pharynx, gastrointestinal tract, kidney, and ovary and respiratory diseases such as pneumonia. Major health effects are discussed below.

Lung cancer is currently responsible for the largest number of deaths from exposure to asbestos. It has been associated with exposure to all the principal commercial asbestos fiber types. Excess lung cancer has been documented in groups involved with the mining and milling of asbestos and the manufacture and use of asbestos products. Studies in which the extent of exposure can be approximated provide evidence that lung cancer increase linearly with both level and duration of exposure. Cigarette smoking and asbestos have a strong synergistic interaction in development of lung cancer. Asbestos exposure appears to multiply the underlying risk of lung cancer. Consequently, when exposed to asbestos, the risk of lung cancer for smokers [for whom the risk of lung cancer is already high] is much higher than that for nonsmokers exposed to asbestos. Most persons who develop lung cancer die within 2 year.

Many human studies have also shown that exposures to asbestos produce mesotheliomas, which are cancers that occur as thick diffuse masses in the serous membranes (mesothelia) that line body cavities. Mesotheliomas occur in the pleura (the membrane that surrounds the lungs and lines the lung cavity) and the peritoneum (which surrounds the abdominal organs and lines the abdominal cavity). Most persons who develop mesothelioma die within the first 2 years after diagnosis, often after having been in constant pain. Epidemiology studies suggest that the incidence of mesotheliomas is related to dose and time from first exposure. Association of mesothelioma with smoking is weak or nonexistent. Asbestos fibers appear, by far, to be the most common cause of mesotheliomas.

Asbestosis, which involves fibrosis of lung and pleural tissues, is another serious chronic disease associated with exposure to asbestos. There is no effective treatment for asbestosis and it is often disabling or fatal. Asbestosis is diagnosed from findings which may include radiographic changes, breathlessness, and abnormal lung function. Since some clinical symptoms of asbestosis are similar to those of other fibrosing lung diseases, a history of occupational exposure to asbestos is often a key feature of its diagnosis. Asbestosis can appear and progress decades after exposure to asbestos fibers. Under working conditions where average fiber concentrations in the air were high (more than 10 fibers per cubic centimeter [f/cc]) asbestosis has accounted for more than 7 percent of observed deaths (Ref. 11). It is apparently less common than lung cancer or mesothelioma at exposures lower than the current Occupational Safety and Health Administration (OSHA) workplace standard of 2.0 f/cc. Some recent data on the incidence of asbestosis appear compatible with a linear exposure-response relationship with no threshold (Ref. 12). However, it is still considered uncertain whether asbestosis occurs as a result of nonoccupational exposures.

In occupational studies where the primary route of exposure is through inhalation, lung cancer and mesotheliomas usually account for about 90 percent of the excess cancers seen among workers exposed to asbestos. However, as noted in the CHAP report (Ref. 1), a number of other cancers, principally of the gastrointestinal tract, have been associated with asbestos exposure. These are cancers of the larynx, pharynx, oral cavity, esophagus, stomach, colon, and rectum. Statistically significant excesses of cancers of the kidney and ovary have also been shown. In addition, the excess of cancers at all other sites combined is statistically significant in some studies.

The conclusions from epidemiology studies concerning the health effects of asbestos are also supported by results of laboratory studies. Animals treated with asbestos have shown increased incidence of fibrosis, lung cancer, and mesotheliomas. All commercial forms and several other types of asbestos are implicated from a variety of modes of exposure.

Most occupational studies have been conducted on populations exposed to high airborne concentrations of asbestos for relatively long periods of time. However, short-term occupational exposures have also been shown to increase the risk of lung cancer and mesothelioma. One group of asbestos factory workers with less than 2 months of occupational exposure had a twofold increase in lung cancer risk (Ref. 9). In addition, there are many documented cases of mesothelioma linked to extremely brief exposure to high concentrations of asbestos or long-term exposure to low concentrations (Ref. 4).

Direct evidence of adverse health effects from non-occupational asbestos exposure also exists. Persons who lived in the households of asbestos workers have developed pleural mesothelioma and asbestos-related radiographic changes. In an ongoing study, 4 cases of mesothelioma have been diagnosed among 828 family contacts of amosite workers (Ref. 10). These figures are much higher than that expected to be found among the general population. In addition, 35.9 percent of the contacts showed chest x-ray abnormalities as compared with 4.6 percent of control subjects drawn from the same community. A number of mesotheliomas have also been documented among populations whose only identified exposure was from living near asbestos mining areas, asbestos product factories, or shipyards where asbestos use had been very heavy (Ref. 4). An estimated 1,600 cases of mesothelioma occur yearly in the U.S. among various populations exposed to asbestos (Ref. 6).

In addition to exposure to asbestos fibers in the air, the general population is also exposed through various oral sources, including drinking water containing asbestos. Because of the potential for oral exposure as well as the excess of gastrointestinal tract cancers that has frequently been found in occupational groups exposed to asbestos in the air, there has been much study of the possible health effects of ingestion of asbestos fibers. Despite those efforts, evidence showing health effects from ingestion is still ambiguous.

2. *Cancer risk extrapolation.* As discussed above, numerous human studies have demonstrated that exposure to asbestos has increased the risk of cancer and asbestosis. Since a number of epidemiology studies indicate a positive relationship between asbestos exposure and the risk of lung cancer, several models may be used to extrapolate from risk at higher exposure to risk at lower exposure. The model that EPA believes is most consistent with the available human and animal data is the linear non-threshold dose/response model. This model assumes that (1) any exposure increases risk, and (2) the increase in risk is proportional to the background risk in the nonexposed population and to the level of exposure, defined as duration of exposure times concentration of asbestos fibers to which populations may be exposed.

The choice of the linear model is reasonable since there is no evidence for a threshold level of asbestos exposure below which there is no increased risk. It is further supported by evidence of cancers among populations whose asbestos exposure is believed to have been lower than levels reported in the epidemiology studies of asbestos workers mentioned above.

The model adopted by EPA to estimate excess mesothelioma incidence due to asbestos exposure relates disease