the Pneumoconiosis Research Unit. We have started a programme of radiological surveys at selected pits and we shall attempt to correlate our findings with the results of dust surveys. For this latter purpose it is essential that we should have some rapid and simple method of assessing dust concentrations. Hitherto all methods in common use either have been laborious or have involved the use of cumbersome equipment. Mr. H. H. Watson has devised a simple method (Watson and Hounam, 1948) by which air is drawn through a piece of filter-paper by a simple hand-pump and the resultant stain of coal dust is rapidly assessed by a photo-electric densitometer. Using this method, we have already carried out many surveys. Perhaps the most important preliminary result of these surveys has been the demonstration that there are tremendous variations in dust concentrations both from minute to minute and from day to day at the same face with unchanged working conditions. There is thus great difficulty both in giving representative single figures for air-borne dust concentrations and in assessing dust conditions by means of a brief visit from a mines inspector or a dust control officer. Some automatic method of continuous recording of dust concentrations is needed, and our physicists are now turning their attention to the development of such a method.

Pneumoconiosis in England and Scotland

Finally, we must consider briefly the incidence of pneumoconiosis of coal-miners in Great Britain outside South Wales. The total number of certified cases in South Wales is approximately seven times the number in the rest of the country (see Chart I). Since there are nearly six times as many coal-miners in the rest of the country, the incidence of certified disease is nearly 40 times greater in South Wales. The important question is whether this difference in incidence is genuine or whether awareness of the disease has not yet spread to the whole country so that the rising figures of incidence for Great Britain as a whole forbode a disastrous situation arising there during the next few years as it has during the last few years in South Wales. Intensive mechanical methods of mining have been introduced to a greater extent in the rest of the country than in South Wales, and it is not unreasonable to fear that we may see these methods being followed by the same consequences as they have in East Glamorgan. I believe such a pessimistic forecast may be unjustified for three reasons:

1. In Table III it may be seen that the ratio of certified incidence in 1940-5 relative to that in 1931-8 for pits outside South Wales is much closer to the general ratio for South Wales than that for East Glamorgan, where there has been a recent large increase in incidence. This might be interpreted as suggesting that the rising figures outside South Wales are more likely attributable to social and economic factors than to a real increase in disease incidence. A further regional analysis of the ratio shows that its slightly higher value than that for South Wales excluding East Glamorgan is due chiefly to a high ratio in Scotland, Durham, and Denbigh, which may suggest a true recent increase in incidence in these areas.

2. During the past three years 14 mass miniature radiographic surveys have been carried out by local authorities at collieries in England. In these surveys the non-attendance rate has been high, averaging 50%, so that great caution must be used in deriving conclusions from their findings. So far as they go, however, they do not suggest a serious position, the incidence of all abnormalities described as suspected pneumoconiosis being only 1.7% of all employees examined. This compares favourably with Hart and Aslett's findings among coal-hewers in the lowest-incidence mines in South Wales.

3. There is the obvious fact that if overall mass concentration is the most important factor in the causation of the disease then no really dusty pit can be a low-incidence pit. The low incidence outside South Wales should therefore mean that there are no really dusty pits in the other coal-fields in Great Britain. Statements to the contrary, however, have been made (Graham and Jones, 1947), and we felt that we should investigate this point. With the help of the Mines Inspectorate we have been introduced to several reputedly dusty pits in North Staffordshire, Northumberland, and Cumberland which have a low incidence of certified disease. Mr. Watson has made estimations of the dustiness at coal-faces in these pits, and to our satisfaction he has found so far that the air-borne dust concentrations, although they may reach levels which we find in high-incidence pits in South Wales after dust suppression, do not reach the levels which existed under the former uncontrolled conditions. Our explorations as yet are only preliminary, but they do not lend support to the idea that many pits in Great Britain are sufficiently dusty to give rise to an incidence of pneumoconiosis such as has prevailed in the pits of South Wales.

It is with considerable hesitation that I suggest that there is no reason to fear the development of pneumoconiosis in Great Britain as a whole on a scale of severity such as that to which South Wales has been subject, for I am aware that doctors have in the past been guilty of disastrously mistaken complacency. However, we shall not remain content with this fragmentary evidence, and shall seek further sound information. Meanwhile the results of fuller inquiries may be awaited with reasoned confidence.

[The second lecture, with a list of references, will appear in our next issue.]

Dr. Conrad Berens, of New York, was elected president of the Pan-American Association of Ophthalmology at the Third Pan-American Congress of Ophthalmology held in Havana, Cuba, Jan. 4-10. The next Congress will be held in Mexico City, 1952. The Congress adopted statutes and by-laws establishing the Pan-American Association of Ophthalmology as a continuing organization with the objects of fostering the progress of ophthalmology, establishing contacts among ophthalmologists of the Western Hemisphere, and promoting measures to conserve eyesight and prevent blindness among the peoples of the hemisphere. To achieve these aims permanent committees were established to deal with the following matters: research, glaucoma, trachoma, lighting and optics, contact-lens centres, orthoptics, prevention of blindness, neuro-ophthalmology, legal and industrial ophthalmology, standardization of ophthalmic hospitals and clinics, inter-American medical relationships, establishment and guidance of ophthalmological societies, and scientific cinematography. A board of censors was formed to supervise the relations of Association members to the lay press. According to the resolution adopted at Havana, local representatives of the Association's press relations committee must approve publication of articles in the lay press concerning any member.