

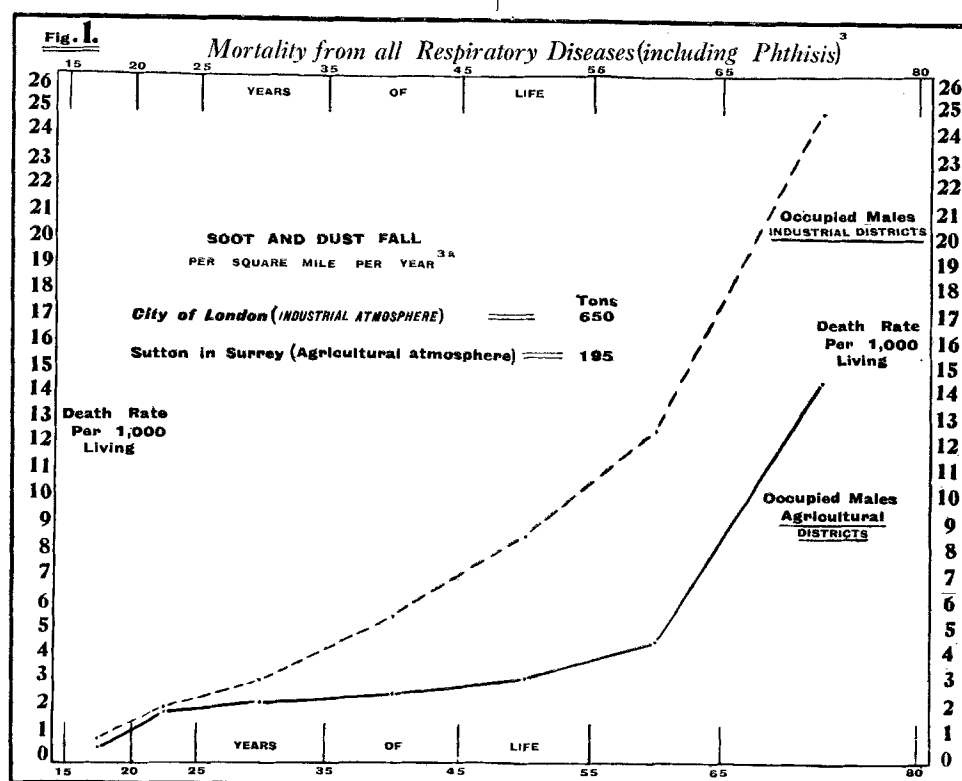
MILROY LECTURES (1915).
INDUSTRIAL PNEUMONOCOINOSSES,
 WITH SPECIAL REFERENCE TO
 DUST-PHTHISIS,

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'Old things need not be therefore true,
 O brother men, nor yet the new;
 Ah! still awhile the old thought retain,
 And yet—consider it again.'—A. H. Clough.

THE present time, when the recent report of the Royal Commission on Metalliferous Mines and Quarries (1), by drawing attention to some of the effects which follow

struction of our air passages, however, which are specially contrived to impede the entrance of dust; the amount of inorganic matter which nevertheless is found after death in our lungs—an amount which increases with age (2); and the excessive mortality from respiratory diseases experienced by dwellers in dusty atmospheres—an excess which increases with age (see fig. 1), and with the amount of dust present (see table 1); indicate that dust inhalation plays an important part in determining the mortality from respiratory diseases experienced by the general population.



upon the inhalation of dust, has stimulated inquiry into this subject, is opportune for reviewing our knowledge of dust diseases inherited from the past, and considering it again in the light of more recent investigations. The title chosen for the present course of lectures, Industrial Pneumonoconioses, or diseases of the lungs induced by dust inhaled during occupation, may seem somewhat tautologous, because the existence of pneumonoconioses (a term of Greek derivation, πνεύμων, lung, and κόνις, dust, introduced by Zenker) (102) apart from occupation is not generally recognised. The con-

Table 1.

RELATION OF ACUTE LUNG DISEASES TO FOG ⁴		
City of Manchester		
Period	Fog Days	Death Rate Per 1,000 from Acute Lung Diseases
1896-1900	36 '8	5 '04
1901-1905	23 '4	4 '28

Other influences may affect this mortality, but I shall attempt to show that dust inhalation plays a part by discussing its relation to the main respiratory diseases, asthma, bronchitis, pneumonia and phthisis. The

general atmosphere, especially in closely populated districts, contains dust, but the varied conditions of industrial life present opportunities in an intensified form for observing the effect exerted by different dusts; and I intend, therefore, to deal with the mortality and invalidity suffered by operatives exposed to such intensified conditions.

Dusts may be divided into two groups, the first containing particles capable of exhibiting the phenomena of life, *i.e.*, germs, and the second containing particles which do not possess this capacity. Knowledge of the existence of germs, or microbes, came from the brilliant work of Pasteur, but diseases of

human industries," and Sir Charles Lyell (5) and Dr. Isaac Taylor (6) have described such localisation in prehistoric factories for the manufacture of flint implements. From one of these factories, Grime's Graves, near Brandon, ascribed by Reginald Smith (7) to the palæolithic period, human remains—one the calvaria of a man, the other the skeleton of a young child—undoubtedly belonging to the people of the period in which the mines were worked, have recently been added to the museum of the Royal College of Surgeons.

I have shown (8) that to-day the flint-knappers of Brandon, the lineal occupational representatives of this the oldest of industries, who still use tools similar in shape to

Table 2.

Table comparing the Mortality from Phthisis of Flint Knappers with that of certain other Classes.

Class.	Cause of Death, stated as Percentages, from				Total Number of Deaths.	Average Age at Death.	Calculated Death-rate from Phthisis per Annum among 1,000 living.
	All Causes.	Phthisis.	Respiratory Diseases other than Phthisis.	All other Causes.			
Flint knappers (average number employed for 25 years estimated at 16·5).	100·0	77·8	7·4	14·8	27	46·0	41·0
Wives (2) and widows (11) of flint knappers.	100·0	0·0	15·4	84·6	13	73·0	0·0
Brandon rural district† (population about 5,150)	100·0	6·5	11·7	81·8	63	—	0·8
All males§ (England and Wales, 1900-02)	100·0	11·2	17·6	71·2	509,567	Median age at death between 56 and 57.	1·6

† The figures for this class, supplied by Dr. A. Harris, M.O.H., Thetford, Norfolk, are for all ages, 1901-10.

§ The figures for this class, calculated from the Supplement to the Sixty-fifth Annual Report of the Registrar-General, are for all males age 15 years and upwards, 1900-02.

the lungs arising from microbic life, except when they occur in lungs modified by the inhalation of particles belonging to the second group, are not considered as pneumoconioses, a term which should be restricted to disturbances in health following upon changes induced in the lungs by inhalation of non-viable particles. And just as all germs are not pathogenic, so all kinds of non-viable particles do not give rise to pneumoconioses. Hereafter I shall use the word "dust" to denote non-viable particles.

How early in the history of mankind industrial pneumoconioses appeared is a subject for interesting conjecture. Herbert Spencer, in his account of human progress, says the starting-point was "localisation of

the deer-horn picks of their prehistoric ancestors, suffer a terrible mortality from phthisis induced by flint dust generated in their work; and early last century Bourgoin pointed out the ravages produced among the population of Meusnes in France by the introduction of the gunflint industry. "By a fate," says Chateaufort (9), "which seems connected with all that concerns the art of war, this industry slays those who follow it; it kills them before their time; for them there is no old-age. When asked the cause of so premature a mortality, doctors and officials give the same reply—pulmonary phthisis induced by prolonged inhalation of dust generated from working flints." Probability suggests, therefore, that the starting-point of

human progress was associated with at least one form of industrial pneumoconiosis, and that, if tuberculosis affected prehistoric man, the mortality experienced must have been as severe as that found in existence to-day. "At hercule homini plurima ex homine sunt mala." (16)†

In historic times references are to be found in the works of ancient writers who, however, seldom distinguish between the various forms of respiratory disease, but rather refer to a general connection between lung affections and dust inhalation. For this reason the history of pneumoconioses is best taken as a whole, rather than separately for each form of respiratory disease. Since extracts from ancient writings, apart from archæological interest, are apt to be wearisome, I shall only make references which illustrate definite points. Hippocrates in his *Epidemics* (in a rather obscure passage of which Ramazzini, with his knowledge of occupational diseases, though differing with Galen and Farr, gives an interpretation closely adhered to by Littré) (10) speaks of the metal digger (ὁ ἐκ μεταλλῶν) who, we may presume, was exposed to dust in his work like the metalliferous miner of later days, as a man who "has his right hypochondrium bent, a large spleen, and a costive belly; he breathes with difficulty (πνευματώδης), is of pale wan complexion, and is liable to swellings in his left knee." (11). Here the father of medicine refers to three points of interest: (a) constipation, to relieve which men exposed to dust inhalation to-day constantly take aperient medicine; (b) shortness of breath, which is invariably the first, and in some cases the only objective sign of damage caused by dust inhalation; and (c) swelling of the knee-joint, which probably represents the disease scheduled to-day among those entitling to compensation as miner's bent knee. Pliny the Elder, in his *Natural History*, speaks (17) of the use of respirators to avoid dust inhalation, "qui minium in officinis poliunt, faciem laxis vesicis illigant, ne in respirando perniciosam pulverem trahant: et tamen ut per illas spectent." A similar device is also referred to by George Bauer, who wrote under the "nom-de-plume" of Georgius Agricola, in his famous work *De Re Metallica* (18), published in 1557. This mediæval writer, who strongly advocated the ventilation of mines,

and whose illustrations anticipated many modern methods, tells how "other mines are very dry, and the constant dust enters the blood and lungs, producing that difficulty of breathing the Greeks call asthma. When the dust is corrosive it ulcerates the lungs and produces consumption, hence it is that in the Carpathian mountains there are women who have married seven husbands, all of whom this dreadful disease has brought to an early grave. At Altenberg, in Meissen, . . . the men . . . bind loose coverings (bladders) to their faces. By this means the dust is not carried into the lungs and blood, and does not hurt the eyes." This is a remarkable passage indicating how asthma follows dust inhalation, how only certain "corrosive" dusts cause consumption, and how female contacts do not contract the disease. Löhneiss, referring to miners in 1690, states (19) the morbid sequence of events even more clearly: "The dust and stones fall upon the lungs, the men have lung disease, breathe with difficulty, and at last take consumption." Ramazzini quotes (12) a description given by Diembroek of several stone-cutters who died asthmatic, "in whose lungs he found such heaps of sand, that in running the knife through the pulmonary vesicles he thought he was cutting some sandy body"; and describes how stone-cutters "oftentimes suck in, by inspiration, the sharp, rough, and cornered small splinters or particles that fly off; so that they are usually troubled with a cough, and some of them turn asthmatic and consumptive" (12). The same author, quoting (13) from the *Acta Hassniensia*, describes pleurisy in a potter, "in whose dissected corps the right lobe of the lungs was found grown to the ribs and tending to a withered dryness and a phthisick; this indisposition of his lungs being attributed to the trade he had worked at"; and his description of the manufacture of earthenware, which is "first baked in a furnace, then covered with lead calcined, pounded with powdered flint and melted, and then put into the furnace again," shows that the potter of that day was exposed to the inhalation of flint dust, which has long been recognised in this country to be injurious. Thus a patent for grinding flints by a wet method granted in 1713 to Thomas Benson, of Newcastle-under-Lyme, states that previously flints were pounded dry, which process "proved very destructive to mankind in so much that any person, ever so healthful and

† "So surely do most of mankind's ills from mankind come."

strong, working in that business, cannot possibly survive over two years, occasioned by the dust sucked into his body by the air he breathes" (20).

While these quotations display a recognition of a causal relationship between dust inhalation and consumption, that piquant observer, Ramazzini, who went personally to inspect the trades he speaks of, knew that some dusts, though injurious, did not tend to the development of consumption, for he tells (14) how there flies out of hemp and flax "a foul mischievous powder, that, entering the lungs by the mouth and throat, causes continual coughs, and gradually makes way for asthma"; and, after describing the process of combing silk cakes, he remarks (14) that "the poor people that comb these threads are usually troubled with a vehement cough, and a great difficulty of breathing; and few of them live to old age in that way of business. The virulence that gives rise to this tragedy is owing to the cadaverous particles of the silkworm that are mixed with these cakes." Note how he distinctly refuses to ascribe the trouble to silk dust (in which he is borne out by the much later work of Givre) (27), and also the omission of any reference to consumption in either of these trades. He is even clearer in speaking (15) of men who sift corn and who "are so plagued with this powder or dust, that when work is done they curse their trade with a thousand imprecations. The throat, the lungs, and the eyes sustain no small damage by it, for it stuffs and dries up the throat; it lines the pulmonary vessels with dusty matter that causes a dry and obstinate cough; . . . hence it is that almost all that live by that trade are short-breathed, and cachectick, and seldom live to be old; nay, they are apt to be seized with an orthopnoea, and at last with a dropsy." Surely an excellent clinical description of dust-bronchitis, emphysema, dilated heart, and failure of circulation.

These distinctions, implied or definitely stated, between the types of respiratory trouble which follow inhalation of different dusts, are the more notable, because even to-day pneumoconioses are pigeon-holed in clinical teaching as a single entity, ascribed to exposure to any and every form of injurious dust, of which pulmonary fibrosis sums up the pathological findings and phthisis the morbid result.

Such generalisation has probably resulted from the publicity accorded to certain special inquiries into the prevalence of dust-phthisis, for example, that of Prof. Alison, who, when speaking (21) of "that modification of phthisis which occurs in middle and advanced life, . . . in those workmen who are much exposed to irritation of the lungs, particularly such as are in the constant habit of inhaling various fine powders into their lungs," says, "I have reason to believe that there is hardly an instance of a mason regularly employed in hewing stones in Edinburgh, living free from phthisical symptoms to the age of 50." The newer parts of Edinburgh were then being built out of Craigleith sandstone, the supply of which is now exhausted. This industrial disease was shown by Gulland to persist among Edinburgh masons in this century (33); and was deplored by that famous writer, geologist, and stone-mason, Hugh Miller, who, when telling of his own narrow escape, writes (22):—

"My general health, too, had become far from strong. As I had been almost entirely engaged in hewing for the two previous seasons the dust of the stone, inhaled at every breath, had exerted the usual weakening effects on the lungs — those effects under which the life of the stone-cutter is restricted to about forty-five years; but it was only now, when working day after day with wet feet in a water-logged ditch, that I began to be sensibly informed, by a dull pain in the chest, and a blood-stained mucoidal substance, expectorated with difficulty, that I had already caught harm from my employment, and that my term of life might fall short of the average one."

And later:—

"The dust of the stone which I had been hewing for the last two years had begun to affect my lungs, as they had been affected in the last autumn of my apprenticeship, but much more severely; and I was too palpably sinking in flesh and strength to render it safe for me to encounter the consequences of another season of hard work as a stone-cutter. From the stage of the malady at which I had already arrived, poor workmen, unable to do what I did, throw themselves loose from their employment, and sink in six or eight months into the grave—some at an earlier, some at a later period of life; but so general is the affection that few of our Edinburgh stone-cutters pass their fortieth year unscathed, and not one out of every fifty of their number ever reaches his forty-fifth year."

And again:—

"I remained for several months in delicate and somewhat precarious health. My lungs

had received more serious injury than I had at first supposed; and it seemed at one time rather doubtful whether the severe mechanical irritation which had so fretted them that the air passages seemed overcharged with matter and stone dust, might not pass into the complaint it stimulated and become confirmed consumption."

That such generalisation, however, is not justified was claimed by Thackrah, who stated (23) that "dust of every kind irritates, but not in an equal degree"; and he quotes (24) the longevity of bricklayers and lime-workers, instancing the old adage, "bricklayers and plasterers' labourers, like asses, never die." He recognised that masons inhaling "particles of sand and dust which arise from chipping stone . . . are short-lived, dieing generally before they attain the age of forty" (25), and cites Patissier's account of phthisis among the stone-dressers of Saint-Roch (known as the disease of Saint-Roch) and Merat to support him; but he noted that "in the lead mines of the North of England, the men are injured by working ore in sandstone, but are sensible of no inconvenience when the ore is in limestone" (26). Thackrah also dwelt on the prevalence of phthisis among the metal grinders of Sheffield, and instances Dr. Knight's opinion that fork-grinding ought to be confined to criminals (28). A few years later Calvert Holland established statistically the sad phthisis mortality experienced by fork-grinders who worked on dry stones, "and the dust which is created, composed of fine particles of stone and metal, rises in clouds and pervades the atmosphere. The dust is thus every moment inhaled . . . and produces permanent disease of the lungs" (29). He portrays the lives of these workers, and then uses these vigorous words: "We do not hesitate to assert that this is a picture of wretchedness which has no parallel in the annals of any country, or in the records of any trade. . . . Fiction can add no colour or touches to a picture like this. Truth transcends the gaudy embellishments of imagination. The distempered fancy has here no room to exercise her powers" (30).

By this time the collection of national mortality statistics, inaugurated in 1832, was providing data for investigations; and Dr. Farr, the first superintendent of statistics, placed valuable information (31) as to the prevalence of respiratory diseases, and in particular of phthisis, among the tin-miners

of Cornwall, and the lead-miners of the North of England, before the Royal Commissioners appointed in 1862 to inquire into the health of men employed in metalliferous mines. Dr. Peacock, physician to St. Thomas' Hospital, who, on account of the attention he had paid to respiratory diseases, and in particular because of his work on the phthisis mortality of millstone builders (36), a mortality ascribed by him to the dust generated in dressing buhrstone, was called in to assist these commissioners; and his careful report, a splendid clinical study still worth close attention, based on an examination of over 600 miners, together with evidence from local medical men, established the existence of "miner's disease," thus giving the clue to the mortality figures of Dr. Farr. Peacock, in describing the disease (32) carefully distinguishes it from ordinary phthisis.

"The form of the disease in which there is local consolidation in some portion of the lungs, bears a close general resemblance to true consumption, and especially where, as often happens, the voice is husky and the patient expectorates blood. There are, however, features by which it is sufficiently distinguished from that disease. It usually occurs in persons who do not present any hereditary disposition to phthisis—their parents and other relatives often having attained advanced ages and being quite healthy. It commences at a later period of life than phthisis, indeed, in persons who have reached ages at which consumption is by no means of frequent occurrence. It is also much slower and less active in its progress, so that in persons who have been ill for several years the signs often do not indicate extensive or advanced disease. The quickness of pulse, the rapid and extreme emaciation, and the night perspirations so characteristic of true phthisis, are also generally absent or only slightly marked, and there is rarely diarrhœa, indeed, the bowels are often obstinately confined."

As a source of information the Report of the Commissioners is invaluable, but, notwithstanding the evidence of several witnesses, particularly the miners themselves, that the "stour" or dust was far worse than anything else they had to contend with, the conclusion arrived at, based, I may say, on practically unanimous medical opinion, that the influence of dust was subsidiary to the many other adverse conditions of ventilation, exposure to fumes of explosives, and variations of temperature, which at that time surrounded the mining industry, was unfortunate. At that time, however, all researches

into the causation of phthisis, for example, the writings of Alison (21) and of Chateaufort (9), were proving the importance of bad housing, poverty, and lack of ventilation, and, although the prevalence of phthisis in certain dusty industries was noted, the absence of the disease in other dusty industries obscured the issue, and Peacock, influenced by the thought of his day, may be forgiven for ascribing the prevalence of the disease to the imperfect hygienic conditions he saw, rather than to the then disputed point of dust inhalation. Fifty years later a Departmental Committee, of which Dr. J. S. Haldane was a member, was appointed in 1902 to reinvestigate the causation of the still persistent high phthisis mortality among Cornish tin-miners; and this committee brushed aside every other influence except dust inhalation, deciding (34) that—

“So far as the Cornish miners are concerned it seems evident enough that stone-dust which they inhale produces permanent injury of the lungs—gradually in the case of ordinary miners, and rapidly in the case of machine-drill men—and that this injury, while it is apparently capable of gradually producing by itself great impairment of the respiratory functions, and indirectly of the general health, also predisposes enormously to tuberculosis of the lungs, so that a large proportion of miners die from tubercular phthisis. That the primary injury to the lungs is due solely to inhalation of stone-dust would seem to be practically certain.”

In the decade preceding the work of the Mines' Commissioners of 1862, organised study of public health had commenced; and we find H. Headlam Greenhow appointed to lecture on public health at St. Thomas' Hospital. In the elaborate statistical inquiry he carried out in preparing his lectures he immediately found that “one of the most evident facts brought to light . . . is the influence of occupation on health.” With this Finlaison's conclusion, arrived at (51) in 1853, is in close accord, that “the real practical difference in the distribution of sickness seems to turn upon the amount of the expenditure of the physical force. The density of aggregation, described under terms of city, town, or rural districts, seems to exercise little or no real influence”; and this fundamental point was restated (52) in 1903 by Watson, who said, “The proportion of members sick during any year varies with occupation.” Greenhow's investigation proved of

such importance that Mr., later Sir, John Simon, then medical officer to the General Board of Health, brought it to the attention of the Board, by whom it was published. Shortly after Simon became medical officer to the Privy Council, and he entrusted to Greenhow the duty of pursuing the subject further by visiting the great industrial centres. The reports which followed in 1861 (38) and 1862 (39) have formed a mine of information from which later writers have freely drawn; they are the first example of State medical inspection of factories, and are a monument to Simon's sagacity in grasping the great influence exerted by occupation upon health, and to Greenhow's keen insight and powers of observation. Throughout these reports runs as a theme the influence of dust inhalation in causing pulmonary disease, whether among lead-miners in Yorkshire, tin-miners in Cornwall, needle-pointers in Alcester, cotton operatives in Lancashire, flax-hecklers in Pateley Bridge, metal grinders in Birmingham and in Sheffield, coal-miners in South Staffordshire and in South Wales, or stone-dressers in Stroud. Why work so well started was then allowed to lie dormant for so long, while other aspects of public health were being strenuously developed by medical officers of health with inspectors of nuisances appointed for every town and district, reinforced now by a battalion of tuberculosis officers, is astonishing.

Stimulated by what he had seen in industrial centres Greenhow obtained specimens of workers' lungs, and between 1860 and 1870 from time to time described the conditions he found before the Pathological Society, and his reports in the Transactions of those years have been relied upon by subsequent workers to establish the pathology of pneumoconioses. The specimens themselves are still preserved in the museum of the Middlesex Hospital. At this time Virchow, Zenker, Knauff and other Continental workers were also dealing with the subject, but there is no record of personal inspection of industries like Greenhow's.

The period of Pasteur's marvellous work now followed, and, arising from it, Lister's methods of antiseptic surgery, and the discovery by Koch in 1882 of the tubercle bacillus. Soon after this Arnold (95) published a comprehensive monograph on the subject of dust inhalation, in which he pointed out that dust particles may be found in the liver,

spleen, and bone marrow, as well as in the lungs; but for the moment the germ causation of disease diverted attention from the influence of dust: yet ten years later Arlidge wrote (40): "I doubt if these bacilli actually develop phthisis, unless there be some antecedent change in the vitality of the affected tissue; a change wrought by depressing causes connected with the mode of life, or with constitutional debility and inherited taint, or with occupation followed; of which contributory factors two or more may co-operate. And assuredly the breathing of dust may be reckoned as one such of no slight energy." The painstaking observations of this authority, however, and the productive labours of Oliver, need no mention here; they form the basis of our present-day knowledge, and are to be found in every text-book on the subject.

The researches just summarised compel us to recognise that respiratory diseases are influenced by dust inhalation; but some plan must be adopted in dealing further with the subject. Classification has been attempted by Hirt (74), Arlidge (40), and others on various plans, based usually on consideration of dusts, either by origin, animal, vegetable, or mineral (first suggested by Chateauneuf) (9), or by physical properties, hardness, sharpness, or the like; but such classifications have brought dusts which produce different pathological results into the same class. Recently, however, Heim and Agasse-Lafont have suggested (41) that the effects caused should be the basis of classification, and I intend adopting this suggestion, and considering first the relation of each of the main respiratory diseases to dusts, and then from that standpoint examining the properties of the dusts which are associated with an undue prevalence of each of these diseases.

Without, however, anticipating subsequent consideration of these properties, *size* may here be referred to. Dust particles to be inhaled must be sufficiently small to remain suspended in moving air, and so be carried into the air passages. Virchow, in the middle of last century, for a time doubted whether inhaled dust gains access to the lungs, and maintained that the pigment found in the lungs of city dwellers was derived from blood pigment, and not from inhaled carbon; but the work of Knauff (35), who, after exposing dogs to fumes of a smoky lamp for periods varying from one day to three months, showed

that carbon was found in the lungs in amount varying directly with the length of exposure, and of Zenker, who demonstrated (103) the presence of excessive amounts of oxide of iron in the reddened lungs of factory workers exposed to the fine powder of rouge, which is composed of this material, in making gold-leaf and in polishing mirrors, finally convinced him that inhaled dust reaches and is deposited in the lungs. [A portion of one of Zenker's original specimens is in the museum of St. Thomas' Hospital (No. 1840A); and there is in the Home Office collection, through the courtesy of Dr. J. S. Haldane, an even more convincing specimen taken from a man who worked in ironstone mines in this country, then went to the Transvaal gold-mines, and finally returned home to the ironstone mines. The period of gold-mining is indicated by the presence of grey fibrous tissue, and that of ironstone mining by bright red discoloration (*see frontispiece*).] Possibly a few particles, as suggested by Calmette (42), may reach the lungs through the lymphatic circulation after first entering the digestive tract; but no one has yet produced a condition suggestive of pneumoconiosis by feeding animals on dust, and this channel of entry, as has been pointed out by Oliver (94), may be neglected for practical purposes; while Goadby's experiments (43) which show that lead poisoning is caused one hundred times more easily by inhaling lead dust than by eating it, have demonstrated that this toxic dust is chiefly dangerous because it definitely reaches and is absorbed by the lungs; and, further, W. Watkins-Pitchford's remarks on Transvaal gold-miners that "the lymph nodes in the gastro-hepatic and gastro-splenic omenta, and the mesenteric and retroperitoneal nodes are usually of normal appearance in fatal cases of silicosis" (44) and that he was unable to detect siliceous particles in them, conclusively show that the digestive tract is not the usual path of ingress.

Dust particles inhaled into the air passages may be divided into those which are too large to pass through the finer bronchioles and enter the alveoli, and those which are so small that they can pass through these passages; and upon this simple point may possibly depend differences found to exist between different dusts and the types of respiratory disease associated with their inhalation. The larger particles become

entangled in mucus and are swept away by ciliary action; the smaller ones when they reach the alveoli are removed and carried into the lung tissue by phagocytes, probably through the pseudostomata. How these fine particles are carried into the alveoli is not quite clear. Lister, noticing that "in simple fracture of the ribs, if the lung be punctured by a fragment, the blood effused in the pleural cavity, though freely mixed with air, undergoes no decomposition" (45), concluded that inspired air must be "filtered of germs by the air passages, one of whose offices is to arrest particles of dust, and prevent them entering the air-cells"; and Tyndall, working with a beam of light, showed (45a) that the deeper air of the lungs is optically dark, *i.e.*, free from suspended particles of even ultra-microscopic size. Moreover, if aeration of the blood is carried on by diffusion of gases between the residual air of the alveoli and the inspired air, dust particles can hardly be carried into the alveoli by such diffusion; even though, as Watkins-Pitchford points out, "the alveolar sacs, being surrounded by elastic fibres, undergo a passive dilation and contraction synchronously with the movements of the thorax, and we conclude therefore that this process of 'diffusion' must at least be materially assisted by the rhythmical variations in the capacity of the air sacs. Some physiologists, however, have pointed out that, as the capacity of the trachea, bronchi, and bronchioles is about 140 c.c., and as about 500 c.c. of air pass in and out of the chest during each ordinary respiratory cycle, some 360 c.c. of this tidal air must flow directly into and out of the air sacs—in other words that some of the tidal air must strike right down to the alveoli at each ordinary inspiration. . . Quite large particles of siliceous mineral are often found in the pulmonary alveoli in early cases of miners' phthisis. Their size is often so great as to render it extremely improbable that they have escaped into the alveolus from the lung tissue, for the particles in the lung tissue are practically all of very small dimensions" (44). Probably we are at any rate justified in considering that, during deep breaths, preliminary to a cough or sneeze, stimulated by the necessity for expelling dust-laden mucus, inspired air may carry with it into the alveoli particles of dust sufficiently small to pass through the smallest bronchioles. No particles have been found (46)

in the lung tissue, which exceed 10μ in diameter, and these could have entered in this way; and definite evidence is wanting to show that particles ever pass into the lung tissue through the walls of the bronchi or larger bronchioles.

One further point, *solubility*. — Only particles which are insoluble in the fluids of the body when carried into the air passages remain as foreign bodies either to stimulate the ciliated epithelium to overaction for their expulsion, or, if they gain access to the lymph channels, to give rise to a proliferation of connective tissue; thus dusts of ivory, horn, bone, and other animal structures, and of calcium sulphate (plaster-of-Paris and alabaster), of limestone, and of oxide of iron are not associated with pneumoconioses in the way that dusts of vegetable husks, emery, glass, sandstone and flint are. Generally speaking dusts are more injurious as their chemical composition differs from that of the human body, or from the elements of which the body is normally composed. Other distinctive properties of injurious dust will be referred to when the special respiratory diseases to which they give rise are discussed.

ASTHMA.

Asthma is a term used to indicate a train of symptoms rather than a disease, and *per se* seldom appears as a cause of death on death certificates; therefore, mortality statistics give no indication of its prevalence, indeed, asthma does not appear in the three years, 1910-12, as a cause of death among 195 deaths of cotton-strippers, who are known to suffer markedly from this complaint. That asthma occurs as a result of dust inhalation has already been mentioned. Agricola, in the quotation given (18), referred to its occurrence as the result of dust inhalation among Carpathian miners; Ramazzini refers (14) to it as resulting from the inhalation of flax and hemp dust; Diembroek mentions (12) its occurrence among stone-masons; and later inquiries have confirmed these earlier observations. Thus all writers upon the health of metalliferous miners describe the prevalence of attacks of shortness of breath, which they call asthma. Greenhow, when dealing with Cornish tin-miners, mentioned (38a) that "for the most part they become more or less asthmatical about the age of forty." Greenhow, however, it is only fair to say, remarks

(39a) "the terms 'asthma' and 'asthmatical' are commonly used by various classes of operatives to designate any form of pulmonary disease attended by dyspnoea arising from their occupation. These terms are therefore employed . . . in their popular and not strictly in their pathological sense." Similarly the Committee on the Health of Cornish Miners noted (34a) among tin-miners that "shortness of breath appears to be almost always the first prominent symptom." Greenhow also said (38b) of lead-miners "as life advances, dyspnoea is added to the other symptoms, and at length most of the miners become asthmatical, are unable to move without more or less difficulty of breathing, and suffer habitually from cough and expectoration. . . . The age at which miners for the most part become decidedly asthmatical is about the 45th year"; and a retired lead-miner recently told me that asthma still persists in the Durham lead mines. Cumpston (48) and Summons (49) speak of asthma among Australian gold-miners; and it is referred to by Watkins-Pitchford (44) and in all the numerous reports on Miners' Phthisis in the Transvaal. Arlidge states that "flint-millers . . . suffer sadly with asthma and interstitial pneumonia" (40a); and the same authority says "the features of potters are rather those of asthmatical subjects" (40b).

Personally I have not found asthma prominent either among grinders of metal in Sheffield or elsewhere, or among Aberdeen granite cutters, or among silica-brick makers, and, although some stone-masons have spoken of it, I have not found that asthma (as distinguished from attacks of air hunger) is common among them, although all suffer in excess from dust-phthisis; and West, when speaking (47) of the extreme shortness of breath exhibited by these workers, says "this is often spoken of loosely as asthma, but true spasmodic asthma is by no means common." On the other hand operatives exposed to certain dusts do suffer in a marked degree from true asthma; and I think that attacks of dyspnoea, which occur in cases of dust-phthisis, are essentially different in causation and character from such cases of asthma. True dust-asthma, which I have seen in a pronounced form among cotton strippers, is associated with a physical configuration of the chest, and a type of breathing quite different from those seen among operatives who experience a heavy mortality from dust-

phthisis. The course of the disease was far more distressing and more liable to invalidate the sufferer than the dyspnoea described among gold-miners and others.

Cotton-strippers are exposed, at one of the first processes of cotton spinning, to dust arising from cotton husk and debris which is thrown in a fine cloud into the air when the cylinders of cotton carding-machines are brushed out or "stripped." The amount of dust generated varies with the grade of cotton used, and is greatest from coarser grades, particularly from Surat and some American cottons, and least from finer grades, such as Egyptian. Each spinning mill usually deals only with material of special grades, so the effect of the different amounts of dust could be studied at different mills. Thus I found (53) among men working on coarse grades of cotton 91 per cent. more or less affected, on medium grades 72 per cent. and on fine grades 62 per cent.

Exposure to this dust has unpleasant effects for a chance visitor, who, not infrequently, suffers within twelve hours from an attack of mill fever, with sharp but transient febrile symptoms, but operatives soon become inured to such attacks. An operative stripping cotton-carding machines, after years of work, varying from five to twenty, according to idiosyncrasy and the amount of dust, finds his chest becoming affected; at first the only symptom is difficulty in breathing on Monday morning, or after any interval away from the dust, and after the first day is over he may remain unaffected for the rest of the week. As time passes this difficulty becomes worse and extends later and later into the week, developing into a typical form of asthma as long as he is in the dusty atmosphere. At the same time he loses flesh and becomes thin in face and body. As the case develops the action of the diaphragm becomes less and less effective, until the only action of this great respiratory muscle is to fix the lower ribs. At the same time the superior intercostal muscles and the extraordinary muscles of respiration are more and more called into play to carry on the ordinary act of breathing. The sternum becomes more prominent and the chest barrel-shaped. Meanwhile the extra tax thrown on the lungs leads to some degree of emphysema. There is little or no sputum produced, and what little there is, is expectorated with difficulty. When this stage is reached, *i.e.*,

after about twenty years' work, the individual is usually compelled to seek other employment, and so, although the employment is not arduous, few old men are found at work. I found only 139 aged 45 years and over in every 1,000, as compared with 231 metal-grinders and 434 lace-workers. The distinctive symptoms experienced are attacks of spasmodic asthma precipitated by exposure to dust. The trouble is, however, rapidly disappearing owing to improved methods of dust prevention, which are even enabling affected men to resume their employment. These operatives do not suffer markedly from phthisis, though there is some slight excess late in life; but they experience a high mortality from pneumonia, and an excessive mortality from bronchitis.

Other cotton-operatives, weavers, occasionally suffer from an acute form of spasmodic cough with asthmatic symptoms, but this affection I believe (90) to be due to inhalation of a special mildew which from time to time appears on cotton thread; this disease, however, since it is probably a form of aspergillosis, does fall within the definition previously laid down of a pneumoconiosis, and only calls here for passing mention.

Greenhow had previously noted (38c & 39b) that carding-room operatives, especially those who strip the cards and the card-grinders, were very apt to become asthmatical about middle life in proportion to the amount of dust generated which varied with the grades of cotton used; but at that time the dust, owing to hand-stripping, was not generated so freely as when I made my inquiry, and Greenhow gives no clinical description of the disease. He did, however, describe (38d) the same condition among flax-hecklers at Pateley Bridge, where he found at one factory 23 out of 27 hecklers habitually asthmatical; he speaks of the older men as short-breathed, with "rounded shoulders, emaciated frames, prominent eyes, and laborious wheezing respiration," and says that to find men aged 60 years at work must be deemed exceptional; and the following passage may be compared with the description given above of cotton-strippers' asthma (which was written without any knowledge of Greenhow's previous work):—

The effect on a healthy stranger of entering these rooms is most unpleasant: the dust floating in the atmosphere irritates the nasal and bronchial passages, producing sneezing and a

sense of oppression in the chest, which do not cease till some time after the visitor has left the apartment. Although the effects of temporarily inhaling the atmosphere of the dusty departments of a flax mill are so obvious, the operatives, after a time, become inured to it, and are able to tolerate it for some time without sensible injury. It was stated that the operatives are more affected by the dust at the beginning of the week, and that they always suffer more on resuming their employment after an interval of cessation. . . . As life advances, the power of resisting the pernicious influence of their occupation diminishes, and more or less of permanent dyspnoea, and other results of bronchial irritation supervene. The ordinary signs of chronic bronchitis, and sometimes of emphysema, may be detected by auscultation.

The observations published in 1873 by Dr. Purdon, of Belfast (61), and the experiences of 14 observers, collected in 1894 by Osborn (50), corroborate this description; for instance, Dr. Lunan, Blairgowrie, stated: "I cannot say I have been able to trace the origin of phthisis to flax dust. I feel quite sure that bronchial catarrh, accompanied in many cases by asthma, is frequently caused by breathing the dusty atmosphere of flax mills"; and Dr. D'Evelyn, Ballymena, said "the hacklers all die young, and all suffer from chronic disease of the lungs, caused by the flax dust. . . . The first thing a hackler does each morning is to drink a glass of raw whiskey, to clear out his bronchial tubes, otherwise he is unable to breathe. After a day off, the men have often told me their breathing is worse." Notwithstanding the then accepted axiom that all forms of dust must predispose to phthisis, five out of the fourteen observers definitely state that flax dust does not have this effect; similarly Givre, speaking of carders of silk, says (27a) "some authorities even deny that these dusts create a predisposition to phthisis; and see a certain antagonism between the emphysema of carders and phthisis."

Inquiries in the flax and jute industries have convinced me that similar asthma still occurs in these industries among operatives exposed to dust generated in the initial stages of textile manufacture—at flax-heckling and at jute-opening—but the symptoms, at least under modern methods of dust removal, are seldom pronounced.

When once this asthmatical condition, which is especially associated with exposure to vegetable husk, has been recognised, its

occurrence in a modified form can be traced among those exposed to dusts of similar origin, such as those arising from wood bark and some of the harder woods—for instance, Powell and Hartley describe (75) the case of a man exposed at his work to the dust of rosewood; this man was subject to severe attacks of dyspnoea, which had the paroxysmal character peculiar to asthma; his symptoms ceased after absence from work, but returned when he resumed his employment which he finally had to give up. True, dust asthma is always associated with an excessive incidence of bronchitis. Thus 32, or 16.4 per cent., of the 195 deaths already referred to among cotton-strippers were due to this cause, as compared with 8.3 per cent. for Occupied and Retired Males.

The distinctive features of this form of asthma are (i.) occurrence of asthmatic attacks during exposure to dust, and the cessation of attacks on leaving the dusty atmosphere; (ii.) immobility of the diaphragm; and (iii.) over-action of the superior intercostal and extraordinary muscles of respiration. Contrast these with Peacock's description of asthma among Cornish tin-miners with their high mortality from dust-phthisis—"the difficulty of breathing is extreme, and is aggravated by any slight exertion, as by ascending stairs or any slight elevation, and it is usually increased by certain states of the atmosphere and when the patient takes cold. Notwithstanding the great effort which is made in breathing the movements of the chest are most imperfect, there is little change of capacity with inspiratory and expiratory acts, and the respiration is almost entirely abdominal." This type of breathing I have seen among grinders of metals in Sheffield and elsewhere, and among stone-masons, and it has been described by the Committee on the Health of Cornish Miners (34) and by all observers of miners' phthisis on the goldfields of the Transvaal and of Australia.

Broadly speaking, then, there are two distinct types of dyspnoea caused by dust. (1) One type, seen among operatives who suffer from dust-phthisis, in which convulsive but ineffective respiration is carried on by the diaphragm; and Watkins-Pitchford adequately explains (44) the condition as follows: "The phenomenon is quite independent of pleuritic adhesions, and is due

to the gradual loss by the lungs of their elasticity—or, in other words, their capacity of accommodating themselves to the varying capacity of the thorax during respiratory movements. As soon as the lungs have ceased to be distensible, the chest wall becomes fixed; for as the lungs are now incapable of following the chest wall, its outward movement is necessarily opposed by the overpowering pressure of the atmosphere." (2) Another type seen among operatives who do not suffer from dust-phthisis, but who do suffer from bronchitis, in which the diaphragm is fixed and the ordinary type of asthmatic breathing is exhibited. Here the underlying pathological condition is different—the elasticity of the air vesicles is not seriously impaired, but the bronchial mucosa is chronically inflamed and ready, when dust falls on it, to start excessive respiratory impulses. Hence it follows that this form of asthma is provoked by exposure to dust and is of peripheral origin; while the other form is provoked by exertion and is a form of air hunger of central origin, indeed in advanced cases chronic cyanosis is present.

Fifty years ago asthma was common among coal-miners. "Then in every little mining village," writes the secretary of a miners' association, "there was a contingent of old miners, past work, on account of difficulty of breathing, a stage usually reached between forty and fifty years of age"; and this statement is borne out by Greenhow, who tells (39c) of the ravages wrought in his day among coal-miners in South Staffordshire by asthma; "some miners retain their health till an advanced period of life, but the greater number suffer, more or less, from asthmatical symptoms before attaining the age of 50, and many break down and are disabled at 40 to 50 years of age . . . a miner is usually an old man at 50; and few men . . . are found at work beyond that age." The same observer also mentioned (39d) the disease as prevalent in the South Wales coal-field, and while attributing it to bad ventilation of the mines, states that the miners blamed the fumes from explosives. He contrasts (39e) the condition with that seen among lead-miners and tin-miners, as one with emphysema more frequent, with less pneumonia, developing later in life, and, while associated with chronic bronchitis, not associated at an early period of life with

slight dyspnoea. In America Drs. Wainwright and Nichols report (88) that, at Scranton, asthma accounted, 1894—1904, for 7 per cent. of all deaths amongst coal-miners, as compared with 1.6 per cent. amongst all occupied males; and these observers state that the condition as seen among the miners is one of chronic bronchitis and emphysema. Synchronous, however, with improved ventilation of mines the disease has disappeared in this country: improved ventilation has minimised exposure to several adverse influences, *e.g.*, fumes from explosives, soot and other products of combustion from naked lights, gaseous impurities, and dust. The opportunity of ascertaining which was the determining cause has gone, and also of obtaining a good clinical description of the condition; but the following note sent me by Dr. J. Taylor, Chester-le-Street, taken in conjunction with Greenhow's observations, suggests that coal-miners' asthma was true spasmodic asthma. Dr. Taylor writes: "One case only do I recollect. In this case the breathing was carried on by the respiratory muscles of the chest, and the diaphragm did not enter much into the mechanism of inhalation. This patient suffered at all times of the year, but a windy day always appeared to be the starting point for an attack." If the supposition is correct that coal-miners' asthma was true asthma, possibly the miners were correct in ascribing it to fumes from explosives, which, as Oliver has pointed out (89), would contain nitrous fumes; and in this case the disease should not be classed as a pneumoconiosis. The disease, however, common though it used to be, has passed almost unobserved from our midst, and conjecture as to its character and causation are idle.

(To be continued.)

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THE WORK OF A TUBERCULOSIS DEPARTMENT.*

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THE following paper deals with the work now being carried out at the three tuberculosis dispensaries, situated respectively in the County Borough of Wigan and the Boroughs of Chorley and Leigh, and serving not only these boroughs, but the surrounding townships, comprising altogether a population of nearly 300,000 persons. The staff, in addition to myself, consists of two assistants, five nurses, and two clerks.

I have been fortunate in being allowed considerable freedom in the organisation and management of these dispensaries, and I think that some account of the methods and procedure adopted may perhaps prove of interest.

Although the functions of a tuberculosis dispensary as laid down in the *interim* report of the Inter-departmental Committee in 1912 are fairly definite, there appears to be no little diversity of opinion as to the best means of carrying these recommendations into effect. This is not unnatural when the varying circumstances of the districts concerned, whether urban or rural, are considered. Apart from this, however, there are sharp differences both in theory or practice in areas apparently similar in character.

The tuberculosis dispensary enters into relationship with—

- i. Public Health Department.
- ii. General practitioners.
- iii. The general public.
- iv. Other organisations.

I.—RELATIONSHIP WITH PUBLIC HEALTH DEPARTMENTS.

This should be as intimate and cordial as possible. The problem of tuberculosis is closely associated with questions of housing and sanitation, which are the concern of the medical officer of health. The latter has, moreover, certain statutory obligations under the Tuberculosis Order, 1912. On this account there should be a definite system for the prompt and ready exchange of information between him and the tuberculosis officer. The former receives notifications as to persons suffering from tuberculosis of all forms, and also returns

* Read before a meeting of the North-Western Branch of the Society of Medical Officers of Health on January 15th, 1915.