

# Asbestos Exposure, Smoking, and Neoplasia

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Asbestos insulation workers, as a group, have a high risk of dying of bronchogenic carcinoma (about seven or eight times expected). We have observed 870 such workmen from Jan 1, 1963 to April 30, 1967. Our findings indicate that asbestos exposure alone is not the entire explanation. Of 87 nonsmokers, none died of bronchogenic carcinoma. Of 283 workmen with a history of regular cigarette smoking, 24 died of bronchogenic carcinoma, although only three were expected to die of this disease. Calculations suggest that asbestos workers who smoke have about 92 times the risk of dying of bronchogenic carcinoma as men who neither work with asbestos nor smoke cigarettes. We conclude that asbestos exposure should be minimized, that asbestos workers who do not smoke should never start, and that those now smoking should stop immediately.

In 1964, we reported on deaths occurring between Jan 1, 1943, and Dec 31, 1962, among 632 members of the International Association of Heat and Frost Insulators and Asbestos Workers.<sup>1</sup> All of these men had been occupationally exposed to asbestos dust for many years. Their death rate from lung cancer was found to be 6.8 times as high as that reported for the general white male population of the United States during the same years, with age taken into consideration. Three of the men died of diffuse pleural mesothelioma and one died of a neoplasm histologically suggestive of peritoneal mesothelioma. This was of interest since mesothelioma is a very rare disease in the general population but is reported to be associated with exposure to asbestos dust.<sup>2</sup> In addition, their death rate from cancer of the stomach, colon, and rectum was higher than expected; but this may have been

due to chance, the number of such deaths being small. During the latter part of the study, we obtained information on the smoking habits of most of the survivors, but we could not obtain reliable information on the smoking habits of those who had died at an earlier date. Therefore, we could not at that time investigate death rates in relation to smoking habits and exposure to asbestos dust which were considered both separately and jointly.

There is abundant evidence that cigarette smoking leads to a high rate of death from lung cancer in the absence of occupational exposure to asbestos dust.<sup>3</sup> Our findings outlined above suggested (but did not prove) that exposure to asbestos dust may lead to a high rate of death from lung cancer in the absence of cigarette smoking. If the latter be so, then the combined effect of both types of exposure might or might not be equal to or greater than the sum of the two effects. On the other hand, it was possible that exposure to asbestos dust increases the risk of lung cancer among cigarette smokers but does not lead to lung cancer among nonsmokers.

The present study was undertaken primarily to investigate these possibilities. In addition, we wished to obtain more information on the occurrence of mesothelioma and gastrointestinal cancer among asbestos workers.

## Material

From records of New York Local 12 and Newark, N.J. Local 32 of the International Association of Heat and Frost Insulators and Asbestos Workers, a list was made of every man who was a member of either one of these locals on Dec 31, 1942, or who joined between that date and Dec 31, 1962. No one was omitted regardless of his subsequent work history.

Personnel data from union records indicated that of the 632 on the union rolls on Jan 1, 1943, 37 of the men had first been occupationally exposed to asbestos dust prior to 1923, and an additional

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Table 1.—Subjects Classified by Age as of Jan 1, 1963, and by Years From First Occupational Exposure to Asbestos Dust up to Jan 1, 1963

| Age, yr | Total No. of Subjects | No. of Years Since First Exposure to Asbestos |       |      |     |       |       |     | No. of Deaths |
|---------|-----------------------|-----------------------------------------------|-------|------|-----|-------|-------|-----|---------------|
|         |                       | 25-34                                         | 15-24 | 5-14 | 0-4 | 45-54 | 35-44 | 25+ |               |
| 35-39   | 2                     | 2                                             | ...   | ...  | ... | ...   | ...   | ... | ...           |
| 40-44   | 13                    | 12                                            | 2     | ...  | ... | ...   | ...   | ... | ...           |
| 45-49   | 32                    | 17                                            | 2     | 13   | ... | ...   | ...   | ... | 2             |
| 50-54   | 100                   | ...                                           | 1     | 80   | 20  | ...   | ...   | ... | 18            |
| 55-59   | 60                    | ...                                           | 1     | 18   | 34  | 8     | 1     | ... | 11            |
| 60-64   | 42                    | ...                                           | 1     | 3    | 11  | 19    | 9     | ... | 16            |
| 65-69   | 40                    | ...                                           | ...   | 1    | 10  | 10    | 10    | 2   | 17            |
| 70-74   | 20                    | ...                                           | ...   | ...  | 3   | 12    | 6     | 17  | 10            |
| 75-79   | 21                    | ...                                           | ...   | ...  | ... | 1     | 5     | 15  | 6             |
| 80-84   | 4                     | ...                                           | ...   | ...  | ... | 1     | 1     | 2   | 3             |
| Total   | 370                   | 34                                            | 6     | 123  | 68  | 70    | 30    | 26  | 90            |

Table 2.—Subjects Classified by Age and by Smoking Habits on or about Jan 1, 1963

| Age, yr | Total No. | Never Smoked Regularly | Pipe, Cigar Only | Ex-cigarette Smokers* | Current Cigarette Smokers* |             |             |           |
|---------|-----------|------------------------|------------------|-----------------------|----------------------------|-------------|-------------|-----------|
|         |           |                        |                  |                       | 1-9 a Day                  | 10-19 a Day | 20-39 a Day | 40+ a Day |
| 35-39   | 2         | 1                      | ...              | 1                     | ...                        | ...         | ...         | ...       |
| 40-44   | 13        | 3                      | ...              | 2                     | ...                        | ...         | 5           | 4         |
| 45-49   | 32        | 2                      | 1                | 9                     | ...                        | ...         | 12          | 12        |
| 50-54   | 100       | 12                     | 6                | 28                    | 3                          | 5           | 33          | 24        |
| 55-59   | 60        | 6                      | 5                | 16                    | ...                        | 3           | 20          | 10        |
| 60-64   | 42        | 7                      | 4                | 15                    | 1                          | ...         | 11          | 4         |
| 65-69   | 40        | 6                      | 0                | 17                    | ...                        | 4           | 9           | 5         |
| 70-74   | 20        | 7                      | 7                | 12                    | 1                          | 4           | 4           | 3         |
| 75-79   | 21        | 3                      | 7                | 6                     | ...                        | 1           | 3           | 1         |
| 80-84   | 4         | 2                      | 1                | 1                     | ...                        | ...         | ...         | ...       |
| Total   | 370       | 48                     | 28               | 126                   | 5                          | 17          | 97          | 69        |

\*Includes cigarette smokers who also smoked pipes or cigars.

... between the beginning of 1953 and the end of 1962. All of these men were successfully traced through Dec 31, 1962, and 362 of them were found to have died by that time. Of the 94 deaths, seven occurred prior to the 20th anniversary of the men's exposure to asbestos dust and 255 occurred after the 20th anniversary. Thus, of the 632 men, 370 were still living on Jan 1, 1963.

These 370 men were the subjects of the present investigation. Table 1 shows their age distribution as of Jan 1, 1963, and the elapsed time from exposure up to that date. All of them have been traced, and 94 of them were found to have died during the four-year

four-month interval from Jan 1, 1963, to April 30, 1967.

Beginning in October 1962, we made arrangements to examine these men periodically, once every six to twelve months; the interval depended on age and physical condition. The examinations included chest x-ray films as well as physical examination and cover past and present smoking habits, occupational history, medical history, and present physical complaints. Altogether, we have examined 338 (91.4%) of the men at least once and have repeatedly examined most of those who were still living.

Information on smoking habits was obtained by personal interview with the 338 men who were examined. Of the 32 men who were not examined, 28 gave us their smoking habits by telephone and 4 gave us the information by mail. The local secretaries (who personally know these men) ascertained the smoking habits of 18 men, family members supplied the information on 3 missing men. This accounts for all of the 370 men. Table 2 shows their smoking habits as of Jan 1, 1963, the men being classified by their ages on that date, even though some changed their smoking habits between 1963 and

1967. Of the 370 men, 45 never smoked regularly, 39 had smoked pipes or cigars but never cigarettes regularly, and 283 had smoked cigarettes regularly. Some of those with history of cigarette smoking also smoked pipes or cigars. Of

101 were ex-cigarette smokers, five currently smoked one to nine cigarettes a day, 17 smoked 10 to 19 cigarettes a day, 97 smoked 20 to 39 cigarettes a day, and 63 smoked 40 or more cigarettes a day. The smoking habits of the 370 subjects were compared with the smoking habits of a large number of men selected from the general population.\* These were proportionally more cigarette smokers among the 370 subjects than were found in the general population sample; age was taken into consideration.

**Cases of Death.**—A copy of the death certificate was obtained for each of the 94 deaths. In addition, we examined hospital records, postmortem findings (41 cases), as well as the surgical and pathologic reports when surgery was performed (39 cases). We also reexamined histologic specimens. It was found that the death certificate was inaccurate in 14 instances. However, this did not alter the picture as much as might have been expected since there were several compensating errors. For example, in one instance the death certificate indicated bronchogenic carcinoma as the cause of death while a review of the histologic specimen showed that death was due to pleural mesothelioma; but in another instance exactly the reverse was found. Likewise, review in one instance resulted in changing the reported cause of death from bronchogenic carcinoma to cancer of the stomach with metastasis to the lungs while review in another instance resulted in exactly the opposite change. The 94 deaths were ascribed to the following causes: bronchogenic carcinoma, 34; pleural

Table 3.—Observed and Expected Number of Deaths Among 370 Asbestos Workers During the 52-Month Period

| Cause of Death                                 | Observed Deaths | Expected Deaths* |
|------------------------------------------------|-----------------|------------------|
| Total, cancer (all sites)                      | 49              | 8.6              |
| Cancer of lung, pleura, bronchus, and trachea  | 27              | 2.3              |
| Gastrointestinal carcinoma                     | 24              | 1                |
| Pleural mesothelioma                           | 3               | 1                |
| Peritoneal mesothelioma                        | 7               | 1                |
| Cancer of stomach                              | 3               | 0.6              |
| Cancer of colon and rectum                     | 8               | 1.2              |
| Cancer of all other sites combined             | 7               | 4.5              |
| Asbestosis                                     | 16              | ...              |
| Heart and circulatory disease including stroke | 22              | 28.5             |
| All other causes of death                      | 8               | 10.4             |
| Total, all causes                              | 94              | 47.5             |

\*Based upon US mortality data disregarding smoking habit.  
 †United States data not available, but figure should be only slightly less than 2.3.  
 ‡United States data not available, but these are rare causes of death in general population.

mesothelioma, three; peritoneal mesothelioma, seven; cancer of the colon, four; cancer of the rectum, one; cancer of the stomach, three; cancer of the pancreas, two; cancer of buccal cavity and pharynx, two; cancer of bladder, one; cancer of undetermined primary site, two; asbestosis, 16; cor pulmonale, one; coronary heart disease, 17; congestive heart failure, one; cerebral vascular lesion, two; aortic aneurysm, one; cirrhosis of the liver, three; bronchopneumonia, one; encephalopathy, one; acute pancreatitis, one; Wegener's granulomatosis, one; and accidental fall, one.

**Expected Deaths.**—For purposes of comparison, we wished to ascertain how many of the 370 subjects would have died during the 52-month period (Jan 1, 1963, to April 30, 1967) if their age-specific death rates had been exactly the same as for the general white male population of the United States. For this purpose, we made use of the United States 1964 life table for white males; this provided the most stable basis for comparison. It should be noted that for white males total death rates and death rates from respiratory cancer were slightly higher in the industrial states of New York and New Jersey than in the United States as a whole.<sup>1</sup>

On the other hand, respiratory cancer death rates in white men aged 20 to 64 are reported to be a trifle lower than average among laborers, not elsewhere classified employed in construction work.<sup>2</sup>

From the life table we determined for each of the 370 men the probability of his dying within a period of 52 months, considering his age on Jan 1, 1963, and assuming that the life table probability applied to him. Summing these probabilities for the 370 men yielded an estimate of the "expected" number of deaths under the null hypothesis that the age-specific death rates of these asbestos workers are the same as for United States white males in general. The computation indicated that 47.5 deaths would have been expected.

Next, we wished to estimate the expected number of deaths from each of several causes. For this, we made use of the percentage distribution of deaths by cause of death among United States

white males of various ages during the year 1964 as reported by the National Center for Health Statistics. These percentages were then standardized for age according to the age distribution at time of the 47.5 expected deaths. The results are shown in Table 3.

**Expected vs Observed Deaths.**—As shown in Table 3, there were 94 observed deaths (ie, 94 of the 370 asbestos workers died) as compared with 47.5 deaths expected on the basis of the age-specific death rates of all white males in the United States in 1964. Thus, there were 94 minus 47.5 = 46.5 excess deaths. The excess deaths were due to bronchogenic carcinoma, mesothelioma of the pleura and peritoneum, asbestosis, and cancer of the stomach, colon, and rectum.

**Cancer of Lung, Pleura, and Trachea.**—In published mortality data for the United States showing deaths each year from various causes by age, sex, and race, the following diseases are combined: cancer of the lung (including sarcoma of the lung), cancer of the bronchus, cancer of the pleura, and cancer of the trachea. For this group of diseases, there were 27 observed deaths and only 2.3 expected deaths, a ratio of nearly 12 to 1.

It is well known that, for the United States as a whole, all except a very few of the deaths reported in the combined category are due to bronchogenic carcinoma. Thus, it may be assumed that there were close to 2.3 expected deaths from this cause as compared with 24 observed deaths, a ratio of over 10 to 1.

**Mesothelioma.**—Ten of the 94 observed deaths were due to mesothelioma, three were due to pleural mesothelioma, and seven were due to peritoneal mesothelioma. This is such a rare disease that if the 370 subjects had been selected as a random sample from the general population, one would not have expected any of them to die of mesothelioma within a period of 52 months.

All three of the men who died of pleural mesothelioma had a history of regular cigarette smoking. Of the seven who died of peritoneal mesothelioma, one never smoked regularly, one smoked only pipes and cigars, and five had a history of regular cigarette smoking.

**Cancer of Stomach, Colon, and Rectum.**—In our earlier study of asbestos workers, there were more deaths than expected from cancer of the stomach, colon, and rectum (9.4 expected, 29 observed). As compared with a total of 1.8 expected deaths from these causes, there were eight observed deaths in this study, due to cancer of the following sites: stomach, three; colon, four; and rectum, one. Although this bears out our earlier findings, the number of deaths from these causes was so small that we still refrain from drawing any conclusions at this time.

**Asbestosis.**—Asbestosis accounted for 16 of the 94 deaths. While it is not surprising that deaths from this disease occur among men exposed to asbestos dust, attention must be called to the fact

men had first been examined between the beginning of 1923 and the end of 1942. All of these men were successfully traced through Dec 31, 1962; and 262 of them were found to have died up to that time. Of the 332 deaths, seven occurred prior to the 20th anniversary of the man's first exposure to asbestos dust and 255 occurred after the 20th anniversary. Thus, of the 632 men, 370 were still living on Jan 1, 1963.

These 370 men were the subjects of the present investigation. Table 1 shows their age distribution as of Jan 1, 1963, and the elapsed time from first exposure up to that date. All of them have been traced, and 94 of them were found to have died during the four-year and four-month interval from Jan 1, 1963, to April 30, 1967.

Beginning in October 1962, we made arrangements to examine these men periodically, once every six to twelve months; the interval depended upon age and physical condition. The examinations included chest x-ray films as well as physical examination and cover past and present smoking habits, occupational history, medical history, and present physical complaints. Altogether, we have examined 91.4% of the men at least once and have repeatedly examined most of those who are still living.

Information on smoking habits was obtained by personal interview with the 336 men who were examined. Of the 32 men who were not examined, 16 told us their smoking habits by telephone and 16 gave us the information by mail. The local union secretaries (who personally knew these men well) ascertained the smoking habits of 18 men. Family members supplied the information on the remaining three men. This accounts for all of the 370 men. Table 2 shows their smoking habits on or about Jan 1, 1963, the men being classified by their ages on that date, even though some changed their smoking habits between 1963 and 1967.

Of the 370 men, 48 never smoked regularly, 39 had or had smoked pipes or cigars but never smoked cigarettes regularly, and 283 had smoked cigarettes regularly. Some of those with history of regular smoking also smoked pipes or cigars. Of these, 283 had a history of regular cigarette smoking,

Table 1.—Subjects Classified by Age as of Jan 1, 1963, and by Years From First Occupational Exposure to Asbestos Dust up to Jan 1, 1963

| Age, Yr | Total No. of Subjects | No. of Years Since First Exposure to Asbestos |       |       |       |       |       |     | Deaths, 52 Mo |
|---------|-----------------------|-----------------------------------------------|-------|-------|-------|-------|-------|-----|---------------|
|         |                       | 20-24                                         | 25-29 | 30-34 | 35-39 | 40-44 | 45-49 | 50+ |               |
| 35-39   | 2                     | 2                                             | ...   | ...   | ...   | ...   | ...   | ... | ...           |
| 40-44   | 13                    | 12                                            | 1     | ...   | ...   | ...   | ...   | ... | 1             |
| 45-49   | 20                    | 17                                            | 2     | 15    | ...   | ...   | ...   | ... | 2             |
| 50-54   | 100                   | ...                                           | 1     | 90    | 29    | ...   | ...   | ... | 10            |
| 55-59   | 60                    | ...                                           | 1     | 16    | 34    | 8     | 1     | ... | 11            |
| 60-64   | 42                    | ...                                           | 1     | 3     | 11    | 19    | 8     | ... | 18            |
| 65-69   | 40                    | ...                                           | ...   | 1     | 10    | 18    | 10    | 2   | 17            |
| 70-74   | 30                    | ...                                           | ...   | ...   | 3     | 12    | 6     | 17  | 28            |
| 75-79   | 21                    | ...                                           | ...   | ...   | ...   | 1     | 5     | 15  | 8             |
| 80-84   | 4                     | ...                                           | ...   | ...   | ...   | 1     | 1     | 2   | 5             |
| Total   | 370                   | 33                                            | 6     | 113   | 86    | 59    | 39    | 36  | 94            |

Table 2.—Subjects Classified by Age and by Smoking Habits on or about Jan 1, 1963

| Age, Yr | Total No. | Never Smoked Regularly | Pipe, Cigar Only | Ex-Cigarette Smokers* | Current Cigarette Smokers* |             |             |           |
|---------|-----------|------------------------|------------------|-----------------------|----------------------------|-------------|-------------|-----------|
|         |           |                        |                  |                       | 1-9 a Day                  | 10-19 a Day | 20-39 a Day | 40+ a Day |
| 35-39   | 2         | 1                      | ...              | 1                     | ...                        | ...         | ...         | ...       |
| 40-44   | 13        | 2                      | ...              | 2                     | ...                        | ...         | ...         | ...       |
| 45-49   | 22        | 2                      | 1                | 8                     | ...                        | ...         | 17          | 12        |
| 50-54   | 100       | 12                     | 6                | 26                    | 3                          | 5           | 33          | 24        |
| 55-59   | 60        | 6                      | 5                | 16                    | ...                        | 3           | 20          | 10        |
| 60-64   | 42        | 7                      | 4                | 15                    | 1                          | ...         | 11          | 4         |
| 65-69   | 40        | 6                      | 8                | 17                    | ...                        | 4           | 9           | 5         |
| 70-74   | 30        | 7                      | 7                | 12                    | 1                          | 4           | 4           | 3         |
| 75-79   | 21        | 3                      | 7                | 6                     | ...                        | 1           | 3           | 1         |
| 80-84   | 4         | 2                      | 1                | 1                     | ...                        | ...         | ...         | ...       |
| Total   | 370       | 48                     | 30               | 106                   | 8                          | 17          | 97          | 63        |

\*Includes cigarette smokers who also smoked pipe or cigars.

101 were ex-cigarette smokers, five currently smoked one to nine cigarettes a day, 17 smoked 10 to 19 cigarettes a day, 97 smoked 20 to 39 cigarettes a day, and 63 smoked 40 or more cigarettes a day.

The smoking habits of the 370 subjects were compared with the smoking habits of a large number of men selected from the general population. There were proportionally more cigarette smokers among the 370 subjects than were found in the general population sample; age was taken into consideration.

**Cases of Death.**—A copy of the death certificate was obtained for each of the 94 deaths. In addition, we examined hospital records, postmortem findings (41 cases), as well as the surgical and pathologic reports when surgery was performed (39 cases). We also reexamined histologic specimens. It was found that the death certificate was inaccurate in 14 instances. However, this did not alter the picture as much as might have been expected since there were several compensating errors. For example, in one instance the death certificate indicated bronchogenic carcinoma as the cause of death while a review of the histologic specimen showed that death was due to pleural mesothelioma; but in another instance exactly the reverse was found. Likewise, review in one instance resulted in changing the reported cause of death from bronchogenic carcinoma to cancer of the stomach with metastasis to the lung while review in another instance resulted in exactly the opposite change. The 94 deaths were classified by the following causes: bronchogenic carcinoma, 54; pleural

Table 4.—Estimated Number of Lung Cancer Deaths Expected to Occur During a Period of 52 Months per 10,000 Men Living at the Start of Period; by Age and by Smoking Habits\*

| Age, Yr<br>(Jan 1, 1960) | Never<br>Smoked<br>Regularly | Past<br>Cigarette<br>Only | Ex-cigarette<br>Smokers | Current Cigarette Smokers |                |                |              |
|--------------------------|------------------------------|---------------------------|-------------------------|---------------------------|----------------|----------------|--------------|
|                          |                              |                           |                         | 1-9<br>a Day              | 10-29<br>a Day | 30-39<br>a Day | 40+<br>a Day |
| 35-39                    | 0                            | ...                       | 0                       | ...                       | ...            | ...            | ...          |
| 40-44                    | 2                            | ...                       | 71                      | ...                       | ...            | 15             | 15           |
| 45-49                    | 2                            | 2                         | 10                      | ...                       | ...            | 30             | 40           |
| 50-54                    | 7                            | 12                        | 22                      | 25                        | 44             | 60             | 70           |
| 55-59                    | 6                            | 15                        | 55                      | ...                       | 91             | 117            | 150          |
| 60-64                    | 15                           | 24                        | 71                      | 80                        | ...            | 190            | 250          |
| 65-69                    | 14                           | 22                        | 97                      | ...                       | 157            | 205            | 300          |
| 70-74                    | 12                           | 55                        | 100                     | 100                       | 225            | 280            | 400          |
| 75-79                    | 20                           | 53                        | 100                     | ...                       | 185            | 241            | 320          |
| 80-84                    | 25                           | 32                        | 140                     | ...                       | ...            | ...            | ...          |

\*Based upon data from a prospective study with adjustment for US mortality experience.  
 (22) ... the rates derived for categories with no subjects in this study. See Table 2.  
 (23) ... who also smoked pipe or cigar. Men with a history of only cigarette smoking have higher lung cancer rates than shown here.  
 (24) ... obtained by smoothing the data.

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**Bronchogenic Carci-**  
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 white males. However, as previously mentioned,  
 evidence at hand suggests that there were propor-  
 tionally somewhat more cigarette smokers among  
 the 370 subjects than among white males in the  
 United States as a whole, age being taken into  
 consideration. This might have partially accounted  
 for the high bronchogenic carcinoma death rate of  
 the subjects. For this and other reasons we made  
 estimates of the expected number of bronchogenic  
 carcinoma deaths, the smoking habits of the men  
 being taken into consideration. This was done as  
 follows:

Data are available on lung cancer deaths in re-  
 sponse to the smoking habits of 440,000 men en-  
 rolled by American Cancer Society volunteers in  
 a prospective epidemiological study between Oc-  
 tober 1959 and March 1960 and traced through  
 Sept 30, 1964. Causes of death were ascertained from  
 death certificates, but whenever cancer was men-  
 tioned on a death certificate inquiry was made of  
 the physician who signed the certificate. In case  
 of disagreement between the two sources of infor-  
 mation, the physician's statement was accepted.  
 For the purpose at hand, we only made use of data  
 covering the 52-month period beginning on June 1,  
 1960, and ending on Sept 30, 1964. The number of  
 lung cancer deaths occurring during the 52-month  
 period was divided by the number of men alive at  
 the beginning of the period. This was done by five-  
 year age groups for men in each of the following  
 smoking categories: (1) never smoked regularly  
 (nonsmokers and occasional smokers being com-  
 bined); (2) history of regular pipe or cigar smok-  
 ing, past or present, but never smoked cigarettes  
 regularly; (3) ex-cigarette smokers (including those  
 who had smoked or currently smoked pipes or  
 cigars); and (4) current regular cigarette smokers  
 (including those who also had smoked or currently  
 smoked pipes or cigars). The last of these cate-  
 gories was further divided by current number of  
 cigarettes smoked per day: (4a) one to nine ciga-  
 rettes a day; (4b) 10 to 19 cigarettes a day; (4c)  
 20 to 29 cigarettes a day; and (4d) 30 or more  
 cigarettes a day. Since the rates shown in Table 4  
 are per 10,000 men, the number of men in each

divided into many five-year age groups, some of the  
 subgroups contained only a small number of men.  
 In consequence, the lung cancer death rate was  
 statistically unstable in some of the very small sub-  
 groups. In three instances where the observed rate  
 in a small subgroup appeared to be badly out of  
 line, we arbitrarily made an adjustment to bring it  
 more into line with adjacent figures in the table.  
 These adjusted figures which are indicated with  
 symbols in Table 4 carry very little weight in the  
 final calculation. All of the rates were then ad-  
 justed as follows:

Lung cancer death rates in the United States  
 have risen steadily year by year and were higher  
 in 1964 than during the period 1960 to 1964 as a  
 whole. Furthermore, in the study described above,  
 we avoided enrolling seriously ill people and, as of  
 the cut-off date for preparing the computer tape,  
 we had not yet received death certificates for all  
 of the men now known to have died during the  
 specified period of time. For these reasons, lung  
 cancer death rates in the study population were  
 appreciably lower than those reported for white  
 males in the United States in 1964. To compensate  
 for this, we raised the rate of each individual smok-  
 ing category so that the total lung cancer death  
 rate (disregarding smoking habits) in each five-  
 year age group would be the same as that of all  
 United States white males (based upon the 1964  
 life table and the 1964 distribution of deaths by  
 causes of death). The results of these computations  
 are shown in Table 4. (It should be noted that  
 Table 4 shows only such rates as were required for  
 further calculations.)

The rates shown in Table 4 were then applied to  
 the number of asbestos workers shown in each of  
 the corresponding internal cells of Table 2. This  
 yielded an estimate of the number of lung cancer  
 deaths expected to occur during a 52-month period  
 among the 370 asbestos workers classified by their  
 smoking habits. By "expected" number, we here  
 mean an estimate of the number of lung cancer  
 deaths which would have occurred under the null  
 hypothesis that asbestos exposure has no effect on  
 lung cancer rates. The expected number of lung  
 cancer deaths is shown in Table 2.

Table 5.—Observed and Expected Bronchogenic Carcinoma Deaths by Smoking Habits\* for 370 Asbestos Workers

| Smoking Habits                        | Observed Deaths | Expected Deaths |
|---------------------------------------|-----------------|-----------------|
| Never smoked regularly                | 0               | 0.05            |
| History of pipe, cigar smoking only   | 0               | 0.13            |
| History of regular cigarette smoking† | 24              | 2.98            |
| Total                                 | 24              | 3.16            |

\*Based upon data in Table 2 and Table 4.

†Includes cigarette smokers who also smoked pipe or cigar.

Table 6.—Expected and Observed Deaths Among 632 Asbestos Workers Exposed to Asbestos Dust 20 years or Longer

|                                  | 1943-1962 | 1963-1967 | Total<br>1943-1967 |
|----------------------------------|-----------|-----------|--------------------|
| Total deaths: all causes         |           |           |                    |
| Expected                         | 203.5     | 47.8      | 251                |
| Observed                         | 255       | 94        | 349                |
| Total cancer: all sites          |           |           |                    |
| Expected                         | 38.5      | 8.6       | 47.1               |
| Observed                         | 95        | 49        | 144                |
| Cancer of lung, trachea, pleura  |           |           |                    |
| Expected                         | 5.6       | 2.3       | 7.9                |
| Observed                         | 45        | 27        | 72                 |
| Cancer of stomach, colon, rectum |           |           |                    |
| Expected                         | 9.4       | 1.0       | 10.4               |
| Observed                         | 29        | 8         | 37                 |
| Cancer all other sites combined  |           |           |                    |
| Expected                         | 23.5      | 5.3       | 28.8               |
| Observed                         | 21        | 14        | 35                 |
| Asbestosis                       |           |           |                    |
| Expected                         | 0         | 0         | 0                  |
| Observed                         | 12        | 15        | 27                 |
| All other causes                 |           |           |                    |
| Expected                         | 167       | 38.9      | 205.9              |
| Observed                         | 149       | 30        | 179                |

into consideration. The results are summarized in Table 5 which shows the expected and observed number of lung cancer deaths in each of three smoking categories.

Taking smoking habits as well as age into consideration (Table 5) a total of 3.2 bronchogenic carcinoma deaths were expected whereas taking only age into consideration 2.3 deaths were expected from this cause (Table 3). Thus, perhaps one of the excess bronchogenic carcinoma deaths might be attributed to the fact that there appear

to be a proportionally somewhat more cigarette smokers among the 370 subjects than among men of the same ages in the general population.

The following statements are based upon the data shown in Table 5. Twenty-four deaths from bronchogenic carcinoma occurred among the 370 subjects compared with only 3.16 expected, a ratio of about 7.6 to 1. This is slightly higher than found in our earlier study which indicated a ratio of 6.8 to 1 (not taking smoking habits into consideration). It should be noted in this connection that the 370 subjects in this study had been exposed to asbestos dust somewhat longer than the subjects of our previous study (the present 370 subjects are survivors as of Jan. 1, 1963, of subjects in the previous study).

Of the subjects who never smoked regularly and those who smoked only pipes or cigars, none died of bronchogenic carcinoma whereas 0.18 of these men were expected to die of lung cancer. This suggests that exposure to asbestos dust does not increase the risk of bronchogenic carcinoma among

men who never smoked cigarettes regularly. However, considering the small number of such subjects in this study, we only conclude that exposure to asbestos dust does not greatly increase the risk of bronchogenic carcinoma among men who have smoked cigarettes regularly.

Twenty-four of the men with a history of regular cigarette smoking died of bronchogenic carcinoma whereas only 2.98 were expected to die of it, a ratio of 8.05 to 1. From this it appears that exposure to asbestos dust greatly increases the risk of lung cancer among cigarette smokers.

Now we may ask how greatly is the risk of bronchogenic carcinoma increased by the combined effects of cigarette smoking and exposure to asbestos dust. To answer this question, we applied rates shown in Table 4 for nonasbestos workers who never smoked regularly to the number of subjects with a history of regular cigarette smoking as shown in Table 2. This indicated that only 0.26 of the subjects with a history of regular cigarette smoking would have been expected to die of bronchogenic carcinoma if they had never smoked regularly and had never been occupationally exposed to asbestos dust. Since 24 of them actually died of this cause, the ratio of observed to expected deaths is 92 to 1 (ie, 24 divided by 0.26=92). This appears to indicate that cigarette smoking plus occupational exposure to asbestos dust increases the risk of bronchogenic carcinoma by a factor in the order of magnitude of 92 to 1. It should be noted that this estimate does not take current amount of cigarette smoking into consideration.

**Comparison With Earlier Findings.**—As explained we started with a cohort of 632 asbestos insulation workers, the entire membership of the union local on Jan. 1, 1943. We have now traced each man through April 30, 1967. Table 6 shows the observed and expected number of deaths for each of two periods (the first, 1943 to 1962, being previously reported) and for the entire period. In respect to respiratory cancer (lung, trachea, and pleura) and in respect to cancer of the stomach, colon, and rectum, the findings in the two periods are in close agreement.

#### Comment

The increased risk of neoplasia (mainly bronchogenic carcinoma and mesothelioma) among insulation workers reported here should be evaluated in the knowledge that these men have comparatively light exposure as asbestos workers. Primarily employed in construction work, many of the materials they use contain little or no asbestos and others have only 5% to 15%. Conditions of work vary; these men often work outdoors unlike asbestos operators in factory work. Comparatively few dust exposure surveys have been made in this trade but their results have generally been within the 0.1 to 1.0 mg/m<sup>3</sup> range for asbestos dust. This study is jointly supported by the Asbestos Control and Environmental Industries Association and the

may not be easy to unravel the interrelationship which might exist between community air pollution and cigarette smoking. Both the exposure and cigarette smoking have a known causal relationship with cancer and heart disease, yet for cancer, especially lung cancer, they are not known to be independent risk factors.

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13. *Shimada, H.C., and Soren, M.L.*: Cigarette Smoking and Lung Cancer. *Am J Public Health* 48:1-10 (Jan) 1958.

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Many, possibly most, of the words in the dictionary stand there as representatives of a whole family of forms. Not even the thinking of the linguistically timid will run to the dictionary for encouragement when, for instance, they want to refer to a spell of "hiccuping," provided they are certain that Webster does know "to hiccup."

All the tense forms, the participles, the gerunds are assumed to be authorized by implication the moment the infinitive is known to exist. The plurals of nouns are similarly taken for granted, and the forms of comparison and the adverbial forms of adjectives.

This phenomenon is generally covered by the assertion that a dictionary is not a grammar and that each individual entry in a dictionary stands simultaneously for all its grammatically possible forms. (For details, consult your grammar.)

But is a gerund a grammatical form? Or is it a suffix-derived noun?

I am not really looking for an answer. I ask these questions to suggest that the dividing line between grammatical form and derived neologism is both hard to define and artificial. If I distinguish—among men—the "hunting" from the "hunted," I have done no more than form (grammatically) two nouns from two adjectives which are forms (grammatically) implied in the existence of "to hunt." But if "hunting" is implied, why not "hunter"? Why not "hunter" and "hunterable" and "hunterability"?

The question of when a new word is a new word and when it is merely an "implied" form of a conventional term is indeed more complex than is generally apparent. Take "dehairability" as an example. Can I claim the word is implied in the existence of "hair," or must I assume the responsibility for having spawned a monster?

Or take "unequivocably," which indeed was the starting point of all this reasoning and wondering, for it was spotted as a bold neologism in *JAMA* in the sentence, "Research at the Public Health Service Hospital at Lexington, Ky, has unequivocally proven that methadone has all of the euphoric properties of morphine."

Now, clearly, the adverb "unequivocably" is grammatically implied in the adjective "unequivocal," and this in turn is implied—grammatically or semi-grammatically or otherwise—in "equivocal." If we grant further that formality in "-able" or "-ible" are likewise legitimate without special dispensation, we shall conclude that "unequivocably" is in no sense a bold departure since "to equivocate" is a firmly established, standard English word.

But there is a hitch and a flaw in the argument. "To equivocate" means, "to use ambiguous language" and (by extension) "to render ambiguous." But "equivocal" can only suggest the trait of "being apt or able to be made ambiguous," and that, I fear, was not intended. Which means, by (unintentional) implication, that the discrepancy between the obviously intended meaning of "unequivocably" and its structurally suggested significance was felt even by the neologism's creator.

Which is of course possible, and even likely, but "unequivocably" is not a new word.