surface of the lung and the gut[9]. Reports of these mesotheliomas as they are called have increased steeply over the last 10 years. There is general agreement in most industrialized countries that there has been a real increase of this form of cancer[9]. In about 80% of cases there is a history of exposure to asbestos dust at some time in the past. A feature of these tumours is the long interval between first exposures to asbestos dust and the detection of the cancer. It is rarely less than 20 years and may be up to 50 or more years. In some instances the exposure to the dust has been short, only a few months, but the highest incidence of tumours has occurred in those most heavily exposed to asbestos dust. Cigarette smoking seems to play no part in these tumours, but some research workers think there may be other co-factors present as well as asbestos[10].

The only other specific injury caused is the formation of asbestos corns on the fingers when the fibres lodge in the skin. The removal of the fibre usually cures the corn and no cancers of the skin relatable to asbestos have been reported.

PRACTICAL IMPLICATIONS OF THE BIOLOGICAL EFFECTS OF ASBESTOS

Inhalation of the fibre

For all practical purposes the risk from asbestos is limited to inhalation of the fibres. Thus control of the airborne dust levels and their monitoring by instruments, which will measure that part of the dust which can gain access to the deeper parts of the lung, is an essential step in the safe use of all types of asbestos. Although asbestos fibres can be ingested in minute amounts in beverages which have been filtered through asbestos, or water supplies[11], there is no firm evidence that such tiny traces have any ill-effects. Feeding massive doses of asbestos to animals has so far failed to produce any mesotheliomas or other cancers.

Size and shape of fibres

Recent research has helped to clarify the probable influence of fibre length and diameter in producing asbestosis and the bronchial cancers. The fibrosis is thought to be caused principally by the fibres between about 5 and 100 μm in length. Fibres much larger than this in the environment settle out quickly and are not inhaled. Further size separation occurs in the air passages, the important size parameter being fibre diameter since it is this dimension rather than fibre length that governs the falling speed of the fibres. Thus fibres greater in diameter than about 2 μm (these also tend to be the longest) mostly fall or impact in the upper respiratory tract and are carried away with the sputum. In the narrow airways any long fibres remaining are deposited by interception and fibres longer than about 100 μm seldom reach the finest bronchioles. This means that for the control of asbestosis, and probably bronchial cancers, the dose of fibres between about 5 μm and 100 μm in length and up to about 2 μm in diameter is the fraction of the dust which has to be measured.

For the mesotheliomas the evidence about the biologically important size is much less complete. Using information from many sources, such as the aerodynamic behaviour of fine fibres, the size and shape of fibres which are retained in the lungs of animals and man following exposure to different types of asbestos, and the epidemiological studies of the incidence of these tumours in man for different types of fibre, it seems probable that the important fibres are likely to be those which are straight, small in diameter (up to about 1 μm) and perhaps 10 μm in length. It is not yet known whether the ultra-fine fibres only visible under the electron microscope are biologically important. Such fibres are present in large numbers in the lungs of those who have been exposed to asbestos, but their combined mass is extremely small. It is too early yet to use this information to establish with confidence a separate dust standard to prevent the development of these mesotheliomas. This is a field of intensive research at the present.

Some of the new evidence suggests that the size and shape of the fibre are more important than its chemical composition, provided it is relatively insoluble. It may be that extremely fine fibres of many different materials can penetrate cells without immediately killing them, but once inside can damage the mechanisms of cell divisions. An implication of this view is that care should be taken to avoid exposure to dusts of all types of fibre less than 0·5 μm diameter and several micrometres in length.

Types of asbestos and occupations within the industry

The last 10 years have shown the importance to health of the type of asbestos inhaled and the occupation of the workers within the industry. Earlier medical reports did not differentiate between one type of asbestos and another, and most of the surveys were concerned with asbestos textile workers. A full assessment of the risks would ideally be based on studies of workers only exposed to each type of fibre and in all the operations within the industry in which this fibre was used. In practice the information is much less complete than this. Exposures to one type of fibre have usually occurred only in the mining and fibre separating. This work usually takes place in countries where the medical records are scanty and the labour turnover is rapid. A notable exception is in the chrysotile mines in Quebec where a very comprehensive survey has just been completed[12–14]. In the manufacturing countries several types of fibre are often mixed together or have been processed concurrently so that employees have been exposed to several types of fibre in unknown quantities. Past records of dustiness are rarely available for relating to the incidence of the diseases. Thus the current assessment of the relative risks in the past from different types of fibre and occupations is based on information which is far from complete. Use can be made of experiments in animals, especially rats, because most of the diseases seen in man can be produced in these animals. New information is rapidly accumulating which may give a clearer indication of the way in which different types of asbestos produce their biological effects.

There is general agreement that asbestosis and bronchial cancers can be caused by all types of commercially used asbestos (amosite, anthophyllite, chrysotile, and crocidolite) if the dust is inhaled in sufficient quantities, but it now seems likely that the risk from chrysotile may be less than with the other types of fibre. There is also evidence that the risk is lowest in mining and increases along the fibre separating and manufacturing processes. This is thought to be due to the higher proportion of airborne dust consisting of respirable fibres able to penetrate into the deepest part of the lung. In practice this means that the cleaner the fibre and the more completely it is separated into individual