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Historical Background to the Asbestos Problem

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EARLY BEGINNINGS

Asbestos has been known in various forms and used for different purposes since prehistoric times. In Finland, for example, pottery dating from 2500 B.C. has been found to incorporate asbestos (presumably anthophyllite) fibers, and Busmanoid pottery attributed to stone-age times (before the middle of the first century B.C.) has been found containing amphibole in the region ranging from southern Sudan to northern Kenya (70, 93). Finnish peasants are also reported to have used asbestos rock to pack crevices in their log huts from time immemorial. One of the earliest historical records tells of the use of asbestos wick in a gold lamp for the goddess Athene in the fourth to fifth century B.C. At the turn of that century Theophrastus described the persistence of the wick after the oil was burned off, and Strabo and Plutarch continue the story (28, 44, 84). Herodotus, writing about 456 B.C., remarks on the use of an asbestos cloth for retaining the ashes of the dead during cremation, and Pliny in the first century A.D. calls it the funeral dress of kings. Such a shroud is reported to have been recovered from a pre-Augustinian tomb (23b, 44, 50). Plutarch described other articles into which the material was woven.

One form of the Greek word σασβεστος signified "unquenchable;" the perpetuity of the flame given by wicks containing asbestos would have justified the appelation. The concept of indestructibility seems to have been added to the connotation later. Some confusion has resulted from another form ήασβεστος of the same word that signified what today we would call slaked lime (95).

The term "amiantos" and its variations, common in mediterranean countries, also has a confused etymology. Lithos amiantos is said to be the original term, as used by the Greeks to indicate a rock unstained, untainted, or undefiled, referring presumably to the cleansing of asbestos material by fire (19). It has been suggested, however, that the Karpasian flax referred to by Pausanius (second century A.D.) came from a village in Cyprus known as Amianto, which might be the town of Amiandos near which chrysotile has been found in recent times. In England, the term "amianthus" survived until the end of the 19th century, when the word "asbestos" took its place. In France today, "amiante" is used at least as frequently as "asbeste."

The property of being unconsumed and even purified by fire is emphasized in the account given by Marco Polo (ca. 1250 A.D.) of a cloth reputed to be of salamander skin, but actually consisting of "amianto" prepared from rock by a process that persisted well into the nineteenth century (50). Apparently a similar account given some 150 years earlier did not attract antiquarian interest (48). The story of Charlemagne's tablecloth and the impression made on guests when he threw it into the fire has been many times recounted in recent literature (21, 50).

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INTERMEDIATE YEARS

The turmoil and superstition of the middle ages militated against development of the practical arts and manufacture in Europe, and apart from a passing reference to its use in body armor at the siege of Rouen (1490), the next we hear of asbestos is mention of a Chinese merchant's exhibit of "salamander's wool" in London in 1676 (21, 79, 85). Asbestos wicks and paper were apparently manufactured in Norway in the early years of the 18th century, and the discovery of substantial deposits in the Urals about 1720 led to the establishment of an industry under Peter the Great, that persisted for about 50 years before lapsing for lack of demand (23b). According to Tara, the art of weaving was a little known and well-kept secret (85). To Lena-Parenti goes the credit of rediscovering the making of threads early in the 19th century (50, 85). She apparently went on to make paper, cloth, and even lace and received recognition from the National Institute of Italy in 1806–1807. Tara relates that asbestos threads were utilized in Africa and Asia for sewing the labia of female infants; that shepherds in the Pyrenees used the material in making leggings, ropes, belts, and bags; and that it was used as insulation in the construction of stoves in Corsica.

In 1725, shortly after his arrival in London, Benjamin Franklin wrote to Sir Hans Sloane that he had brought with him from "the northern parts of America . . . a purse made of the stone asbestos . . . which is of the same nature and called by the inhabitants Salamander Cotton" (5). What is believed to be the same article now reposes in the British Museum, but since it is made of tremolite, the source of the fiber would seem not to have been American, but possibly a mediterranean country like Italy.

Aldini and Cavanessi experimented with asbestos clothing about 1827, but it was not until the period 1850–1870 that production of woven materials, including paper for banknotes, was started in Italy (23a, 50). In 1862 a specimen of Canadian asbestos was on display at a London exhibition, and in 1869 Wertheim came across some of the first asbestos yarns manufactured in England and used them in Germany for ropes and packing (17). In 1866, two Glaswegians, Robson and McLellan, formed a group with the prescient title of the Patent Asbestos Manufacturing Company, Ltd. (22). Industry was ready, all that was needed was a good supply of the magic material with which to work wonders.

THE BREAKTHROUGH PERIOD

The rediscovery and development of very large deposits of asbestos in Canada and South Africa provided the opportunity. Development of deposits in other countries soon followed.

Canadian Production

Attempts to work chrysotile deposits discovered in 1860 in the Des Plantes River region were unsuccessful, but the Thetford–Colerain deposits, first noted by Logan in 1847 and rediscovered by Fecteau and Ward in 1876–1877, proved more extensive and amenable (21, 23a, 49, 50, 51, 74). [An overlapping account gives the credit to one Andrew Johnson, who transported handpicked material by oxcart 31 miles to the nearest railroad and established the pioneer producer of Canadian asbestos (12)]. The early optimism, subsequent disillusionment, and final realistic approach so often attending new commercial ventures were well described for asbestos by Cirkel (23a). The 1880s witnessed a rapid development, mines were worked on a large scale, and the surrounding population increased to several thousand. But the primitive methods of hand extraction permitted

only those mines with high grade material to prosper, and even so there was overproduction and the industry languished through the nineties. Mechanical methods of mining and milling were then introduced, demand increased, and by 1905 there were 16 mills with a capacity of 3500 tons of rock per day operating successfully. Thereafter the industry embarked upon the exponential growth that we know so well, with only minor and temporary aberations (19). The mode of mining was entirely by open pit at first, and this method is still common. But by 1959 it was reported that of 14 mines, 3 had changed entirely to underground mining, 2 more were intending to do so, and others used both methods (80).

South African Production

Meanwhile, events in South Africa were pursuing a parallel course. In 1891 Oats, a Director of the De Beers Consolidated diamond mines, formed a group to exploit the crocidolite which had first been noticed in the northwest of the Cape Province in 1803–1806, and named in 1831, but had remained unused. The syndicate had less success than the Canadian developers for a variety of reasons, including the Boer War. The first officially recorded production came in 1910, but the tonnage remained below 10,000 annually until 1940. In the 1940s, presumably with the stimulus of wartime demands, modern consolidated mining methods became the rule (81, 82).

In the meantime, another type of asbestos, to be called "amosite" after the acronym of the company, had been discovered in northeast Transvaal. Once again, early experience was discouraging. Production started in desultory fashion in 1910, but it was not until 1926 that the Cape Asbestos Company, capitalizing on its experience with crocidolite, literally put the material on the market (6). By 1928, production has risen to 7000 tons. In South Africa, also, open-pit mining was the original method and some quarrying still persists; but underground mining became increasingly more common after 1930. Milling replaced hand cobbing after 1915 (81).

Italian Production

The historical experimentation with tremolite and chrysotile deposits, mainly in the northern Appenine valleys, culminated in the formation of the Italo-English Pure Asbestos Company in 1874, with a factory at Turin, but the discovery of the more workable Canadian chrysotile temporaily ended significant use of Italian sources (11). Annual production remained below 1000 tons until 1923. Thereafter it fluctuated until 1947. In the 1950s it began to share in the expanding world production, although in 1970 it still provided only 3.4% of the total (19, 24).

Russian Production

Until after the 1918 revolution, production methods remained fairly primitive (56). Production remained low until the period 1925–1928, when a new plant was constructed. By 1938 it had risen to 135,000 tons per year (10). By 1963 large fields were being developed in Siberia and other sites, and by 1970 it was estimated that annual production had reached 1,150,000 tons, third in world ranking (24).

United States Production

In 1899–1901 development started in Vermont of deposits at the southern end of the serpentine belt running through Quebec. These deposits remain the mainstay of United States production. Later developments took place in Arizona, California, North Carolina,

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and Georgia (9, 24). By 1970 the annual production amounted to 125,314 tons, or 3.3% of the world figure (24).

Rhodesian Production

Mining of chrysotile started in the Mashaba region in 1906. Peak production of 95,000 tons occurred in 1968. Later figures are somewhat lower (8).

Other Production

In 1970 3.8% of the world total was mined in various other countries, including China, Australia, and Finland (24). Included in those figures was some crocidolite produced in Australia and anthophyllite in Finland.

MANUFACTURE AND USE

Machines for the production and use of power introduced by the industrial revolution furnished an immediate stimulus to the asbestos industry through the need for packing and insulation; but the potentiality of the new material for other purposes was evident from the start. On the American scene, for example, a Mr. Johns read of asbestos in the Encylopedia Americana as early as 1859, and began manufacturing some asbestos products in 1868. The issue of Scientific American for February 26, 1881 had asbestos for its cover story. World War II provided a tremendous boost in the demand for asbestos and multiplied its uses in spectacular fashion. The immediate postwar literature was full of fresh ideas, and subsequent decades have continued the challenge to ingenuity. Table 1 indicates just a few of the outstanding developments. While the precision of the dates cited may be open to some question, the sequence brings out the salient features of the last 100 years' growth, and perhaps conveys something of the excitement that attended the development in spite of periodic hindrances from wars, shortages, labor problems and fears of "dumping."

In 1947 the trade journal "Asbestos" was able to review the scope of asbestos uses neatly as providing protection against weather, corrosion, fire, heat, cold, acid, alkalies, electricity, noise, energy losses, vibration, accident, frost, dust and vermin (a fairly comprehensive list of environmental hazards) (7). But in 1953 the Asbestos Fact Book listed 40 uses for raw asbestos, 16 for asbestos yarn, 29 for asbestos cloth, 17 for asbestos paper, 14 for asbestos mill board, 11 for asbestos–cement flat sheets, and 10 for asbestos composition material (13). In 1967 Johns–Manville took five pages in a brochure, "Notes on the History of Asbestos Fibers," merely to list the names of their products. By 1971 such lists became virtually impracticable, and statisticians were reduced once more to dealing with only a few major categories such as those used in Table 2 (14). Although the data are for the United States alone, they indicate how much the industry had grown in 100 years.

RECOGNITION OF PATHOGENICITY

Although many industrial sites were indescribably dusty, the number of persons employed was small and the duration of employment fairly short until the dawn of the 20th century. Pliny's report of sickness in slaves who worked with asbestos was probably dismissed as of little concern (1, 34). The Annual Report of the Work of the HM Women Inspectors of Factories for 1898 in Great Britain included the following sentient paragraph:

TABLE I

EVENTS IN THE DEVELOPMENT AND MANUFACTURE OF ASBESTOS

Year	Event	References[a]
1857–1880	First lutings (flat sealings, packings) based on asbestos in England	16
1866	First waterglass bonded molded asbestos material for heat insulation	13, 16
1868	Research and development of asbestos published by Johns (United States)	Mar. 1958, p. 2
1868–1869	First United States use of asbestos in roofing felt and cement	23a; Feb. 1971, p. 2
1866–1876	Start of systematic textile processing in Italy	16
1871	Founding of Asbestwerke Louis Wertheim in Germany	16; Oct. 1958, p. 31
	Robson and McLellan founded in Glasgow, using Italian asbestos	23a; May 1966, p. 2 Mar. 1958, p. 2
1873	Johns' first real factory (United States)	
1874	Founding of Italo-English Pure Asbestos Co., in London for yarns and packing cords, in Rome for asbestos board	16
1882	Mattison got idea of substituting asbestos for hemp in insulating "magnesia" (United States)	Feb. 1971, p. 2
1888	Founding of Bell Asbestos Co. Ltd. In collaboration with textile mills of Turner Bros. in Lancashire produced yarns from Quebec chrysotile	16
1890	Beginning of textile processing of Quebec asbestos in United States	16
1893	First spinning of crocidolite by Cape Asbestos Co.	16; Dec. 1968, p. 38
1896	Fabrication of first woven brake bands by Fedoro Ltd. in England	16
1899	Wet machine process of making asbestos–cement developed by Hatschek in Austria	16
Turn of the century	Asbestos–cement pipe industry had beginnings in Italy	Sep. 1973, p. 8
1903	Production of asbestos cement in United States	16
1904	Flat asbestos–cement board manufactured in United States	Nov. 1958, p. 10
1906	Asbestos first used as brake lining	13; Apr. 1946, p. 4
First decade	Asbestos combined with formaldehyde resins	Apr. 1967, p. 2
1911	Asbestos industry started in Japan	45
1918	Molded clutch facings developed	Apr. 1946, p. 4
1928	First pipe making machines imported into United States	16; Sep. 1973, p. 8
1931	Technique of spraying asbestos developed in Britain	Sep. 1966, p. 6
1934	Amosite felt developed for turbine insulation	33
Fourth decade	Asbestos–cement pipes introduced into Britain	May 1966, p. 2
1939–1946	Marked development of protective asbestos clothing during World War II	Dec. 1946, p. 10 Feb. 1947, p. 10
1944	Spraying of asbestos on deckheads and bulkheads begun in British naval ships	40, 41

Year	
1945	Multifl coat
1946	Asbest
1947	Asbest stee
1950	Massi for i
1963	Spray
1967	Asbes pai
1971	Bulk
1972	70% cer me

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Floor tile
Friction materials
Paper
Asphalt felts
Packing and gasket
Insulation
Textiles
Other

[a] Chrysotile, sh
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[c] Spinning.
[d] Shingle and p
[e] Shorts.

TABLE 1—*Continued*

Year	Event	References[a]
1945	Multiflex material consisting of asbestos fabrics with coating of resin introduced for air-ducts	July 1945, p. 12
1946	Asbestos filters for wines, etc.	Jan. 1946, p. 16
1947	Asbestos–cement pipes adopted by Montreal because of steel shortage	Sep. 1947, p. 2
1950	Massive amosite sections replace 85% magnesia mattresses for insulation	40
1963	Spraying of asbestos discontinued in British naval vessels	40, 41
1967	Asbestos now incorporated in a wide variety of plastics, paints, and asphalt	Mar. 1967, p. 2 Apr. 1967, p. 2
1971	Bulk handling system for fiber developed	Mar. 1971, p. 8
1972	70% of world's output (4 million tons) goes into asbestos–cement. Britain weaves long asbestos fibers into 4 million meters of cloth and spins 16 km of yarn	24

[a] Dates followed by page numbers indicate the location in the trade journal *Asbestos* from which the information was taken. Numbers by themselves refer to the list of references at the conclusion of the article.

> The evil effects of asbestos dust have also attracted my attention, a microscopic examination of this mineral dust which was made by H.M. Medical Inspector clearly revealed the sharp, glass-like, jagged nature of the particles, and where they are allowed to rise and remain suspended in the air of a room, in any quantity, the effects have been found to be injurious, as might have been expected (94).

In 1902 Anderson was moved to include asbestos in the dusts long known as injurious to man (1). In 1908 Scarpa reviewed the fate of 30 asbestos workers who attended his clinic over the period 1894–1906 with serious pulmonary disease and found rapidly progressive tuberculosis to be the rule (75). In 1906 H. Montague Murray reported to a Departmental

TABLE 2
UNITED STATES ASBESTOS CONSUMPTION—1972 (14)[a,b]

End uses	BM I[c]	BM II[d]	BM III[e]	Total
Construction	—	214,800	108,600	323,400
Floor tile	—	4,700	80,000	84,700
Friction materials	5,400	24,000	47,600	77,000
Paper	—	2,100	67,200	69,300
Asphalt felts	—	17,000	29,200	46,200
Packing and gaskets	2,000	18,000	10,800	30,800
Insulation	2,600	2,300	10,500	15,400
Textiles	7,600	—	100	7,700
Other	1,000	80,800	33,700	115,500
	18,600	363,700	387,700	770,000

[a] Chrysotile, short tons.
[b] Reproduced with kind permission of the publisher of *Asbestos*.
[c] Spinning.
[d] Shingle and paper.
[e] Shorts.

Committee on Industrial Hygiene in England on a case of pulmonary fibrosis in an asbestos worker on which he had performed a postmortem in 1899. The account seems not to have been published, but by great fortune histological material has been preserved, and a photomicrograph of tissue has kindly been given us by Dr. Morris Greenberg, Health and Safety Executive, London (Plate 1).

In 1899, also, Auribault reported numerous deaths in a French asbestos spinning-mill and weaving factory over the period 1890–1895 (15). Vague warnings of disease associated with asbestos were sounded in continental Europe as well as in Britain prior to World War I, but the etiological connection was not made. The British Factory Department made a survey in 1910, following the report (probably Murray's) of a death certified as "acute pulmonary phthisis" in an asbestos worker, but no health hazard was

PLATE 1. Photomicrograph of tissue from the original Montague Murray case of asbestosis (1899). Provenance is provided by the antique inscription on the slides, giving details, and by the chain of passage: Dr. Hislop (compensation doctor employed by mine owners ca. 1912); Dr. Middleton (H.M. Medical Inspector of Factories); Dr. Doig (H.M. Medical Inspector of Factories); Dr. Lloyd Davies (Chief Employment Medical Advisor and architect of Employment Medical Advisory Service) to Dr. Morris Greenberg. (Reproduced with the kind permission of Dr. M. Greenberg.)

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seen. In 1917 The Department again found no evidence of disease, but nevertheless ordered improved ventilation (65, 66). A Canadian health inspector in 1912 noted the remarks of one of the oldest practitioners in Bedford that the large amounts of dust floating in the air of the cobbing room had a weakening effect on the lungs, but the generality failed to impress (3). In 1918 Hoffman called the attention of the Prudential Insurance Company in Boston to the probable harmful effect of asbestos dust, and apparently persuaded the company not to issue policies on asbestos workers (42).

The turning point came in 1924, when Cooke reported a second death in England from pulmonary fibrosis in an asbestos worker (25). Cooke, McDonald, and Oliver reported further on this case in papers published in 1927 (26). Zenker in 1867 had introduced the generic term "pneumonokoniosis" for lung disease caused by inhalation of dust and had opened the way to more specific names according to the dust involved. In the second of his 1927 papers, Cooke used the term "asbestosis" for the first time. In his 1924 paper Cooke had mentioned the presence in the lungs of mineral particles of various shapes, but not until 1929 did he describe the "curious bodies" later to be called "asbestos bodies" (27).

Acceptance of the pathogenicity of asbestos came but slowly. Tuberculosis was still a prevalent disease, and the importance of silica tended to obscure the possible pathogenicity of silicates (71, 72). Further cases of asbestosis reported by Haddow and others in 1927 (39), and what Seiler claimed in 1928 to be the first case free from any question of other causes (76), stimulated official recognition. In 1930 Merewether and Price presented a report to the British parliament establishing "the fact that the inhalation of asbestos dust over a period of years results in the development of a serious type of fibrosis of the lungs," and indicating that the remedy would be in dust suppression (67). Three almost simultaneous papers in 1930 made the first reports of cases of asbestosis in the United States (60, 68, 83). In 1929 the Metropolitan Life Insurance Company of New York initiated what may well be the first epidemiological investigation of asbestos workers (58).

On the European continent recognition was developing slowly. After Fahr's 1914 brief demonstration of chronic indurative pneumonia in an asbestos worker (32), little seems to have been published until four papers on German cases appeared in 1931 (2). From Italy little was heard after Scarpa's early account until the Johannesburg conference on silicosis in 1930, when participants described well-developed situations (4). In other European countries, the first reports of local cases appeared later, possibly because intensive manufacturing got under way at a later time.

CLINICAL COMPLICATIONS

Although it presented some differences, the pulmonary fibrosis developing in response to the inhalation of asbestos seemed at first to be readily understandable in the light of other dust diseases: asbestosis was just another instance of Zenker's general pneumonokoniosis. In some respects it appeared simpler, because the progressive massive fibrosis (PMF) that commonly develops as a complication of silicosis and coal workers' pneumoconiosis seldom occurs in asbestosis. But other complications began to appear that were not so easily fitted into conventional patterns. These were finally to force reconsideration of etiological ground rules.

Plueral Asbestosis

A certain degree of involvement of the visceral pleura is only to be expected in extensive pulmonary fibrosis. In the 1930s there were scattered references to calcareous markings in chest radiographs (77), and Gloyne described "horn-like" changes in the pleura (35). But it was not until 1935 that Lynch and Smith reported a case in which "the pleura of the right lung is thickened as a whole and is of cartilaginous and even partly calcareous quality over the base. That of the left lung is likewise thickened, but over the free portion it is rough, congested and 'furred,' with small nodules in the surface" (61). Lanza extended the description in his text of 1938 (57). The characteristic "ground glass" appearence seen in some chest radiographs was accepted as due to pleural involvement; but there was little mention of pleural calcification in the earlier accounts of asbestosis (77). In 1943 Siegal and his colleagues reported the finding of numerous instances in examinations of talc miners and millers (78). In 1955 Jacob and Bohlig found pleural calcification in some 5% of 343 asbestos workers examined in Dresden (47). Since that time the presence of pleural plaques has been reported with increasing frequency; to the point that their demonstration has often been accepted as fairly conclusive proof of exposure to asbestos. The explanation for the lack of early reports is that pleural plaque formation and subsequent calcification is a slow process that seldom has time to develop in those who are responding with marked parenchymal asbestosis and relatively early death (77).

The pathognomonic nature of pleural calcification was brought into some question in 1960, when Kiviluoto reported finding calcified pleural plaques in persons living in Finland many miles away from any asbestos workings; findings which were extended in later publications (53, 54). The explanation was offered that the soil was rich in asbestiform material and that the pleural developments resulted from long exposures to doses too small to induce parenchymal fibrosis; an explanation to receive support later by reports of calcified plaques developing without radiological evidence of parenchymal changes in workers exposed to low levels of asbestos, and in other rural situations with asbestiform material in the soil.

Mesothelioma

In 1931 Klemperer and Rabin published an account of five primary neoplasms on the pleura, although they did not clearly establish the relationship with asbestos exposure, but referred back to Wagner's account of such tumors in 1870, which was before asbestos was used in any but very small quantities (55). They did, however, suggest that the term mesothelioma "be accepted to designate all the diffuse neoplasms of the pleura that arise from the mesothelium, whether they appear to be composed of epithelium, connective tissue, or both."

In 1947 Mallory *et al*. reported a case of mesothelioma of the pleura and pericardium in an asbestos worker (62). In 1953 Weiss reported that in the 31 cases of asbestosis autopsied in Germany and described by Wedler in 1947 there were two malignant tumors of the pleura, and he himself reported a third case (91). Leichner in 1954 described unexpected pleural growth of a type that would now be classifield as mesothelioma in a patient with asbestosis and tuberculosis (59). In 1958 Van der Schoot reported on three insulation workers who had died of neoplasms, two of them apparently mesothelioma of

the pleura, and in the discussion Schornagel mentioned a case that he had seen of peritoneal mesothelioma (86). McCaughey in the same year described a series of cases in Belfast (64), but gave no account of exposure. Keal, searching the records of the London Hospital since 1948, was able to report in 1960 that of 23 women who had been inpatients with asbestosis, one had an ovarian carcinoma, four had peritoneal growths, and four had carcinomatosis of the peritoneum without a primary lesion being found (52).

In 1960 Wagner and his colleagues (89) firmly established the existence of mesothelioma and finally put to rest the objections of Robertson that "only sarcomas can be classified as primary malignant tumors of the pleural tissues, and that all other growths are secondary" (73). The distinguished Willis, however, continued his opposition even to 1967 (92). Wagner *et al.* announced that in the previous 4 years they had seen 33 histologically proven cases of mesothelioma of the pleura, and that 28 of these had some association with the Cape asbestos field, and four had been exposed to asbestos in industry. By contrast, no neoplasm of this nature had been diagnosed among 10,000 lungs examined at the Pneumoconiosis Bureau or the South African Institute for Medical Research. In the following year they were able to supplement the record with eight more cases (81). Wagner later went on to demonstrate the experimental development of pleural mesotheliomatous tumors by the intrapleural injection both of chrysotile and of crocidolite (87). At the International Congress on Occupational Health in 1963 he was able to report on more that 120 cases seen since 1956 (88). More than half of the cases never worked in the asbestos industry but lived in the vicinity of the mines and mills, so that the importance of neighborhood exposure was established. Another important point made in the course of this presentation was that there was no correlation between the severity of asbestosis in these persons and the presence of the tumor. This observation opened the way to a later speculation that, perhaps, it is just those whose dosage has been low that escape asbestosis sufficiently long for the mesothelioma to appear.

Associated Bronchogenic Carcinoma

In May 1935 Lynch and Smith published the first report of lung carcinoma in "asbestosilicosis" (61). This was in a man who had worked for 21 years as an asbestos mill weaver. An extensive epidermoid carcinoma was found in the right lung, together with extensive fibrosis and asbestosis, but the authors did no more than draw attention to the coexistence of the two diseases. In October of the same year Gloyne published two cases that had occurred in Britain (36). Both had asbestosis, both had small carcinomas. The author refrained from "any attempt to make out a case for an actiological association of these two diseases."

In July 1936 Egbert and Geiger reported the case of a man who had worked for 18 years as a weaver in an asbestos factory, in whom there was a large tumor in the left lower lobe with extensive metastases (31). In December of that year Gloyne published the report of a third case in Britain (37).

In 1938 Nordmann published an account of two cases in Germany which, like those previously reported, exhibited a long period between initial exposure and the appearance of the tumor (69). Nordmann, too, declined to draw firm conclusions about etiological association.

These reports from three countries intimately concerned with development of the asbestos industry were to be supplemented and other cases added from France (29). By

1943 Homburger was able to list 19 cases by the addition of three of his own (43). He was still cautious, however, in saying merely that the association of the two conditions was remarkably high, but that there was no reliable answer to the question of whether asbestos was involved in the etiology.

Wedler, in 1943, found a prevalence of 16% of pulmonary carcinoma in 92 postmortem reports on asbestos workers described from various parts of the world (90). Merewether reviewed the accumulated data in his 1949 Report of the Chief Inspector of Factories (Britain) and found a prevalence of 13.2% in 235 necropsies on patients with asbestosis, compared with 1.32% in 6884 cases of silicosis (63). In 1949 Wyers reported a prevalence of 14.8% in 115 necropsies (95) and Gloyne in 1951, after reviewing 1247 lung specimens sent to him for examination for pneumoconiosis over the period 1929–1949, commented as follows: "whether [workers with a dust hazard] have a risk over and above [that of the general population] as a result of their occupation cannot yet be clearly shown, but the mortality of the asbestos workers is striking. In the present series 14% of the patients with asbestosis also had primary cancer of the lung. This is all the more striking because so many of them were females" (38).

Hueper, also writing in 1951, came to the following conclusion after reviewing the literature: "Although Warren rather recently maintained that the connection between asbestosis and lung cancer is of a coincidental nature, the actual existence of a causal relationship appears very likely" (46).

In 1955 Doll, reporting on all of the coroner's necropsies since 1935 on persons known to have been employed at a large asbestos works, concluded from the data that lung cancer was a specific industrial hazard of certain asbestos workers and that the average risk among men employed 20 or more years had been 10 times that experienced by the general population (30).

But opposition was not dead! Bohlig and Jacob in 1958, basing their position on cases from industries of Saxony and Thuringia, came to the conclusion that there did not seem to be an increased prevalence of pulmonary carcinoma in asbestos workers, although it did seem to be higher in women and did seem to affect the lower parts of the lung more than usual (18). Braun and Truan, writing in the same year, opposed any significant association as a result of surveying death certificates of a cohort of some 6000 Canadian miners who had a total exposure of 5 or more years (20).

The conflicts of evidence were to be resolved in the immediately succeeding years through better appreciation of epidemiological techniques and realization of the long time interval required from initial exposure before definite conclusions could be entertained about the prevalence of cancer. Intimations of cancer in other organs, notably the gastrointestinal tract, which had been sporadically included in the above reports, had to wait for still further clarification.

SITUATION IN THE 1960s

"What's past is prologue!" The decade of the 1960s provides a convenient time at which to terminate a historical review of asbestos disease. With admirable hindsight from the late 1970s we can see that the essential evidence had already been reported, but not yet assembled or vested with sufficient credibility to be entirely convincing. With few exceptions (30, 58, 81), the evidence at that time rested on scattered reports of small numbers of cases, and the cases themselves suffered from being either selected or simply

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those that happened to come to the attention of the reporter. The population base from which the cases came was seldom mentioned. The significance of pleural changes and the occurrence of mesothelioma in persons without a distinct history of exposure remained in considerable doubt. The idea that asbestos could be at least a cofactor in the production of bronchogenic carcinoma was far from fully accepted. That parenchymal asbestosis was very likely to occur in those who had been exposed to heavy dosage in the early years of the industry was clear enough, but what effect environmental controls that had been introduced in the 1930s might have upon its future prevalence was not known. The possibility that quite low dosages might have grave consequences 30 or more years after first exposure was still unproven.

Many things were needed to confirm the suggestions that were emerging from the studies up to that time. Most importantly, systematic epidemiological investigation was needed of large cohorts drawn from various types of industry, with the inclusion of adequate control populations. Some of these were already organized, but it was too early for the results to be meaningful. We now know that much of the negative evidence stemmed from coming to conclusions prematurely, before the slow processes of carcinogenesis had had a chance to make themselves evident. We now know also that reduction of heavy exposures that lead to early death would reveal such slowly developing diseases as mesothelioma and bronchogenic carcinoma with increasing clarity. But foreknowledge was not available at the time, although some investigators suspected that the auguries were not good. More sophisticated and sensitive ways of recognizing the disease processes at an early stage, before the appearance of marked radiographic changes, were badly needed. A series of international conferences, some already in the planning stages, were to accelerate these developments greatly. Those who felt that it was an exciting time were not to be disappointed. The excitement has not even yet been entirely dissipated.

The material presented here has been condensed from the opening chapter of a recent monograph, Asbestos and Disease, prepared by Irving J. Selikoff and Douglas H. K. Lee, and published by Academic Press.

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