

PNEUMOCONIOSIS OF COAL-MINERS

A STUDY OF THE DISEASE AFTER EXPOSURE TO DUST HAS CEASED

BY

ALICE STEWART

WITH THE ASSISTANCE OF

IDRIS DAVIES, LYNETTE DOWSETT, F. H. MORRELL, AND J. W. PIERCE

*From the Medical Research Council Pneumoconiosis Unit
and Emergency Public Health Laboratory, Cardiff*

(RECEIVED FOR PUBLICATION, APRIL 22, 1948)

Introduction

Throughout the nineteenth century the coal-mining industry of Great Britain steadily expanded and the number of workers increased over twenty-fold. By 1831 it was recognized that colliers were liable to develop "miner's asthma" (Thackrah), and in 1857 Cox referred to this disease as "the scourge of the mines." Working conditions at this time were notoriously bad, but in 1842 the first Mines Act was passed, and eight years later a Mines Inspectorate was established. Thereafter ventilation steadily improved, and by the end of the century it was confidently stated that coal-mining was no longer an unhealthy occupation (Arlidge, 1892). Lung diseases such as bronchitis and emphysema were still prevalent among older miners; but, as colliers appeared to be relatively immune to tuberculosis, it was assumed that inhalation of coal dust did not produce silicosis (Oliver, 1902; Collis, 1915; Haldane, 1931).

Thus, when legislation was introduced to enable workmen to obtain compensation for silicosis (Workmen's Compensation Act, 1925), coal-mining was not scheduled as a dangerous occupation, and it was not until 1931 that workers at the coal face were allowed to apply to the Silicosis Medical Board (Various Industries (Silicosis) Scheme, 1931). Since then the numbers of colliers certified by the Medical Board have rapidly increased, and "coal-miners pneumoconiosis" is now recognized as the commonest variant of silicosis in this country.

The tardy recognition of this disease has a three-fold explanation. In the first place the true nature of the so-called bronchitis and emphysema was not realized until radiological examination came into general use. Secondly, since coal-miners with dust disease were not particularly prone to develop clinically recognizable tuberculosis, the relationship

between "miner's asthma" and silicosis was not appreciated. Finally it was not until the 1880's that there was any large scale development of "hard coal" mining, and it is chiefly in these mines that pneumoconiosis occurs.

In this country anthracite and steam coal (both types of hard coal) are mined in South Wales; and here, according to the only available statistics, the risk of contracting pneumoconiosis is nearly forty times as great as in the bituminous mines of England and Scotland (Table 1). Similar differences have been observed in other parts of the world, and, although the explanation is obscure it is now generally believed that there is a close relationship between incidence of pneumoconiosis and rank of coal, as measured by the non-volatile content of the mineral (Sayers, 1938; Flinn and others, 1941; Moshkovsky, 1941; Hart and Aslett, 1942).

During recent years there have been several changes in legislation relating to industrial lung diseases, which have affected both the numbers entitled to claim compensation and the legal definition of dust disease*. The result of these has been a remarkable increase in the number of coal-miners applying to, and certified by, the Silicosis Medical Board. Undoubtedly this is largely due to increased awareness of the dust hazard, but it is possible that there has also been some deterioration in underground working conditions since the introduction of mechanized mining (Fletcher, 1948.)

Before 1943 the disease contracted by workers in coal-mines was officially known as silicosis, but when

* From 1929 to 1931 miners employed on "special processes concerned with the mining of certain types of silica rock" were entitled to claim compensation for silicosis. In 1931 the Workmen's Compensation Act was amended so that some other underground occupations were scheduled under the Silicosis Schemes, and in 1934 all underground workers were included (Various Industries (Silicosis) Scheme). In 1943 the Act was completely revised, and the Coal-mining Industry (Pneumoconiosis) Compensation Scheme was introduced. Since then surface workers handling coal and coal trimmers have become eligible for compensation.

the Workmen's Compensation Act was revised the legal definition of dust disease was altered and the term "pneumoconiosis of coal-miners" was substituted for silicosis. Under the old ruling three stages of the disease, defined in accordance with the scheme drafted by the International Conference on Silicosis (International Labour Office, 1930) were recognized. After July, 1943, men with a slightly earlier stage of the disease—corresponding to reticulation as defined by Hart and Aslett—became eligible for compensation*.

While it is customary for examining panels of the Silicosis Medical Board to record the stage of the disease as revealed by radiological findings, this is not compulsory. In every case, however, the degree of pulmonary disability is stated, for on this depends the amount of compensation payable by the employer. In practice there is a close relationship between disability award and radiological findings; men with "partial disability" being found in the reticulation and first-stage silicosis categories, and men with "total disability" in the second- and third-stage silicosis categories.

Since no provision has been made for periodic examination of workers in the coal-mining industry, the only official statistics relating to incidence of pneumoconiosis are those compiled by the Silicosis Medical Board, which has, since 1931, handled all applications for compensation from workmen employed in occupations recognized by the Workmen's Compensation Act (Silicosis and Asbestosis Medical Arrangements Scheme, 1931). The Board usually bases its decisions on a single clinical and radiological examination and, if a man is found to be "suffering from the disease to such an extent as to make it dangerous for him to continue in the process," it has the power to suspend him from work. In practice no coal-miner who is certified as suffering from silicosis or pneumoconiosis is allowed to work underground, and once he has left the industry he is unlikely to be examined again. However, if a relative claims further compensation on death, the Board is informed and an autopsy is made.

The Present Investigation

In 1945, when the present investigation was planned, the Silicosis Medical Board was suspending

men from the South Wales coalfield at the rate of over one hundred a week. More than 10,000 cases of pneumoconiosis had been reported, and the country was faced with the problem of providing alternative work for these disabled men. The Government were anxious to implement a rehabilitation scheme (Ministry of Fuel and Power, 1944), but were hampered by not knowing what type of work was most suitable, or whether men with pneumoconiosis suffered from a latent form of tuberculosis which might endanger other workers. Although several writers had described the disease as it occurs in South Wales (Cummins and Sladden, 1930; Welsh National Memorial Association, 1931; Williams, 1933; Harper, 1934; Amor and Evans, 1934; Sen, 1937; Gough, 1940; Hart and Aslett, 1942; Belt and Ferris, 1942; etc.) only one small follow-up study had been reported (Aslett and others, 1943), and it was not known whether the disease continued to progress after exposure to dust had ceased.

It was decided, therefore, to design a socio-medical survey which—in addition to revealing the overall mortality in the certified population, the incidence of open tuberculosis, and any clinical or radiological changes that might have occurred after leaving the mines—would also show what proportion of men in early and late stages of the disease were able to do full-time work, and whether there were any indications that the disease had been affected by subsequent occupations. The survey was begun in November, 1945, and was completed in December, 1946, and only men certified by the Silicosis Medical Board between 1931 and 1944 were included. None of these men had worked underground or handled coal on the surface after being examined, so that it could be safely assumed that there had been no exposure to dust between the two examinations.

The incidence of the disease in different pits in South Wales had been computed by the Ministry of Fuel and Power, and copies of the certificates issued by the Silicosis Medical Board on behalf of men employed in every mine were available from that department. Since miners necessarily live within travelling distance of the pit where they work, these records provided a convenient starting point for the present investigation; and, before a preliminary survey was instituted to discover the present whereabouts of the certified men, a series of "Mines Lists" was obtained from the Ministry. On these were recorded the names of the men from each pit, together with the address, age, date of certification, and disability award. By consulting the records kept by the Cardiff and Swansea panels of the Silicosis Medical Board it was possible in most cases to add the x-ray category, and the date and

* *Reticulation* is defined by Hart and Aslett as "a fine network shadow, sometimes sharp and lacelike in appearance but more often blurred, which occupies from half of one lung field to the whole of both fields, and is as marked at the periphery as at the hila."

The radiological counterpart of *first-stage silicosis* is "appearances not less than the presence of nodular shadows together with an increase of hilar shadows, linear shadows, and pulmonary reticulation." Three sub-groups are recognized: (a) nodules present but localized; (b) nodules more numerous; (c) nodules generally distributed throughout the films but still discrete.

Second-stage silicosis is described as "nodulation with larger areas of coalescence"; and *third-stage silicosis* as "massive consolidation."

TABLE I
COAL-MINERS CERTIFIED (DURING LIFE) BY THE SILICOSIS
MEDICAL BOARD: SOUTH WALES AND OTHER REGIONS,
1931-1945

Period	South Wales		England and Scotland
	Total	Included in Survey	Total
1931-2	143	100	16
1933-4	364	254	38
1935-6	477	324	66
1937-8	632	391	72
1939-40	823	580	83
1941-2	1,218	695	94
1943-4	2,699	1,431	612
1945	4,180	—	574
Total..	10,536	3,775	1,555
"Incidence" of pneumoconiosis *		8.6%	0.3%

* Men certified 1931-1945 expressed as a percentage of the underground working population in 1931.

cause of death in the fatal cases. In addition, all the original films were available for inspection.

By the end of 1944 over 6,000 miners employed in South Wales had been certified by the Silicosis Medical Board, and between seven and eight hundred deaths had been recorded. These men came from pits in all parts of the coalfield, but the number of cases varied from none to over three hundred in different pits. The "high incidence" pits were mainly in the western part of the coalfield where anthracite is mined, but some steam coal pits in the central part of the coalfield had been responsible for more than a hundred certifications.

In view of geographical difficulties, and the elaborate transport arrangements required to bring patients to Cardiff to be examined, random sampling was not attempted. Instead two regions, one in the anthracite area and one in the steam coal area, were defined, and a preliminary survey was made to discover the whereabouts of certified men from the pits situated in these regions.

Colliery officials had records of men who had remained in receipt of weekly compensation, but a large number had settled their claims and were no longer on the colliery books. Fortunately the majority had remained in touch with the Miners' Federation, so that no great difficulty was experienced in tracing men who had changed their address since certification. Surprisingly few had left the district, and during the survey 3,435 of the 3,775 men from the two regions were traced.

In view of misunderstandings which may arise when men in receipt of compensation are asked to

undergo examination, meetings were arranged in order to explain the disinterested object of the enquiry. These were remarkably well attended, and the opportunity was taken to circulate a brief questionnaire relating to employment since leaving the mine. The men showed themselves keen to co-operate and this questionnaire was later circulated to all the men who were traced. In this way answers were obtained from most of the survivors, which were found to be substantially correct when checked by cross-questioning men who afterwards received a medical examination. In addition a large number of deaths which had never been reported to the Silicosis Medical Board was discovered, and in most cases the date and cause of death ascertained.

Statistical Analysis of Findings.—In the following account no attempt has been made to distinguish between men from the anthracite and steam coal pits unless the findings revealed a statistically

TABLE 2
1946 SURVEY: RESULTS OF PRELIMINARY INVESTIGATION*

	Date of certification	Results of Survey			Total		
		Un-traced	Sur-viving	Dead			
		%	%	%	%	No.	
Early Disease Group	1931-6	9	49	42	100	215	
	1937-42	7	74	19	100	692	
	1943-4	10	89	1	100	1,003	
	Total	%	9	80	11	100	
		No.	169	1,533	208		1,910
	Mean age at certification in years	46.4	45.9	51.8	46.3		
Advanced Disease Group	1931-6	13	16	71	100	463	
	1937-42	7	53	40	100	974	
	1943-4	9	79	12	100	428	
	Total	%	9	50	41	100	
		No.	171	926	768		1,865
	Mean age at certification in years	49.5	49.1	51.0	49.9		

* The data cover the certified men from the anthracite and steam coal regions included in the preliminary survey. The early disease group consists of the men certified as having reticulation or first-stage silicosis, and the advanced disease group those certified as having second- or third-stage silicosis.

significant* difference between the cases from the two regions. Since, however, the investigation revealed a considerable difference between men with early and advanced x-ray changes, both in mortality rates and clinical findings, the cases have been divided into two main disease groups. The "early" disease group includes all men certified as having reticulation or first-stage silicosis, and the "advanced" disease group all those in the second- and third-stage silicosis categories. In the few cases (less than 10 per cent. of the total) where the x-ray findings were not recorded by the Silicosis Medical Board, the disability award was used to decide the disease group, "partially disabled" men being included in the first group, and "totally disabled" men in the second.

Early Disease Group (1,533 survivors, 208 deaths, 169 untraced).—The early disease group included just over half the total number of men, the majority of whom had been certified for less than four years and only 10 per cent. for more than ten. Over three quarters of the men were between 30 and 60 years of age when certified, and the average age of the group at certification was 46.6 years. Overall mortality among those who were traced was 12 per cent., but there was a close relation between the proportion surviving and the interval since certification, so that although nearly half the men certified before 1937 were dead, nearly all those certified after 1942 were still alive. The death rate was higher among older men, and there was a difference of nearly six years between the average age of survivors and of men who died (Table 2).

Advanced Disease Group (926 survivors, 768 deaths, 171 untraced).—The advanced disease group originally included nearly as many men as the early group, but by the time of the follow-up there were far fewer survivors. This was due partly to the fact that the former contained the bulk of the long-standing cases, and the latter most of the men certified since 1942. But the contrast was due mainly to a real difference between the mortality rates. For instance, 12 per cent. of men with advanced disease who had been certified since 1942 were known to be dead, compared with only 1 per cent. in the early group.

Men with advanced disease tended to be slightly older than those with early disease, and the average age at certification was 49.9 years. There was, however, a difference of only two years in the mean ages of survivors and those who died.

Answers to Employment Questionnaire.—A more detailed analysis of the answers to the employment

* Where the odds against a difference in the data being due to chance are 95 per cent. or more (that is, not less than 19 to 1) this difference is described as significant.

TABLE 3
LIFE TABLES FOR MEN IN EARLY AND ADVANCED DISEASE GROUPS FROM THE DATE OF CERTIFICATION BY THE SILICOSIS MEDICAL BOARD, 1931-1944

Interval since certification in years	Disease Group					
	Early			Advanced		
	l x	d x	p x	l x	d x	p x
0*	1,000	15	0.985	1,000	71	0.929
½	985	17	0.983	929	89	0.904
1½	968	21	0.978	840	84	0.900
2½	947	18	0.981	756	82	0.892
3½	929	51	0.945	674	71	0.895
4½	878	46	0.948	603	73	0.879
5½	832	51	0.939	530	82	0.845
6½	781	62	0.920	448	53	0.882
7½	719	53	0.927	395	70	0.824
8½	666	46	0.930	325	48	0.853
9½	620	34	0.945	277	48	0.827
Total number of cases	1,741			1,694		
Number of deaths	208			768		

lx = Number of men per 1,000 certifications alive at the beginning of each interval. dx = Deaths per 1,000 certifications during next interval. px = Probability of surviving until beginning of next interval.

* The death rates shown in the first line are for a six months period and require to be doubled to make them comparable with those for subsequent periods.

questionnaire will appear in a separate report. Here it need only be said that certain differences were found between men who lived in the western part of the coal-field, which is a rural area, and those who lived in the more densely populated region in the centre. For instance, there was a higher rate of unemployment among anthracite miners, and those who did find work were often employed out of doors, whereas many steam coal miners worked in factories. More men from the anthracite mines had remained in receipt of weekly compensation, and when they settled their claims they received more money than the steam coal miners. Until 1939 the rate of certifications was higher in the anthracite region, but during 1943 and 1944 a majority of cases came from the steam coal region. Finally the proportion of totally disabled men was higher in the steam coal region.

Judging by the men's own account of their fitness for work, and their difficulty in obtaining jobs, the employment situation was far from satisfactory, although it improved during the war years. Older men evidently experienced greater difficulty in obtaining work than younger men, but a surprisingly large number of men in the advanced disease group felt fit for full-time employment and worked whenever jobs were available.

Mortality Rates.—Mortality rates in the two disease groups have already been mentioned, and the proportions of dead and surviving are shown in

Table 2. The total number of deaths discovered during the survey was 976. In 123 cases the cause of death was not ascertained, in 804 it was ascribed to the disease, and in 49 to other causes. Only 451 of the deaths had been reported to the Silicosis Medical Board.

To show more precisely the probability of survival in the two disease groups, life tables were constructed for the men traced during the preliminary survey. These are shown in Table 3. Each table covers the first ten years after certification, but since only 11 per cent. of the men in the early disease group and 25 per cent. in the advanced group had been certified for as long as ten years, the survival rates for the second quinquennium are based on fewer cases and are less reliable than those for the first five years. In addition, as the tables are based only on the traced men, they necessarily ignore 9 per cent. of the population. Since, however, the percentage of untraced cases in the two disease groups was identical, whereas the advanced disease group had a much higher mortality than the early

group, it is unlikely that it is correlated with mortality. Therefore the omission of the untraced cases is unlikely to have upset the comparison between the two disease groups.

A rough interpolation in these tables shows that about 85 per cent. of men in the early disease group, and 57 per cent. in the advanced disease group, are likely to survive five years after leaving the mines. By the time ten years have elapsed, about 60 per cent. of men in the early and 25 per cent. in the advanced group, may still be alive.

In Chart 1 the survival rates are compared with those for males aged 50 years given in the 1931 English Life Table No. 10 (Registrar General Decennial Supplement). The comparison is not quite fair, because the latter is derived from males in every social class whereas all men with pneumoconiosis are included in Social Classes III and IV. Nevertheless the survival rate in the case of the men with pneumoconiosis is so much lower than in the other group that it is most unlikely that advancing age and the normal hazards of life were the only factors determining the number of deaths.

Separate study of the anthracite and steam coal workers revealed certain differences in the survival rates in these two groups which at first sight suggested that the disease acquired by the anthracite miners followed the more benign course. Since this finding was at variance with the observations of Pancoast and Pendergrass (1931) and with other findings in this survey (see page 128) a more detailed investigation of the men from the two regions was made. This showed that the difference was confined to men with advanced disease, and when this group was separated into its two components it was found that the proportion of third-stage silicosis cases was higher in the steam coal area. Since these men tended to die sooner than those classified as having second-stage silicosis (see Chart 2), the difference in mortality rates in the two regions need not be ascribed to any fundamental difference in the disease in the two parts of the coalfield.

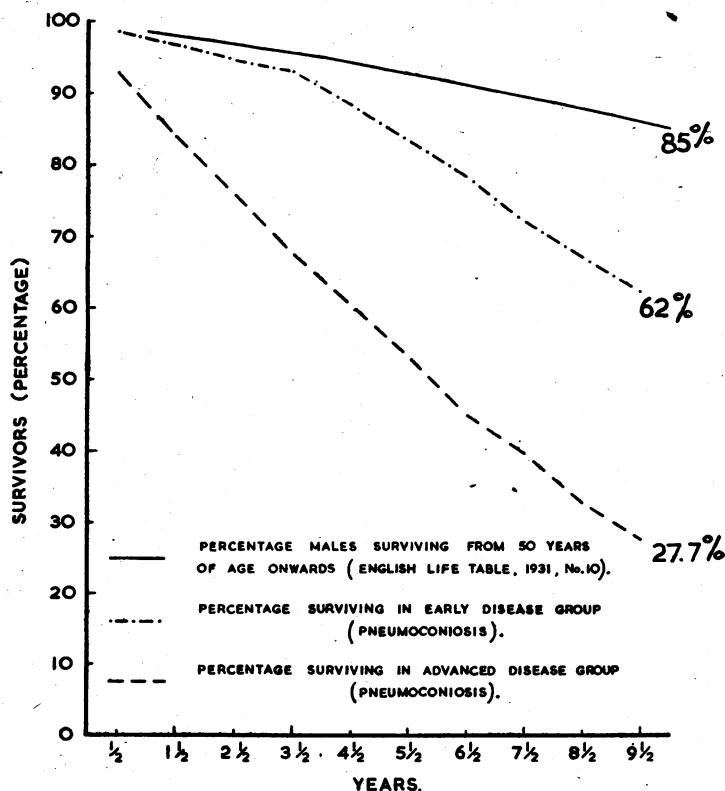


CHART 1.—Mortality after certification by Silicosis Medical Board: men traced in 1946 Survey. The early disease group comprises men certified as having reticulation or first-stage silicosis, the advanced disease group those with second- and third-stage silicosis.

Examination of Survivors.—It was originally intended to examine four hundred men in the early, and four

TABLE 4

1946 SURVEY : SURVIVORS TRACED AND SAMPLE EXAMINED : ANALYSIS BY DISEASE GROUP, AGE, AND DATE OF CERTIFICATION (SAMPLE FIGURES IN BRACKETS)

Age at certification in years	20-48		49 and over		Total
	1931-9	1940-4	1931-9	1940-4	
Early disease group	187 (88)	671 (91)	149 (83)	526 (87)	1,533 (349)
Advanced disease group ..	158 (76)	257 (77)	197 (74)	314 (78)	926 (305)
Total	345 (164)	928 (168)	346 (157)	840 (165)	2,459 (654)

Method of sampling : one hundred cases were chosen at random from each of the third-order classes (i.e., the cells shown in the table). The figures in brackets are the numbers actually examined.

hundred in the advanced disease group, and to choose the two samples so that the time factor and the age distribution were the same in both. This was done by dividing the available cases into eight groups (see Table 4), and taking a random sample of one hundred cases from each. However, owing to a considerable lapse rate, only 654 men were examined, of whom 349 were in the early, and 305 in the advanced disease group. The former included 171 men certified before 1940,

and 178 certified between 1940 and 1944; the latter 150 and 155 respectively. The mean age at certification in the early group was 48.2 years, and in the advanced group 49.8 years.

Most of the men were examined as out patients, but a few were admitted to hospital. In every case a detailed history was taken, and this was followed by a clinical examination, which included a standard exercise test, measurement of the vital capacity and blood pressure, and urine examination. Special investigations included x-ray examination of the chest, and examination of the sputum and blood (haematocrit, erythrocyte sedimentation rate, and Wassermann reaction).

Employment History.—Before certification all the men had been employed underground, and over

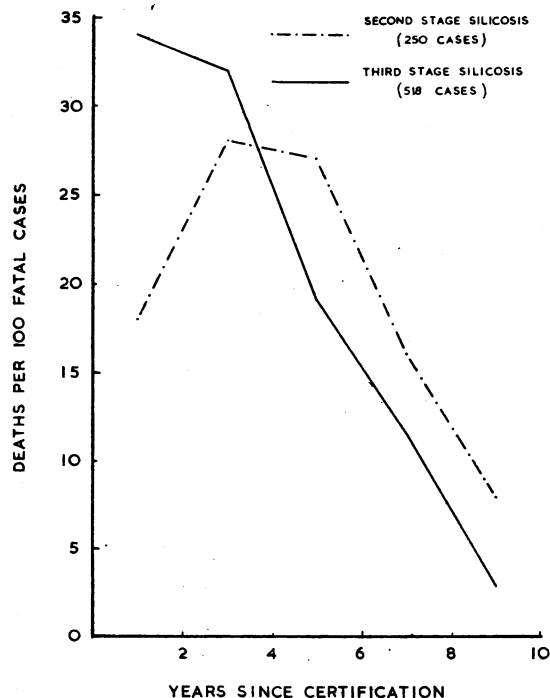


CHART 2.—Intervals between certification and death in advanced disease group : contrast between second- and third-stage silicosis. (1946 Survey.) The advanced disease group comprises men certified as having second- and third-stage silicosis.

TABLE 5

1946 SURVEY : EMPLOYMENT SINCE CERTIFICATION (BY DISEASE GROUP AND AGE AT CERTIFICATION)

Disease group ¹	Age at certification in years	Employment since certification			Total	
		Good ²	Fair ³	Nil	%	Number
		%	%	%	%	
Early	Under 50	65	29	6	100	223
	50 and over	29	29	42	100	126
	Total	52	29	19	100	349
Advanced	Under 50	56	22	22	100	167
	Over 50	17	27	56	100	138
	Total	38	24	38	100	305
Total	%	45	27	28	100	
	Number	299	174	181		654

(1). The early disease group consists of men certified as having either reticulation or first-stage silicosis, and the advanced disease group those certified as having second- or third-stage silicosis.

(2). Good employment = in work for over half the period between certification and follow-up.

(3). Fair employment = in work but for less than half the period between certification and follow-up.

95 per cent. had spent the greater part of the time at the coal face. About half the colliers had spent periods in hard ground (rock drilling) and a few had worked exclusively in rock. The shortest time spent underground was ten years, the longest over fifty years, but there was only a slight difference between the duration of dust exposure in the early and advanced disease groups; the average period being 29.6 years in the former and 30.9 years in the latter*.

After leaving the mines the employment rate was higher among younger men; and men under 50 years with advanced disease found employment more often than men over 50 years with early disease. Approximately one third of the men who obtained employment worked out of doors, one third indoors, and one third in mixed occupations. The proportion of men in the early and advanced disease groups was the same in all types of employment, but whilst 37 per cent. of outdoor workers were over 50 years of age at the time of certification, only 26 per cent. of indoor workers were in this age group.

Symptomatology.—According to the clinical histories obtained at the time of the follow-up, the disease appeared to be relatively benign and to pursue a slow course†, but there did not seem to be much permanent improvement after leaving the mine. Occasionally disease had been discovered before the patient was aware of symptoms, and it was clear that gross radiological changes were compatible with remarkably little disturbance of general health. However, most of the men complained of dyspnoea and cough, and both these symptoms persisted and frequently increased in severity after certification.

Dyspnoea usually preceded cough by several years, but as it was often slight in degree its presence was frequently ignored until some intercurrent infection or "breakdown" occurred. By the time of the follow-up several men who had continued to do a full day's work up to the time of certification, were unable to walk more than a few yards without becoming short of breath. The commonest causes of an aggravation of this symptom were: particular types of exertion to which the man was not accustomed, work which involved heavy lifting, and intercurrent illnesses.

* This close approximation corresponds to the similar age distribution of the men in the two disease groups. Had a random sample of men in the two groups been examined it is likely that there would have been a shorter length of exposure in men with early disease and a longer period in men with advanced disease, corresponding with the difference in average age at certification of the two disease groups (see Table 2).

† This may be an understatement, as the disease was probably less benign and had pursued a more rapid course in some of the men included in the original sample (for example, those who had died shortly after leaving the mines).

TABLE 6
1946 SURVEY: PERCENTAGE INCIDENCE AND SEVERITY OF SYMPTOMS IN 654 MEN WHO WERE MEDICALLY EXAMINED

Symptom	Incidence		Severity	
	Before certification %	After certification %	Worse after certification %	Improved after certification %
Dyspnoea ..	90	98	54	13
Cough	79	87	30	24
Asthenia ..	54	63	43	30
Loss of weight ..	33	27	28	23
Acute respiratory illnesses	24	26	—	—
Chest pain ..	17	34	39	20
Hæmoptysis ..	6	8	—	—
Melanoptysis ..	1	14	—	—
Other ¹ ..	10	33	24	10

(1). Other symptoms included giddiness, palpitations, vomiting, and headache.

Cough, though common, was not as a rule a distressing feature until the disease was well advanced. During the late stages, however, it was often associated with a particularly tenacious type of sputum, and efforts to expectorate this led to severe paroxysms of coughing and intense exhaustion. Hæmoptysis was recorded in 103 cases. This usually accompanied an acute respiratory illness but occasionally occurred without warning. Black sputum was the rule before certification, and this discoloration tended to persist for several months after leaving the mine. A particular type of black spit*, resembling an hæmoptysis both in the abruptness of its onset and in the copious amount of fluid expectorated, was recorded in 101 cases. This so-called "melanoptysis" usually occurred for the first time several years after leaving the mine, and was evidently a feature of the late stage of the disease. In two cases a melanoptysis occurred while the patient was in hospital, and serial radiographs showed a large cavity developing in the centre of an area of consolidation. In one of these patients the sputum was found after the event to contain tubercle bacilli, but in the other sputum tests remained persistently negative.

Most of the men who continued to work underground after dyspnoea had become severe experienced

* Copious black sputum is such a characteristic feature of coal-miners' pneumoconiosis that in early accounts the disease is often referred to as "black spit, or miners' melanosis" (Thomson, 1858).

TABLE 7

1946 SURVEY : RADIOLOGICAL PROGRESSION SINCE CERTIFICATION RELATED TO OTHER DATA

		Radiological progression ¹			Total	
		Nil %	Slight %	Marked %	%	Number
Disease group ²	Early	47	23	30	100	349
	Advanced	26	24	50	100	305
Age when certified in years	Under 50	32	20	48	100	362
	50 and over	43	30	27	100	292
Interval since certification in years ..	Under 5	53	27	20	100	288
	5 and over	23	22	55	100	366
Total	%	37	24	39	100	
	Number	241	156	257		654

(1) In no case was any evidence of regression of the disease observed.
 (2) The early disease group consists of men certified as having reticulation or first-stage silicosis, and the advanced disease group those certified with second- and third-stage silicosis.

either asthenia, loss of weight, or pain in the chest ; and in several cases one or other of these symptoms first drew the patient's attention to his condition. Although leaving the mine often caused temporary relief of these symptoms, later they frequently became prominent features of the disease.

Acute respiratory illnesses, variously described as pneumonia, pleurisy, or acute bronchitis, were recorded in 272 cases. These usually occurred after the onset of other symptoms of pneumoconiosis, and recurrences after certification were common. The illness was sometimes accompanied by hæmoptysis, and several patients had been intensively investigated for tuberculosis, but with negative results. Occasionally symptoms suggested a spontaneous pneumothorax and in five cases radiological evidence of this was found.

A variety of other symptoms such as giddiness, palpitations, and vomiting was described, which became increasingly frequent after certification, and by the time five years had elapsed most of the men had noticed an appreciable deterioration in their general health. This downward trend was more conspicuous among men with advanced disease but was also common in the early disease group.

Radiological Findings.—When the Silicosis Medical Board x-ray films were compared with the ones taken at the time of the follow-up, changes were found to have occurred in the majority of cases. These invariably suggested further progression of the disease and, although a third of the cases showed no appreciable difference between the two radiographs, *no instance of spontaneous resolution of the disease after removal from the dust hazard was*

observed. The commonest findings were an extension of shadows in both lung fields with an associated increase in emphysema, but either of these changes sometimes occurred alone, and sometimes only one lung was involved. Occasionally a large shadow seen in the first film was no longer visible in the second, but it was clear from the context that the "disappearance" was due to cavitation and not to resolution (see illustrations).

These apparently irreversible changes evidently occurred slowly, and only 47 per cent. of cases in which the interval was less than five years showed definite evidence of radiological progression, whereas 77 per cent. of those in which the interval was over five years showed increase of shadows in the second film. The frequency with which changes occurred was also intimately related to the stage of the disease at the time of certification, evidence of radiological progression being nearly half as common again in the advanced disease group as in the early group. Nevertheless 12 per cent. of cases of reticulation (a category first recognized in July, 1943) had developed new shadows in less than three years. Finally more younger men showed evidence of progression of the disease after exposure to dust had ceased.

The earliest stage of the disease included in the present series was represented by radiographs in which fine mottling was visible throughout both lung fields. This tended to obscure normal lung markings, and produced instead a characteristic circle-and-dot pattern which extended right out to the periphery. Accompanying this diffuse shadow, which closely resembles the annular and punctate mottling described by Caplan (1946) there was

almost always increase in the hilar shadows, and striæ radiating from the hila appeared to incorporate several small areas of coalescence.

At the other end of the scale were films in which there was such gross distortion of both lung fields that it was difficult to recognize familiar landmarks. Either the major part of both lung fields was obliterated by ill-defined shadows resembling bunches of cotton wool, or well-defined "cricket ball" or "angel wing" shadows alternated with areas of increased translucency. In the latter, elongated striæ were seen stretching from the large shadows to the diaphragm, mediastinum, and periphery of the lung fields, causing these to assume a most bizarre appearance. Frequently the hila appeared to be displaced or incorporated in larger shadows, and the trachea sharply kinked immediately above the clavicle. A central area of translucency within a massive shadow sometimes suggested the presence of a cavity, but unless this showed evidence of a fluid level it was difficult to distinguish from other translucent areas which were almost certainly due to emphysematous bullæ.

Every intermediate stage between these two extremes was represented, and there appeared to be little doubt that, after the diffuse shadow pattern was established, the disease progressed by the slow development of new areas of consolidation, which gradually coalesced and produced emphysematous changes in the surrounding lung tissue. These conglomerate shadows appeared in both lung fields, but the right lung was usually more heavily infiltrated than the left, and upper and mid zones more than lower zones; the right upper zone immediately below the clavicle appeared to be the site of election for the first "local" shadow, whilst the apices of both lungs often remained quite clear.

In each x-ray category and each sub-group (see footnote, page 121) there were cases in which progression of the disease had occurred within three years of certification, but even in the "third-stage silicosis" group there were cases in which the radiological appearances had remained unaltered for more than ten years. The findings as a whole suggested that the disease might become temporarily arrested at any stage; and evidently further extension of the shadows in one region could go hand in hand with compaction of pre-existing shadows and development of emphysema in another part of the lung. Although more cases in the advanced disease group showed signs of progression, it was impossible to decide from the appearance of the original film whether or not changes would be found in the follow-up plate.

Careful scrutiny of the films failed to reveal any difference between anthracite and steam coal miners,

and the rate of progression was the same in both groups of workers. Neither the length of time spent underground nor the type of work done before certification appeared to influence the course of the disease after leaving the mine; but in each age group men who obtained outdoor work after certification did rather better than those who worked in factories (Table 8).

Tests of significance on the data given in Table 8 showed that when the two age groups were considered separately they did not provide undoubted evidence that the course of the disease had been affected by the type of employment. But when the joint probability was calculated, a statistically significant relationship was established between incidence of radiological progression and type of work done since leaving the mines; the disease showing less tendency to progress in outdoor workers than in factory operatives.

Clinical Findings.—By the time of the follow-up there were 145 men whose radiographs showed evidence of "mild" disease, 175 with "well-established" disease, 188 with "severe" disease, and 146 with "gross" disease*.

Most of the men in the mild disease group were found to have a normal physique, and although 90 per cent. of them complained of breathlessness on exertion, nearly half completed the exercise tolerance test without showing signs of distress, and one third had a vital capacity within normal limits†. Apart

* To obtain an indication of the stage of the disease at the time of the follow-up, the radiographs taken at this time were arranged in four groups. To avoid confusion with the x-ray classification used by the Silicosis Medical Board, and with the two disease groups used for selecting cases for examination, these four groups have been named as follows:

Category 1 (representing mild disease).—Not more than generalized reticulation with small areas of coalescence confined to one or two zones.

Category 2 (representing well-established disease).—Not less than the maximal appearances found in category 1 and not more than generalized reticulation with early emphysema and either widely scattered but small areas of coalescence, or larger areas confined to one or two zones.

Category 3 (representing severe disease).—Not less than the maximal appearances found in category 2 and not more than partial obliteration of the original reticulation by multiple areas of coalescence and emphysema.

Category 4 (representing gross disease).—Not less than the maximal appearances found in category 3 and including films in which the reticulation was completely obliterated by large areas of coalescence and emphysema.

When the films from the Silicosis Medical Board were also catalogued in this way it was found that 35 per cent. of the certification films and 22 per cent. of the follow-up films were in the mild disease group; while 6 per cent. of the certification films and 22 per cent. of the follow-up films were in the gross-disease group.

† For the exercise tolerance test a step 18 inches high was used. The subject placed, and kept, one foot on the step and raised his body to the erect position on the step twenty times in sixty seconds. Men who were too breathless to attempt or failed to complete this test were recorded as "severely dyspnoeic," those who were still out of breath one minute after completing the test were recorded as "moderately dyspnoeic," and those who did the test without undue distress were recorded as normal.

The vital capacity was measured on a simple spirometer and the best of three readings was taken. The result in each case was compared with the "expected" value from men of the same age and same sitting height (McMichael, 1945) and expressed as a percentage of the expected value.

TABLE 8

1946 SURVEY: EMPLOYMENT SINCE CERTIFICATION RELATED TO RADIOLOGICAL PROGRESSION AND ABSENCE FROM WORK OWING TO SICKNESS

Age at certification in years		Under 50		50 and over		Total	
Employment since certification		Outdoor %	Indoor %	Outdoor %	Indoor %	%	Number
Radiological progression since certification	Marked	39	49	16	29	37	111
	Slight	20	20	27	39	24	71
	Nil	41	31	57	32	39	114
Sickness absence from work	Long spells	16	28	13	33	23	68
	Short spells	36	37	38	39	37	109
	Nil	48	35	49	28	40	119
Total	%	100	100	100	100	100	
	Number	87	117	51	41		296 ¹

(1) A further 167 men obtained employment after leaving the mines, but as they had worked partly indoors and partly out of doors they have not been included. The interval since certification and the proportion of men in the early and advanced disease groups was the same in all three types of employment. Tests of significance: when the "marked progressors" and "non-progressors" were compared separately in the two age groups a gross chi squared (with two degrees of freedom) of 5.788 was obtained. Since both age groups showed deviations in the same direction the value of $\frac{1}{2} p$ is 0.03.

from a tendency to poor expansion and rather distant breath sounds, very few showed abnormal physical signs in the chest, but slight clubbing of the fingers was recorded in 12 per cent. of cases, and pale mucous membranes in 5 per cent.

The gross disease group included 43 per cent. of men in whom the physique was recorded as good; and 18 per cent. in which it was poor. Over 80 per cent. were observed to be unduly dyspnoic on

attempting the exercise tolerance test, and nearly 100 per cent. had a sub-normal vital capacity. The tendency to poor chest expansion was not much more marked than in the mild disease group, but many more cases showed other physical signs in the chest. Compared with the radiological findings these were slight and indefinite, but either marked flattening of the chest below the clavicles, hyper-resonance over the bases, or an unusual variation

TABLE 9

1946 SURVEY: CLINICAL AND RADIOLOGICAL FINDINGS AT TIME OF FOLLOW-UP

Clinical findings		Radiological findings ¹				Total	
		Mild %	Well-established %	Severe %	Gross %	%	Number
General condition	Good	85	78	64	43	68	442
	Fair	14	20	29	39	25	168
	Poor	1	2	7	18	7	44
Objective dyspnoea ²	Nil	47	38	32	15	33	219
	Moderate	30	32	31	25	30	193
	Severe	23	30	37	60	37	242
Vital capacity ³	Over 90%	36	19	15	2	18	117
	70-90%	43	50	41	23	40	259
	Under 70%	21	31	44	75	42	278
Chest expansion	2-3 in.	22	22	18	7	17	112
	1-2 in.	70	68	70	73	72	470
	Under 1 in.	8	10	12	20	11	72
Total	%	100	100	100	100	100	654
	Number	145	175	188	146		

(1) For the definition of the x-ray categories shown in this table (see footnote on p. 128).

(2) Objective dyspnoea was classified as nil, moderate, or severe, on the results of a standard exercise tolerance test (see footnote on p. 128).

(3) The vital capacity is expressed as a percentage of normal (see footnote on p. 128).

TABLE 10
1946 SURVEY: RESULTS OF SPUTUM TESTS RELATED TO
OTHER FINDINGS

Number of cases		Sputum ¹	
		Positive	Negative
		17	472
Interval since certification in years	Under 5	11	245
	5 and over	6	227
General condition	Worse	14	290
	No change or improved	3	182
Dyspnoea (subjective)	Worse	9	255
	No change or improved	8	217
Change in weight	Less	12	147
	Stationary or gain	5	325
Radiological progression	None	2	179
	Progression	15	293
E.S.R. mm. per hr. (Wintrobe)	0-9	2	203
	10-60	15	269

(1) Sputa from 489 men were examined for tubercle bacilli; 89 men had no sputum and 42 men with sputum were not tested.

in intensity of the breath sounds over adjacent areas of the lung, were recorded in nearly 100 per cent. of cases and in over 70 per cent. adventitious sounds were heard. Clubbing of the fingers was observed in one third of the cases, and pale mucous membranes in 15 per cent. Albuminuria was recorded in twenty cases, but peripheral œdema (one case) and cyanosis (two) were extremely rare.

A majority of cases (56 per cent.) bridged the gap between mild and gross disease. Two thirds of these men were found to be dyspnoic on exertion and over 80 per cent. had a subnormal vital capacity. On the other hand the physique was good in about 70 per cent. of cases and fair in 25 per cent. Despite this higher level of general physique, abnormal chest signs, clubbing of the fingers, and albuminuria were almost as common as in the gross disease group.

Incidence of "Open" Tuberculosis.—Examination of the sputum is not part of the routine procedure of the Silicosis Medical Board, but most men who have a productive cough are investigated elsewhere for tuberculosis. The present series included 401 men who had had their sputum tested after leaving the mines; but in only two cases were tubercle bacilli detected. One of these patients had a pleural effusion, and although this had resolved by the time of the follow-up (nearly four years later),

other shadows in the radiograph had increased, and he was a very ill man. There appeared to be a large cavity in the left lung and the sputum was found to be still heavily infected with tubercle bacilli. In the second case the original film showed generalized reticulation with a small area of coal-science in the right upper zone. This patient's only symptom was cough, which ceased after he left the mine, and when he was seen three years later he declared that he was feeling quite well. Clinical examination revealed no abnormal physical signs, the sputum was negative, and there was no appreciable difference between the findings in the two radiographs.

During the follow-up it was found that 89 men had no cough, 34 had cough but no sputum, and 531 had a productive cough. Only 42 men failed to return the sputum outfit supplied at the time of the medical examination, and in 489 cases a specimen was examined for tubercle bacilli. Nineteen of these men were admitted to hospital within six months of being examined, and in these cases the sputum tests were repeated on several occasions.

Method.—In every case at least 10 ml. of sputum was concentrated by Jungmann's Method (Jungmann, 1938; Nassau, 1942) and a direct smear was made from the deposit. Heavy inocula were seeded on to eight slopes of Lowenstein-Jensen's medium and eight of Dorset's egg (unglycerinated), and the residue from every fourth specimen was inoculated into a guinea-pig. If either direct smear or culture suggested the presence of tubercle bacilli, the finding was confirmed by guinea-pig inoculation.

Results.—Tubercle bacilli were isolated from seventeen cases. This represents 2.6 per cent. of all cases, 3.2 per cent. of cases with sputum, and 3.5 per cent. of the specimens examined. In two cases a suspicious finding on culture was not confirmed on animal inoculation, and one specimen which yielded a negative culture produced a positive result when injected into a guinea-pig. In only one of the nineteen patients admitted to hospital was the original finding reversed. This man had a negative sputum at the time of the follow-up and again when admitted to hospital four months later. While in the ward he had a melanoptysis and a cavity developed in the right lung; on four subsequent examinations his sputum was found to contain tubercle bacilli.

One patient with positive sputum was found to have a pleural effusion in addition to evidence of advanced pneumoconiosis, but in the remainder the radiological findings were indistinguishable from those found in negative cases. The group as a whole, however, contained a disproportionately large number of "ill" men, most of whom had

developed new shadows after certification and were in an advanced stage of pneumoconiosis. The erythrocyte sedimentation rate (E.S.R.) was usually raised, and the general impression was that these men were suffering from a more rapidly progressive type of disease than men with no bacteriological evidence of tuberculosis (see Table 10).

To this rule, however, there were a few interesting exceptions. For instance one patient with tuberculosis was practically symptomless and showed no signs of radiological progression over a period of four years, and three had "held their own" for more than eight years before their health began to fail. Finally two patients, in spite of being very ill men and showing signs of rapid progression of the disease, had erythrocyte sedimentation rates of less than 7 mm. per hour (Wintrobe).

Hæmatology.—in 641 cases the erythrocyte sedimentation rate and corpuscular volume (hæmatocrit) were estimated by methods described by Wintrobe and Landsberg (1935). The former ranged from less than one to over 60 mm. per hour, with an average value of 15.7 mm. per hour*.

At first there appeared to be little in common between radiological findings and erythrocyte sedimentation rate, as several men with grossly abnormal radiographs showed normal values, and *vice versa*. When, however, the results were finally analysed, it was found that there was a definite tendency for the sedimentation rate to be higher in men with gross than in those with mild disease, while the distribution of sedimentation rate values in the intermediate x-ray categories lay between these two extremes.

More striking, however, was the association between "radiological progression" and raised erythrocyte sedimentation rate (Table 13). Where the interval between certification and follow-up was less than five years, the sedimentation rate was 10 mm. or over per hour in 86 per cent. of cases in which marked progression had occurred, in 81 per cent. of those showing slight progression, and in 42 per cent. in whom no radiological changes were observed. Where the interval was over five years the rate was 10 mm. or over per hour in 67 per cent. of the cases showing marked progression, in 64 per cent. with slight progression, and in 15 per cent. with no radiological changes.

In both long- and short-interval groups the difference between "progressors" and "non-progressors" was statistically significant; the two extremes being represented on the one hand by cases in which marked radiological changes had

* According to Wintrobe and Landsberg the average erythrocyte sedimentation rate for healthy adult males is 3.7 mm. per hour (standard error, ± 0.16).

TABLE 11
1946 SURVEY: ERYTHROCYTE SEDIMENTATION RATES

Interval since certification in years	Radiological progression	Number of cases	Mean E.S.R. in mm. per hr. (Wintrobe)	Standard deviation
Under 5	Nil	150	12.0	11.1
	Slight	75	20.6	12.4
	Marked	58	27.3	14.1
5 and over	Nil	84	6.7	6.4
	Slight	77	13.5	10.5
	Marked	197	17.9	13.2
Total		641 ¹	15.7	13.1
Cases with tubercle bacilli in the sputum ²		17	29.5	14.9

(1) In thirteen cases the erythrocyte sedimentation rates were not estimated.

(2) These cases are included in the main body of the table.

occurred within five years of the erythrocyte sedimentation rate being estimated, and on the other by cases in which the disease had remained stationary for over five years.

The corpuscular volume, as determined from hæmatocrit readings, ranged from 23 to 55 per cent., with an average value of 39.5 per cent. Since the normal range for healthy adult males is 41 to 52.5 per cent., with an average of 46.8 per cent. (Price-Jones and others, 1935), the findings showed that the group as a whole was anæmic.

This tendency to anæmia was fairly closely related to stage of the disease as shown by radiological findings (Table 12). This being so, there was also an association between low hæmatocrit readings and raised sedimentation rates, but further investigation of this relationship indicated that this could not explain the general increase in the sedimentation rate.

Discussion

It is abundantly clear from the foregoing account that pneumoconiosis of coal-miners frequently continues to progress after exposure to dust ceases, but since no comparable survey of men who continued to work underground has yet been made, it is impossible to say how much the course of the disease was affected by change in environment. To judge from the general sequence of events and the clinical histories—which suggested that men with advanced disease may continue working underground for long periods without experiencing disabling symptoms—it is unlikely that leaving the mine was more than slightly beneficial.

The apparent absence of any relationship between time spent underground and progression of the

TABLE 12

1946 SURVEY: ERYTHROCYTE SEDIMENTATION RATE AND HÆMATOCRIT READINGS RELATED TO RADIOLOGICAL FINDINGS AT THE TIME OF THE FOLLOW-UP

		Radiological findings ¹				Total	
		Mild %	Well-established %	Severe %	Gross %	%	Number
E.S.R. mm. per hr. (Wintrobe)	0-9	66	44	37	27	43	275
	10-19	27	30	28	27	28	179
	20-61	7	26	35	46	29	187
Hæmatocrit (%)	41-55	57	42	30	37	40	259
	36-40	37	46	50	47	46	291
	23-35	6	12	20	16	14	91
Total	%	100	100	100	100	100	
	Number	139	171	185	146		641 ²

(1) For the definition of the x-ray categories shown in this table see footnote on p. 128.

(2) In thirteen cases the erythrocyte sedimentation rate and hæmatocrit were not estimated.

disease after leaving the mine suggests that some factor other than dust is necessary if the disease is to run its full course. The radiological appearances, raised sedimentation rates, and tendency to anæmia* all point to infection superimposed on a widespread pulmonary fibrosis; while the fact that areas of coalescence frequently originated in the upper lobe of the right lung, and that the radiological findings in cases with open tuberculosis were indistinguishable from the others, suggest that, despite the low incidence of open tuberculosis, the infective agent may be the tubercle bacillus.

Autopsy studies have produced convincing evidence that tuberculosis plays a major role in the

* See also Tortori-Donati (1947), who found a tendency to anæmia and a raised erythrocyte sedimentation rate in coal-miners with advanced pneumoconiosis.

late stages of coal-miners' pneumoconiosis. But just as in the present study of living men there was a gross disparity between incidence of open tuberculosis (2.5 per cent.) and radiological evidence of progression of the disease (63 per cent.), so also has it often proved impossible to obtain bacteriological confirmation of tuberculosis in fatal cases with gross pathological changes in the lungs (Rogers, 1946; Gough, 1946). Nevertheless, despite the absence of this final piece of evidence, pathologists believe that the late lesions are frequently those of a curiously modified form of tuberculosis (Cummins and Sladden, 1930; Belt and Ferris, 1942).

The disparity between bacteriological findings and clinical and pathological manifestations suggests either that the tuberculous infection has been so

TABLE 13

1946 SURVEY: ERYTHROCYTE SEDIMENTATION RATE RELATED TO RADIOLOGICAL PROGRESSION SINCE CERTIFICATION

	E.S.R. mm./hr.	Radiological progression			Total	
		Nil %	Slight %	Marked %	%	Number
Interval since certification less than 5 years	0-9	58	19	14	39	110
	10-19	25	35	21	26	75
	20-61	17	46	65	35	98
	Total %	100	100	100	100	
	Number	150	75	58		283
Interval since certification over 5 years	0-9	85	36	33	46	165
	10-19	11	38	33	29	104
	20-61	4	26	34	25	89
	Total %	100	100	100	100	
	Number	84	77	197		358

profoundly modified by the co-existent pulmonary fibrosis that the infecting organism is no longer identifiable, or that other infective agents may produce chronic lesions which are morphologically indistinguishable from silico-tuberculosis. It is outside the scope of the present enquiry to determine which of these alternatives is correct, but the low incidence of open tuberculosis and the fact that by the time this develops patients are usually unfit for work, indicate that it is fairly safe for men with pneumoconiosis to be employed alongside other workers. An even greater degree of safety would be achieved if all men with pneumoconiosis underwent regular medical examination.

Nearly all the men who were examined during the follow-up were more breathless than ill, and it would appear that, in the absence of clinically recognizable tuberculosis, pneumoconiosis not only causes remarkably little disturbance of the general health but also often pursues a very slow course. It is likely, therefore, that a majority of men certified by the Silicosis Medical Board will remain fit for full-time employment for several years after leaving the mines, only the type of work that they can do is likely to be limited by the amount of exertion required.

The observation that men who obtained outdoor employment after certification did better than those who worked indoors may be due to selective recruitment. But the even distribution of men in the early and advanced disease groups in the two types of employment is an argument against such an hypothesis, and the possibility that the working environment had some effect on the course of the disease must be considered.

Inasmuch as the late effects of pneumoconiosis may be due to infection superimposed on the original dust disease, the difference between indoor and outdoor workers may be due to the fact that the latter were less prone to contract respiratory infections from fellow workers. On the other hand it is equally possible that either the need to take more strenuous exercise, or the absence of excessive humidity or dust in the working environment, or less exposure to abrupt changes of temperature, may have had a relatively favourable effect on the outdoor workers. Clearly more work must be done before attempting to define optimal conditions of employment but, crude as it is, the observed difference between the indoor and outdoor workers suggests that the successful application of certain measures designed to reduce the incidence of respiratory infections might reduce the tendency to progression. As they exist at present most outdoor jobs are too heavy for men with pneumoconiosis to tackle, so that our findings should *not* be taken

to suggest that these are always suitable. Rather, attention should be directed to improving factory conditions so that the risk of cross infection is reduced to a minimum.

Since the survey necessarily covered only two dates in each case, it is possible to draw only tentative conclusions regarding the erythrocyte sedimentation rate findings. The comparatively large number of normal values observed in men who had left the pits for more than five years supports the general impression gained from examination of the radiographs; namely that the disease may become temporarily arrested at any stage. On the other hand the high proportion of raised sedimentation rates among men who were observed after a short interval and showed no radiological evidence of progression of the disease, suggests that a rise in sedimentation rate may precede detectable changes in serial radiographs, and may thus provide a valuable indication of the immediate prognosis.

It is generally thought that emphysema causes an increase in the number of erythrocytes circulating in the blood stream, but none of the men examined had polycythæmia and many were definitely anæmic. As already suggested, this tendency to anæmia may be due to intercurrent infection; but it is possible that the whole subject of emphysema and polycythæmia needs reinvestigation.

Summary

1. Nearly 3,500 miners who contracted pneumoconiosis while working in the anthracite and steam coal pits of South Wales were followed up after they had been away from the mines from two to fifteen years.
2. The subsequent mortality rates of men who left the mines during the "early" stage of pneumoconiosis were higher than normal. Those who did not leave underground work until the disease had reached an "advanced" stage had even higher mortality rates after leaving the pit.
3. Findings in respect of 654 men who were examined are described. These show that the disease frequently continues to progress after removal from the dust hazard, and suggest that the late results are due to infection superimposed on generalized pulmonary fibrosis. This progression of the disease after leaving the mine was rather more frequent in younger men, and somewhat less frequent among men who worked entirely out of doors during this period.
4. The disease in its early stages is often symptomless and even in late stages dyspnoea on exertion may be the sole manifestation. In men with advanced disease a particular type of black spit may occur

which is associated with breakdown of large areas of diseased lung tissue.

5. The overall incidence of open tuberculosis was less than 3 per cent., but although these men were usually much less fit than the others, the investigation revealed no specific criteria other than sputum examination whereby "tuberculous" and "non-tuberculous" cases may be distinguished.

6. In the absence of tuberculosis the disease frequently pursues a slow course and, apart from dyspnoea, produces remarkably little disturbance in general health despite gross radiological changes.

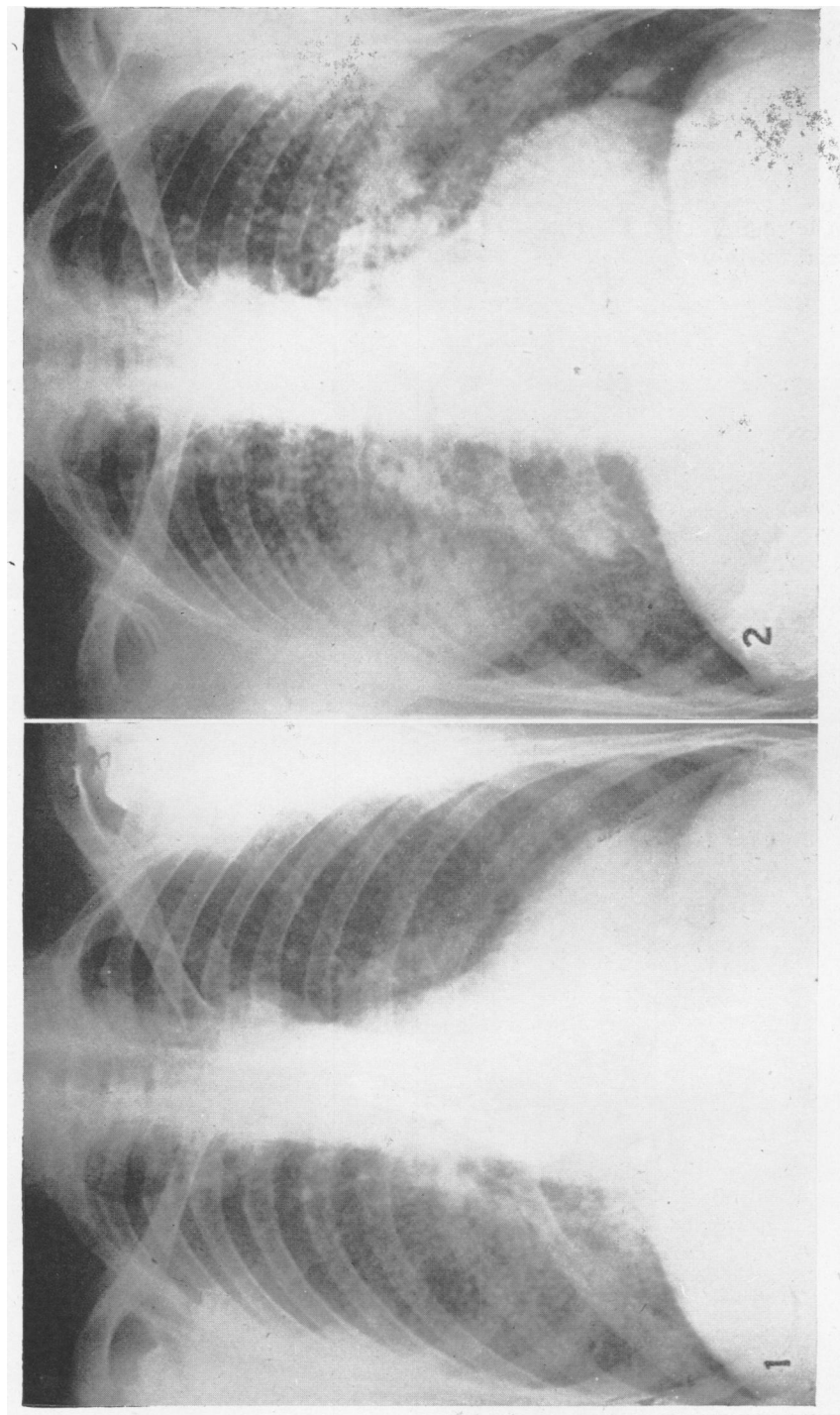
7. Progression of the disease is often accompanied by raised erythrocyte sedimentation rate and periods of arrest by normal sedimentation rate.

8. Early stages of the disease are not associated with any conspicuous alteration in corpuscular volume, but in more advanced stages anæmia is common.

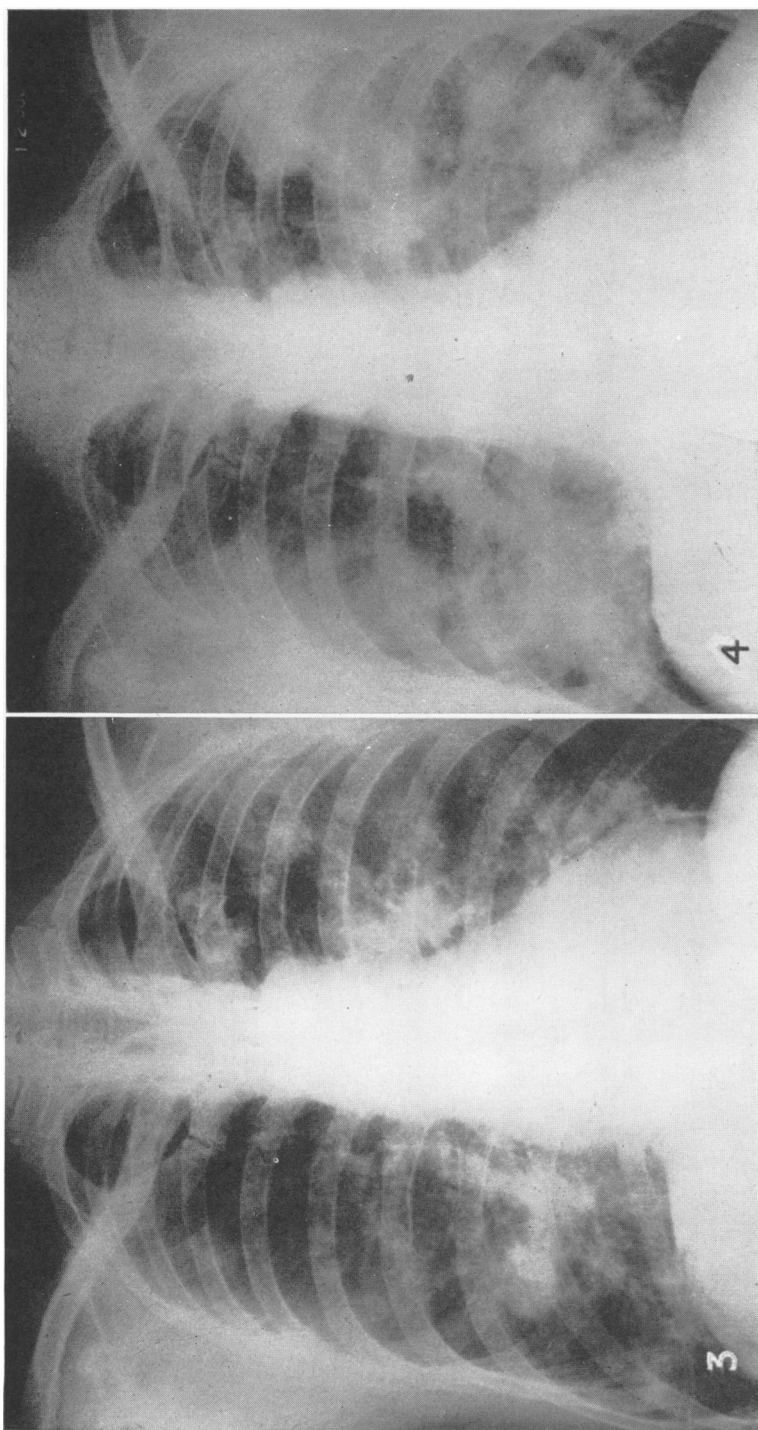
A survey of this magnitude could not have been undertaken without the help of numerous people, many of whom it is impossible to mention by name. We would like particularly to thank Dr. Charles Sutherland, Chief Medical Officer of the Silicosis Medical Board, and his colleagues Dr. Keating and Dr. McVittie, who kindly allowed us access to all the records of this department and gave us much helpful advice. We are also indebted to the Ministry of Fuel and Power for compiling all the "Mines Lists," to the South Wales Miners Federation for organizing a large part of the preliminary survey, to the Oxford Bureau of Health and Sickness Records for sorting all the records, and to Miss Clarke of Ilford's for providing the illustrations. The Cardiff Royal Infirmary should also be thanked for the radiographs. A large amount of statistical work was involved both in planning the experiment and checking the results, and without the assistance of Professor Bradford Hill, Dr. Russell, and Mr. Ian Sutherland the survey could not have been made. Finally we would like to thank Dr. Charles Fletcher, Director of the Pneumoconiosis Research Unit, who was responsible for initiating the investigation and provided us with invaluable help and criticism at every stage.

REFERENCES

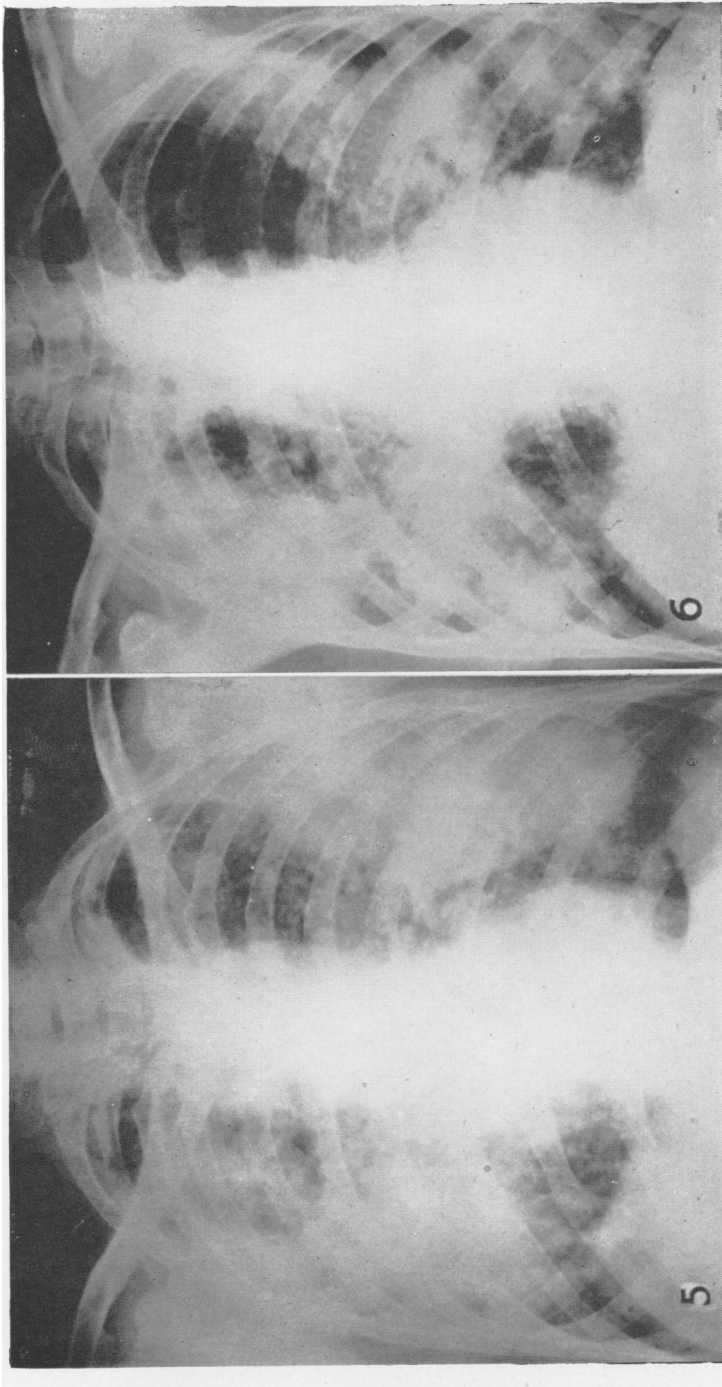
- Arlidge, J. T. (1892). "Hygiene, Diseases and Mortality of Occupations." London.
- Amor, A. J., and Evans, R. G. Prosser (1934). *Practitioner*, 132, 700.
- Aslett, E. A., Davies, T. W., and Jenkins, T. I. (1943). *Brit. J. Radiol.*, 16, 308.
- Belt, T. H., and Ferris, A. A. (1942). *Spec. Rep. Ser. med. Res. Coun., Lond.*, No. 243.
- Caplan, A. (1947). *Proc. Inst. Min. Engrs. and Inst. Metall. Silicosis Conference*. London. p. 33.
- Coalmining Industry (Pneumoconiosis) Scheme. S.R. and O. (1943). No. 885.
- Collis, E. L. (1915). *Publ. Hlth., Lond.*, 28, 252.
- Cox, W. I. (1857). *Brit. med. J.*, 491.
- Cummins, S. L., and Sladden, A. F. (1930). *J. Path. Bact.*, 33, 1095.
- Fletcher, C. M. (1948). "Goulstonian Lectures." *Brit. med. J.*, 1, 1015.
- Flinn, R. H., Seifert, H. E., Brinton, H. P., Jones, J. L., and Franks, R. W. (1941). U.S. Publ. Hlth. Bull. Wash., No. 270.
- Gough, J. (1940). *J. Path. Bact.* 51, 277.
- (1946). Communication to Tuberculosis Association.
- Haldane, J. S. (1931). *Trans. Inst. Min. Eng. Lond.*, 80, 415.
- Harper, A. (1934). *Brit. med. J.*, 1, 920.
- (1935). *Ibid.* 1, 1264.
- Hart, P. D., and Aslett, E. A. (1942). *Spec. Rep. Ser. med. Res. Coun., Lond.*, No. 243.
- International Labour Office (1930). *Proc. Internat. Conf. Silicosis, Johannesburg* (Series F., No. 13, Geneva); (1938). *Proc. Internat. Conf. Silicosis*, Geneva (Series F., No. 17).
- Jungmann, K. (1938). *Klin. Wschr.*, 17, 238.
- McMichael, J. (1945). Unpublished figures.
- Ministry of Fuel and Power (1944). Report of Advisory Committee on Treatment and Rehabilitation of Miners in the Wales Region suffering from Pneumoconiosis. H.M.S.O.
- Moshkovsky, I. I. (1941). U.S.S.R. State Publ. Dept. Med. lit. Moscow-Leningrad.
- Nassau, E. (1942). *Tubercle*, 23, 179.
- Oliver, T. (1902). "Dangerous Trades." London.
- Pancoast, H. K., and Pendergrass, E. P. (1931). *Amer. J. Roentgen.*, 26, 556.
- Price-Jones, C., Vaughan, J. M., and Goddard, H. M. (1935). *J. Path. Bact.*, 40, 503.
- Registrar-General's Decennial Supplement. Part I. Mortality Rates, England and Wales. 1931.
- Rogers, Enid (1946). *Lancet*, 1, 462.
- Sayers, R. R. (1938). See International Labour Office, 1938. pp. 124-191.
- Sen, P. K. (1937). *J. industr. Hyg.*, 19, 225.
- Silicosis and Asbestosis (Medical Arrangements) Scheme. S.R. and O. (1931). No. 341. p. 680.
- Thackrah, C. T. (1831). "The Effect of Arts Trades and Professions on Health and Longevity." London. p. 27.
- Thomson, J. B. (1858). *Edinb. med. J.*, 4, 226.
- Tortori-Donati, I. B. (1947). *Med. d. Lavoro*, 38, 151.
- Various Industries (Silicosis) Amendment Scheme. S.R. and O. (1934). No. 1155, 2, 735.
- Various Industries (Silicosis) Scheme. S.R. and O. (1928). No. 975. p. 823.
- S. R. and O. (1931). No. 342, p. 743.
- Welsh National Memorial Association (1931). *J. Industr. Hyg.*, 13, 19.
- Williams, Enid M. (1933). "The Health of Old and Retired Coalminers in South Wales." Cardiff.
- Wintrobe, M. M., and Landsberg, J. W. (1935). *Amer. J. med. Sci.*, 189, 102.
- Workmen's Compensation Act. (1925). 15 and 16 Geo. 5. c. 84.



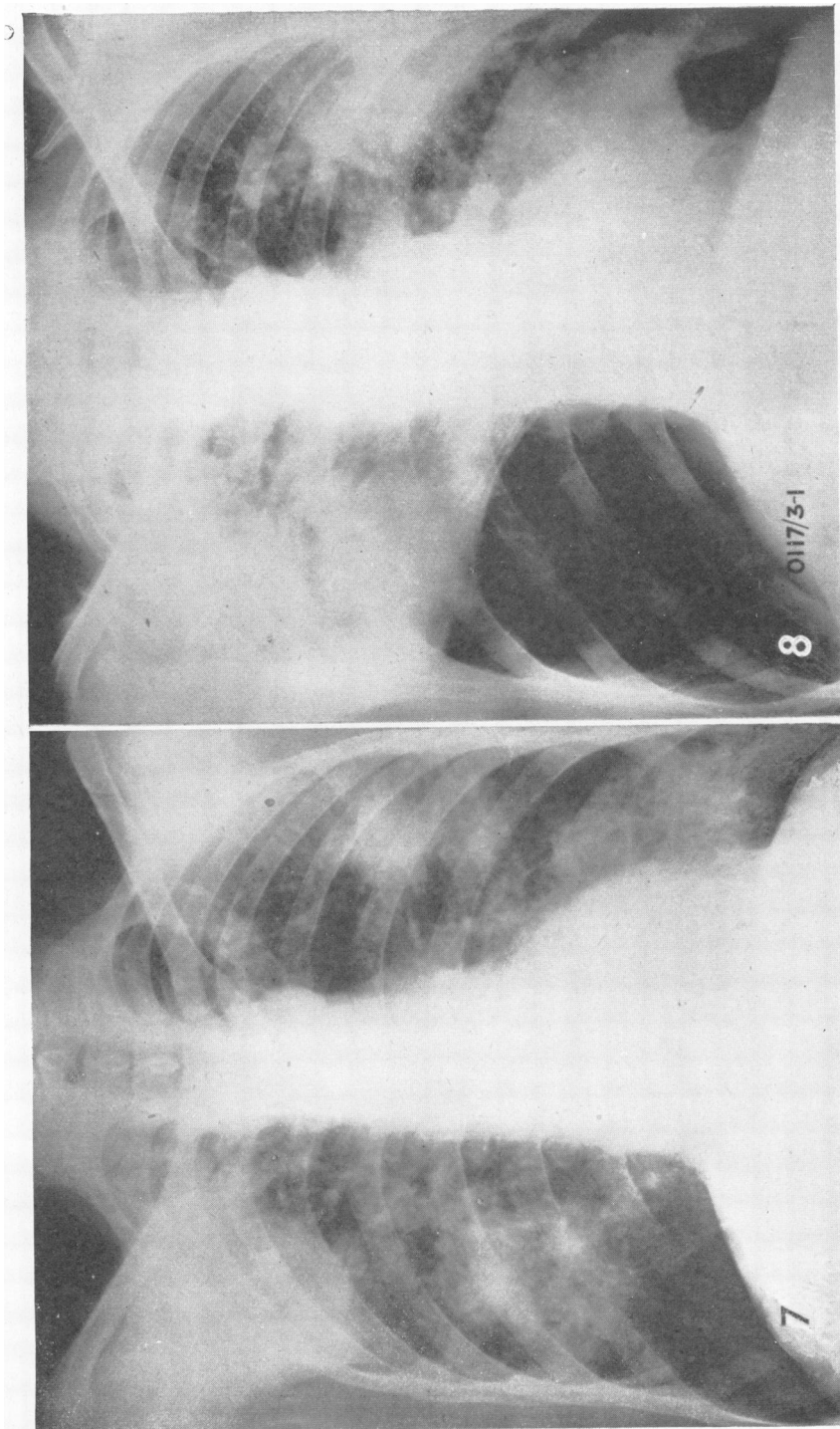
FIGS. 1 and 2.—Steam coal rockworker for sixteen years. Certified in 1937 (first-stage silicosis) at the age of 47. The follow-up nine years after certification showed the general condition to be good; there was no objective dyspnoea but slight clubbing of the fingers, and no abnormal chest signs. Chest expansion was 2 inches, vital capacity 66 per cent., E.S.R. 8 mm. per hour, hæmatocrit 39 per cent., and the sputum negative.



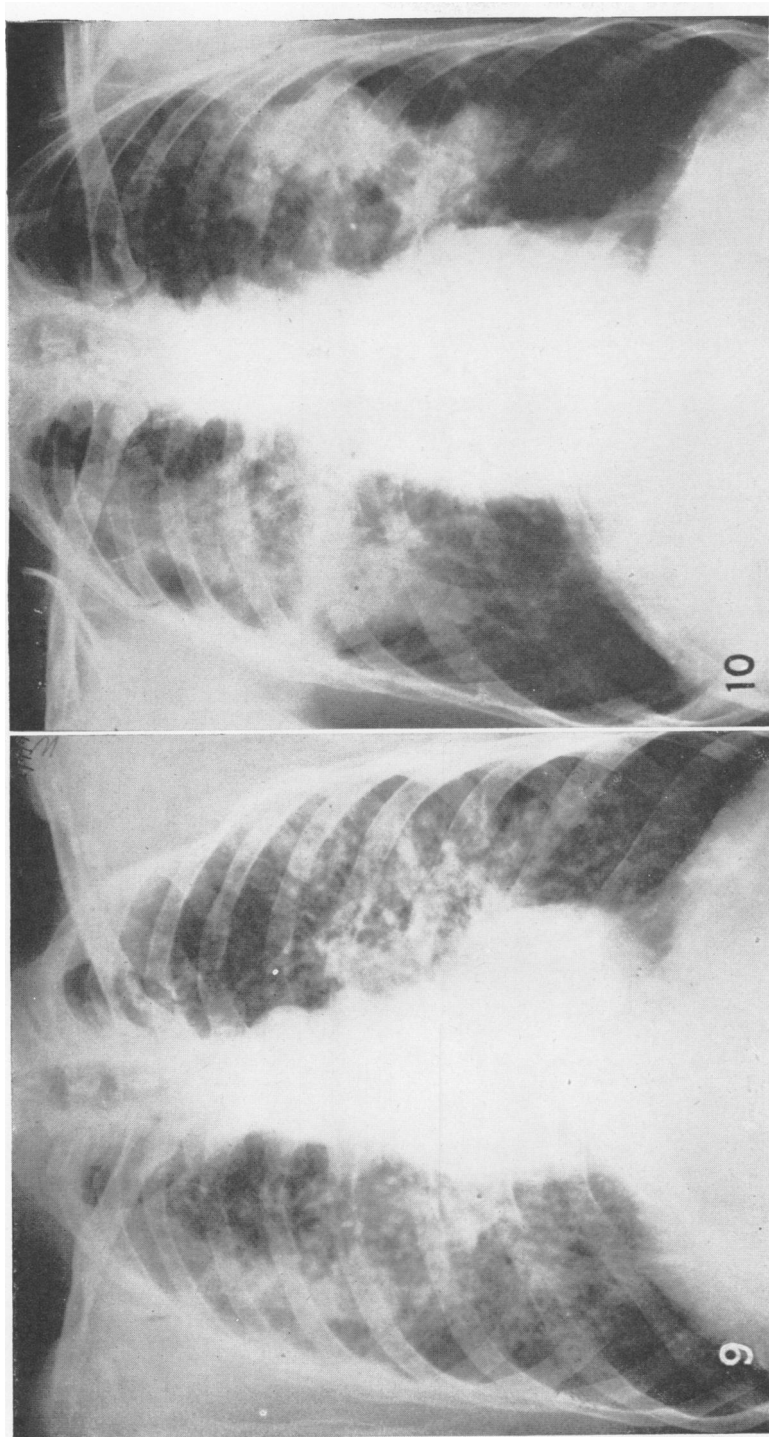
Figs. 3 and 4.—Anthracite collier for twenty-three years. Certified in 1943 (second-stage silicosis) at the age of 42. After leaving the mine this patient had pneumonia with melanoptysis. A follow-up three years after certification showed the general condition to be good; there was moderate dyspnoea but no chest signs, and the chest expansion was $1\frac{3}{4}$ inches. The vital capacity was 73 per cent., the E.S.R. 52 mm. per hour, the hematocrit 36 per cent., and the sputum negative.



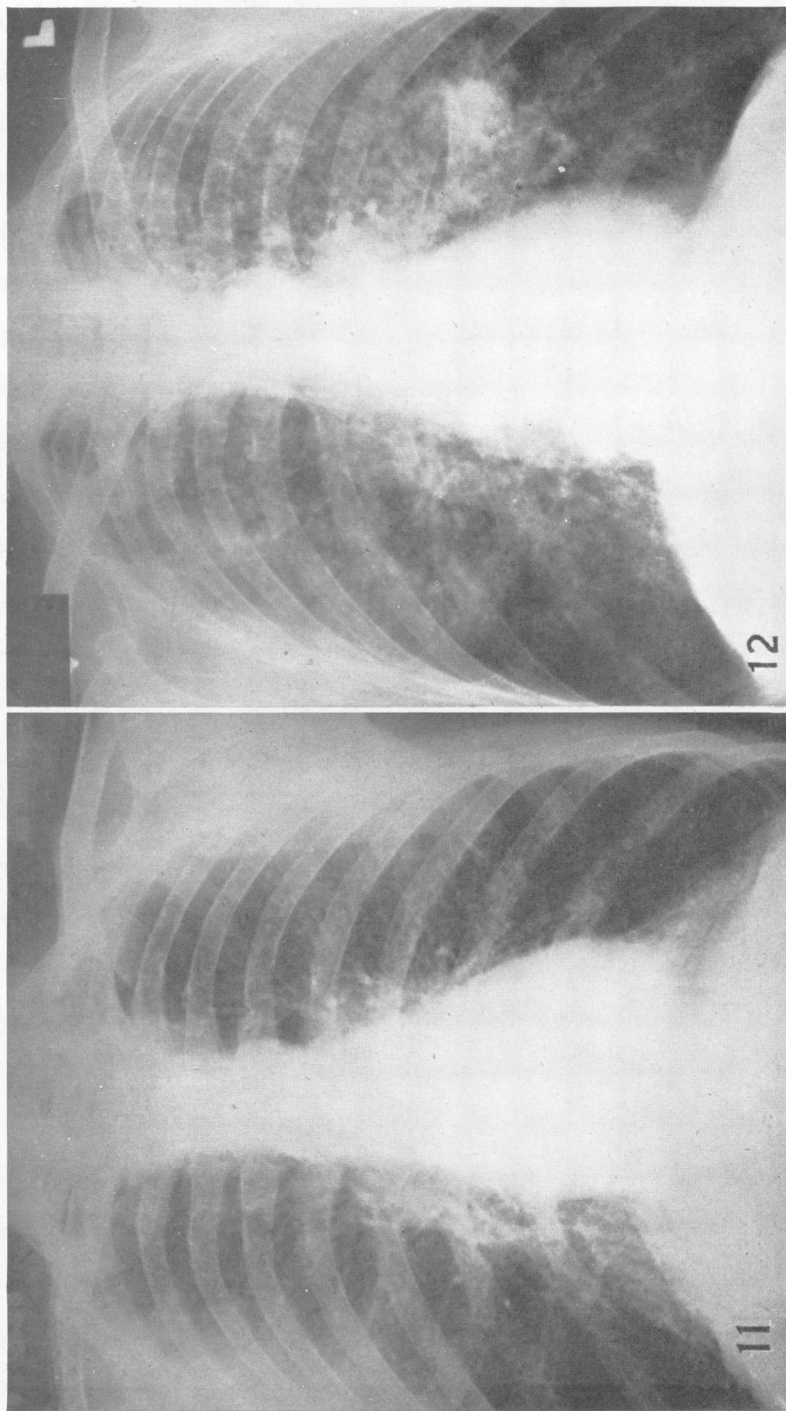
Figs. 5 and 6.—Steam coal collier for twenty-two years. Certified in 1940 (third-stage silicosis) at the age of 38. A follow-up six years after certification showed the general condition to be fair. He was underweight, and had tachycardia and focal signs at the right base. Chest expansion was $\frac{1}{2}$ inch, vital capacity 42 per cent., E.S.R. 42 mm. per hour, hæmatocrit 37 per cent., and the sputum negative.



Figs. 7 and 8.—Steam coal collier for twenty-three years. Certified in 1942 (second-stage silicosis) at the age of 43. This patient had pleurisy in 1945. A follow-up four years after certification showed the general condition to be fair and the nutrition poor; there was severe dyspnoea, hyper-resonance, and prolonged expiration, and the chest expansion was 1 inch. Vital capacity was 50 per cent., E.S.R. 31 mm. per hour, and hæmatocrit 40 per cent. There was no sputum.



FIGS. 9 and 10.—Steam coal collier for twenty-five years. Certified in 1940 (second-stage silicosis) at the age of 41. This patient had occasional hæmoptyses between 1944 and 1946, and pleurisy in 1945. A follow-up six years after certification showed the general condition and nutrition to be poor; there was severe dyspnoea, marked clubbing, and focal signs in the right upper lobe. Chest expansion was 1 inch, vital capacity 39 per cent., E.S.R. 3 mm. per hour, hæmatocrit 36 per cent., and the sputum positive. His wife died of tuberculosis in 1945. (A normal E.S.R. with positive sputum was an exceptional finding; see p. 130.)



FIGS. 11 and 12.—Anthracite collier and haulier for twenty-eight years. Certified in 1937 (first-stage silicosis) at the age of 42. He had pleurisy in 1941. A follow-up nine years after certification showed the general condition to be fair, but there was severe dyspnoea and hyper-resonance. Chest expansion was $1\frac{1}{2}$ inches, vital capacity 76 per cent., E.S.R. 2 mm. per hour, haematocrit 41 per cent., and the sputum negative. He was admitted to hospital with melanoptysis. A repeat radiograph showed a fluid level cavity and repeated tests of sputum gave negative results.