Disease in the Manchester Mummies

by

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Summary

Methods of rehydration and processing of tissue are described which allow the preparation of satisfactory histological sections from Egyptian mummies. A wide range of histological stains proved to be useful, demonstrating the framework and in some cases the cellular detail of the tissue. The mummy of Nekht-ankh showed evidence of sand pneumoconiosis and of pleurisy and pericarditis. Sections from the mummy of '1770' and Asru indicate that they suffered from parasitic worm infestation.

Knowledge of disease in Ancient Egypt has been gained in the past from studies of the medical papyri and from the examination of works of art such as drawings and statues showing malformed persons. However, it was the careful examination of the skeletons and preserved tissue from unwrapped mummies which began early this century that formed the basis for the science of palaeopathology. This term was suggested by Ruffer and defined as 'the science of the diseases which can be demonstrated in human and animal remains of ancient tissues' (Ruffer 1913). The science, therefore, includes the naked eye and histological examination of preserved organs as well as the application of electronmicroscopy and other advanced techniques to the study of ancient tissues.

Although a few early workers including Csermack (1852) had made some drawings of tissue from mummies which had been teased out in sodium hydroxide, it was Ruffer who made the first important observations on histological sections of Egyptian mummies (Ruffer 1911).

Ruffer, who was Professor of Bacteriology at Cairo, published a series of papers on palaeopathology between 1910 and his death at sea in 1917 and these papers have been collected together and published in book form (Ruffer 1921).

Following this basic work by Ruffer there were for many years relatively few histological studies of Egyptian mummies, although those of Simandl (1928) who described histological sections of skin and striated muscle from a 19th or 20th Dynasty Egyptian mummy and Shaw (1938) who carried out a histological study of an 18th Dynasty mummy are worth noting.

More recently Graf (1949) has described histological studies on Egyptian mummies whilst Sandison (1955) has done much to encourage such work. Using Sandison's techniques Rowling (1961) has produced an M.D. Thesis based on his examination of pathological lesions from mummies.

The present studies are based on the collection of Egyptian mummies in the Manchester Museum; they use methods some of which are new whilst others are based on modifications of those described by Ruffer (1911) and Sandison (1955, 1957).

Rehydration

The first stage in the study of mummified material is to re-introduce water into the tissues. This softens it and allows it to regain something of its normal texture. The present workers have found that rehydration occurred satisfactorily in a 5 per cent solution of formol saline but many different methods have been tried in the past. Ruffer (1911) used a mixture of alcohol, sodium carbonate and water, varying the proportions of sodium carbonate and alcohol according to the nature of the original tissue. In general the harder the tissue the more sodium carbonate was used. Other workers have used alcohol alone (Simandl 1928) or merely 1.2 per cent saline (Graf 1949) whilst Sandison (1955) used a modification of Ruffers (1911) solution.

Fixation and Processing

Irrespective of the rehydration procedure, the tissues appear to benefit from 24–48 hours immersion in the commonly used fixative, 10 per cent formol saline.

Processing of the tissue can then be carried out in the usual way preferably by hand although Sandison (1957) has used an automatic tissue processing machine. The present workers used both Gooch crucibles and perforated scintered glass tubes of the Graham Peacock type to help in handling the tissue and to prevent disintegration. A double-embedding technique was also used; after taking the tissue to absolute alcohol it was immersed in 3 per cent low viscosity nitro-cellulose in methyl benzoate followed by toluene to harden the methyl benzoate and to clear the tissue. The tissue was then infiltrated with paraffin wax (melting point 56–58°C). Sections from the blocks were cut on a rocking or rotary microtome in the usual way.

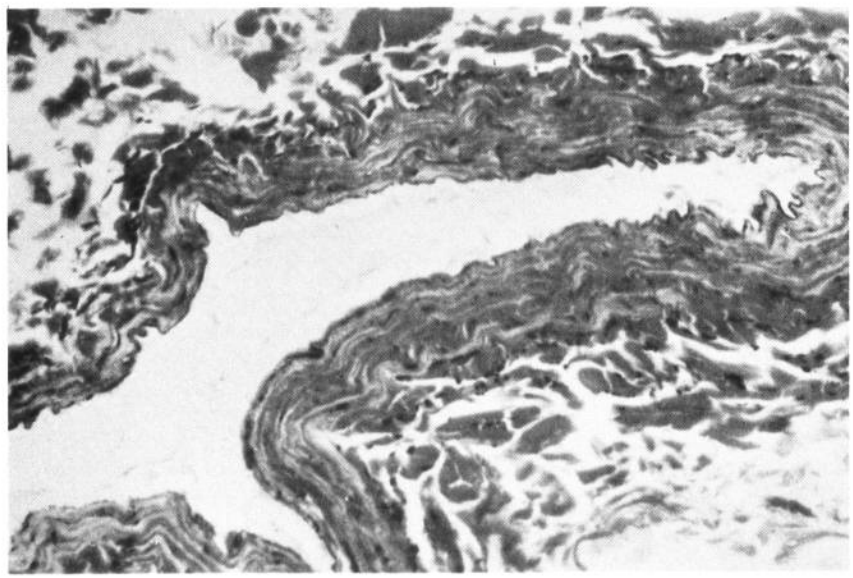
Staining

The following methods have been used:

Haematoxylin and Eosin This stain is used widely in pathology as a routine stain to demonstrate cellular and nuclear detail, but the results with mummified tissue are disappointing. A similar experience has been reported

(**1**) Cartilage stained with haematoxylin and eosin. The nuclei are clearly seen.

(**2**) The Verhoff van Gieson Stain for connective tissue and elastic fibres differentiates the various elements in the dermis.



(**3**) A blood-vessel stained in the same way as (**2**).

previously by Sandison (1963). However, occasionally it may be of value as in the sections of the rib cartilage; here the nuclei are quite clearly stained by the haematoxylin whilst the eosin stains the matrix of the cartilage (**1**). Cell nuclei have been stained previously in the epidermis by Ruffer (1911) and Sandison (1955) but not in other tissues.

Connective Tissue Stains These have proved most useful, Van Gieson giving good differentiation in most instances between collagen and muscle. When used in conjunction with Verhoff's stain for elastic fibres the structure of the dermis of the skin and of blood vessels can be demonstrated (**2** and **3**).

These stains may also be of value in demonstrating the overall structure of organs such as the liver where the cellular detail has been lost. In such organs Gordon and Sweet's stain for reticulin or phosphotungstic acid haematoxylin (PTAH) may also be useful, but in the present work the reticulin framework of the liver was demonstrated most satisfactorily by using the Periodic acid Schiff Reagent followed by celestine blue mordanted with iron alum (**4**).

PTAH was also useful for demonstrating the trabecular structure of bone. Here the osteocyte cannot be seen in the lacunae and the bone marrow has unfortunately disappeared (**5**).

Striations in voluntary muscle were difficult to demonstrate. Clearly the ease with which this may be done depends on the state of preservation of the tissue and from this point of view the demonstration of muscle striations in naturally preserved pre-dynastic bodies is interesting (Ruffer 1911).

Mucin Stains Metachromasia in the matrix of cartilage could be demonstrated readily with toludene blue. This phenomenon has been studied previously in ancient cartilage and bone (Anderson and Jorgensen 1960).

Alcian blue was useful in demonstrating the particles in the damaged lung tissue which proved to consist of sand. These particles stained metachromatically and would appear to be coated with some mucinous material.

The Periodic acid Schiff Reaction for mucins showed the presence of mucin secretion in the epithelium of the large intestine (**6**). This is probably the first demonstration of the persistence of epithelial mucin in mummified tissue.

Stains for Pigments Carbon pigment may be seen unstained in the tissue. Other workers have used the Masson Fontana stain for melanin (Sandison 1957) and Perl's stain for iron pigment but in the latter case there is often doubt about the specificity of the staining (Sandison 1963).

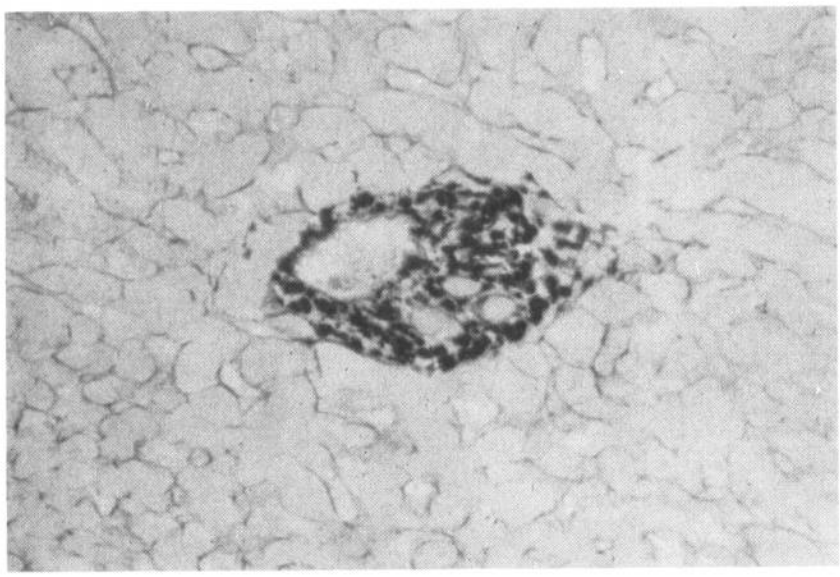
Disease in Nekht-ankh

Nekht-ankh was one of the Two Brothers, unwrapped by Margaret Murray at the beginning of the century (Murray 1910). He is believed to be from the Twelfth Dynasty and to be about sixty years of age when he died. The description given by Murray (1910) indicates that at the time of unwrapping, the tissues were moist and in poor condition. However, many of the fragments had been saved and carefully preserved in glass jars. It was material from these jars that the present author re-examined some seventy years after the unwrapping and amongst which he found fragments of rib. Attached to one piece of rib was some soft tissue and this, under the microscope, was seen to be lung. The lung tissue appeared to be damaged and to contain a good deal of scarring with proliferation of both fibrous and elastic tissues. Amongst the fibrous tissue were several aggregations of fine particles. These were brown or black in unstained sections but stained metachromatically with alcian blue (**7**). This peculiarity of the staining has already received comment.

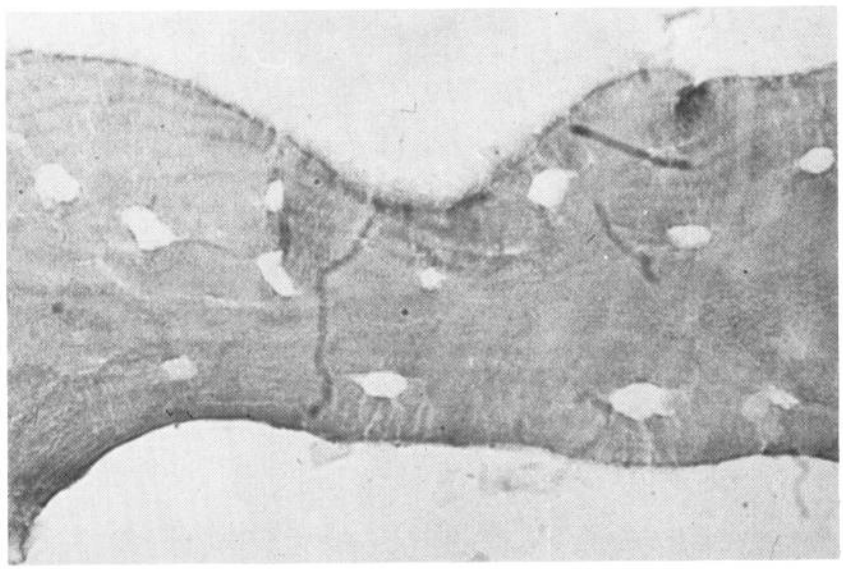
The study of the lungs was assisted further by the finding of material in two of the canopic jars from Nekht-ankh. One of these the 'Hapi' jar was described by Cameron (1910) as containing a hard brittle mass which he believed was a small piece of intestine. This tissue is seen in its original state (**8**). After re-hydration the larger airways and vessels can be seen and it is now quite clear that the specimen is one of lung (**9**). Histological sections again showed damage to the lung and the presence of fine particles. The latter are also seen in the lymphatic channels around large blood vessels in the lungs (**10**). Examination of the particles under polarized light showed birefringence indicating that they had a crystalline structure and were almost certainly silica particles. The electron microscopic studies described elsewhere confirmed the presence of silica and suggested that the particles were composed of sand. Lesions similar to those in Nekht-ankh's lung have been described recently in the lungs of people living in the Sahara and Negev deserts (Policard and Collet 1952; Bar-Ziv and Goldberg 1974) and the disease has been called sand pneumoconiosis. It is very similar to the condition acquired by coal miners and stone workers who inhaled stone dust and in whom the condition is called silicosis. These workers get massive fibrosis of the lung and it has been suggested that sand particles are probably not as damaging to the lung as freshly broken stone particles encountered by coal miners and stone workers. It is clear, however, that the smoother fragments of stone we call sand are also capable of causing considerable damage to the lung.

The method of his embalming and the inscriptions on the tomb found by Murray (1910) indicate that it is unlikely that Nekht-ankh was a stonemason. There is little doubt, however, that the population of Ancient Egypt would be subjected at intervals to sand-storms of the type that desert populations still have to endure today, and that the mechanism producing Nekht-ankh's disease is similar to that going on in present-day desert populations.

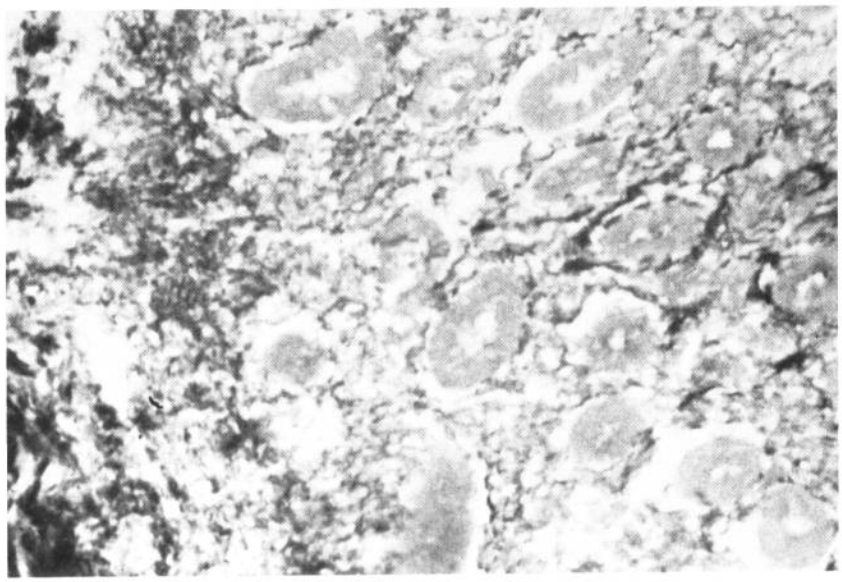
Previous workers (Ruffer 1910; Long 1931) have noted anthracosis (carbon pigment) in the lungs of Egyptian mummies and Shaw (1938) reported anthracosis in association with emphysema and bronchopneumonia. It is only recently, however, that silicotic damage has been described (Cockburn et al. 1975); Tapp et al. 1975). In addition Reyman and his associates (1977) have reported birefringent particles in the lungs of a mummy which analyses have suggested are particles of granite.



(4) The connective tissue framework of the liver is stained and there is a portal tract in the middle.



(5) The trabecular structure of the bone is demonstrated with PTAH but the osteocytes have disappeared.



(6) Mucin secretion is seen in the epithelium lining the glands of the large intestine, the mucin being stained with the Periodic acid Scheff reagent.

Further examination of the specimen of lung from the cannopic jar has shown that Nekht-ankh also had disease affecting the heart, for the pale tissue attached to the lung in one area was shown histologically to be part of the wall of the heart. It is clear that when the embalmers attempted to remove the lungs of Nekht-ankh they found that it was impossible to separate the lung from the heart and consequently instead of leaving the heart behind they had to remove part of the wall of the latter along with the lung. The histological sections show fibrous tissue obliterating the pericardial and pleural cavities and it is clear that there must have been inflammation in this area probably associated with pneumonia some time before death had occurred.

Disease in Asru

Asru was a lady who is believed to have lived in the Late Period. The mummy was unwrapped some years ago but the body itself was left undisturbed. However, a mass of material was found between her legs and although this looked most unpromising, histological examination has been worthwhile. The sections showed that the material consisted of intestines and although only the outlines of the muscular walls of the intestine could be identified, in some places clear evidence of parasitic infestation could be seen. Worms were present both in the mucosa and muscular wall of the intestine and appeared to have been causing significant disease (**11**). It is believed that the worm is a Nemotode and is almost certainly of the genus Strongyloides. Further details of its structure will be dealt with in the section dealing with electron-microscopy.

Strongyloides is a parasite that is found in many tropical and subtropical countries as well as in more northerly latitudes. The life cycle is complicated but in man begins when larval forms burrow through the skin of the feet when the latter come into contact with infected water or contaminated soil. From the skin the immature forms pass along the veins to the lungs where they enter the air passages and pass upwards towards the larynx. They are then swallowed and hence gain access to the stomach and intestines. In the intestines they reach maturity and the female lays eggs which are passed in the stools. Eventually the eggs hatch out into larvae in the soil which are ready to start the cycle again. It is clear that infection with this worm will be endemic in conditions where hygiene is poor and where the feet are likely to come into contact with soil contaminated with faeces. Certainly one can understand it being prevalent amongst the lower classes in Ancient Egypt. Asru, however, is believed to be of high rank and consequently it would appear that the disorder occurred at all levels of society.

It is difficult to know whether the worms were responsible for her death, certainly they may have made her anaemic due to blood loss. Occasionally they produce a severe inflammation of the large intestines and from there spread to other parts of the body and under these circumstances may cause death. It has been mentioned already, however, that tissue from the rest of the body was not available for study.

Disease in '1770'

Reference has been made already to the calcified nodule from the anterior abdominal wall of this mummy which on x-ray proved to be the remains of a Guinea worm (*Dracunculus medinensis*). Infection with this worm is still common in some parts of the Near East, Africa and India. It is acquired by man when during the consumption of water infected with a small crustacean containing immature forms of the worm. The latter are liberated from the crustacean by the gastric juices and the immature worms migrate through the wall of the stomach and grow into adult worms in the anterior abdominal wall. The male worm is only a few centimetres in length and dies after fertilizing the much larger, up to one metre in length, female. It would appear that the worm found in '1770' is the male. Calcification often occurs when a worm dies within living tissues and of course it is this calcification which has preserved the outline of the worm for the past three thousand years.

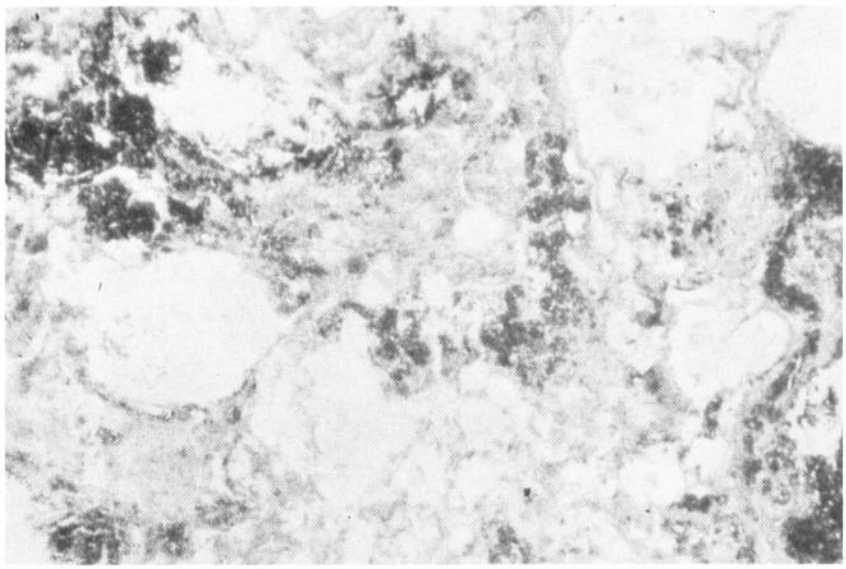
The female worm, after fertilization, wanders through the subcutaneous tissues of the body but usually comes to rest in the legs and feet. Here it causes blistering and later ulceration of the skin (**12**). Eggs are passed through the ulcerated area and if they get into water they are taken up by a crustacean and the life cycle is ready to start again.

Attempts were usually made to remove the worm from the leg and one old method consisted of holding one end of the worm as it emerged from the ulcer in a cleft stick. The worm was then carefully wound on to the stick by turning the latter slowly round so extracting the worm a little at a time each day. If the worm should die before it is removed in this way then severe inflammation occurred in the legs and abscesses were common. It is possible that this happened in '1770' and the child's legs had to be amputated surgically. However, the appearance of the ends of the bones did not support this.

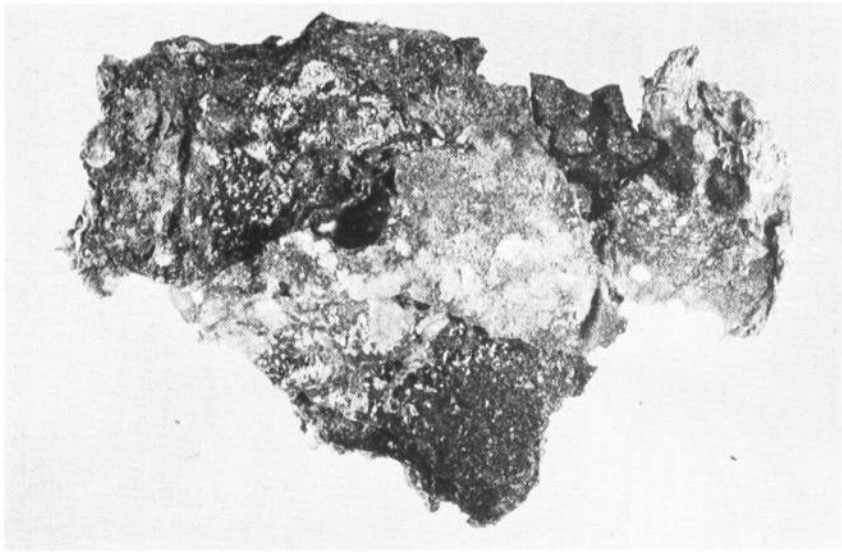
Comments

Previous descriptions of Strongyloides and Dracunculosis in Egyptian mummies have not been found but of course, worm infestations are mentioned in Ancient Egypt writings (Ebbells 1937). Parasitic infestation in Egyptian mummies was first reported by Ruffer who demonstrated the calcified eggs of Bilharzia in the renal tubules of two 20th Dynasty mummies (Ruffer 1910a; 1910b). Ruffer also suggested that some Coptic bodies with enlarged spleens might have malaria but there is no convincing evidence of this (Ruffer 1913). More recently Cockburn and his co-workers (1975) found a single Helminth egg in Pum II which has been identified as Ascaris, whilst Reyman and his associates (1977) have identified calcified bilharzial eggs in the liver of Rom. I. This mummy believed to be a weaver from Thebes was also infected with a flat worm of the species Taenia whilst a cyst of another worm, *Trichinella spiralis*, was found in an intercostal muscle.

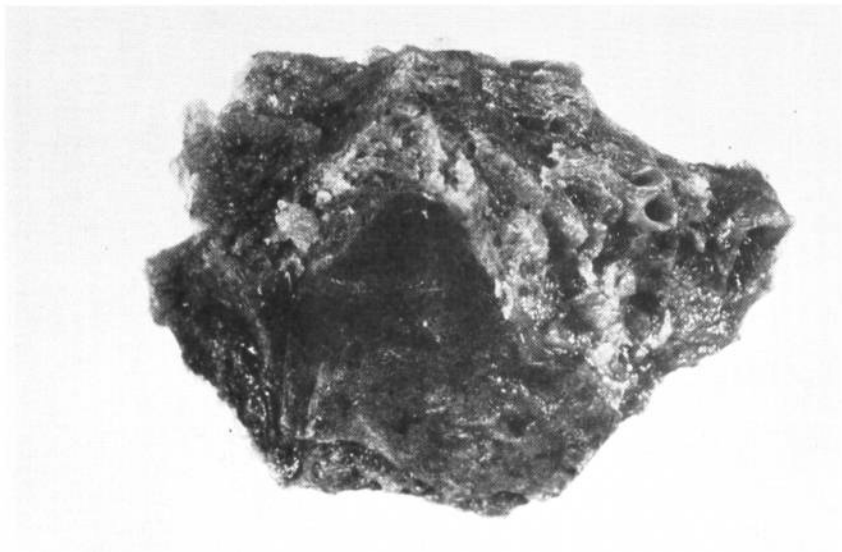
It is interesting to note that the most significant disease found in the Manchester mummies may be related to the local environmental and social conditions in Ancient Egypt. The sand pneumoconiosis in Nekht-ankh is a reflection of the dry dusty climate which exists for much of the year and at times the environment is made much



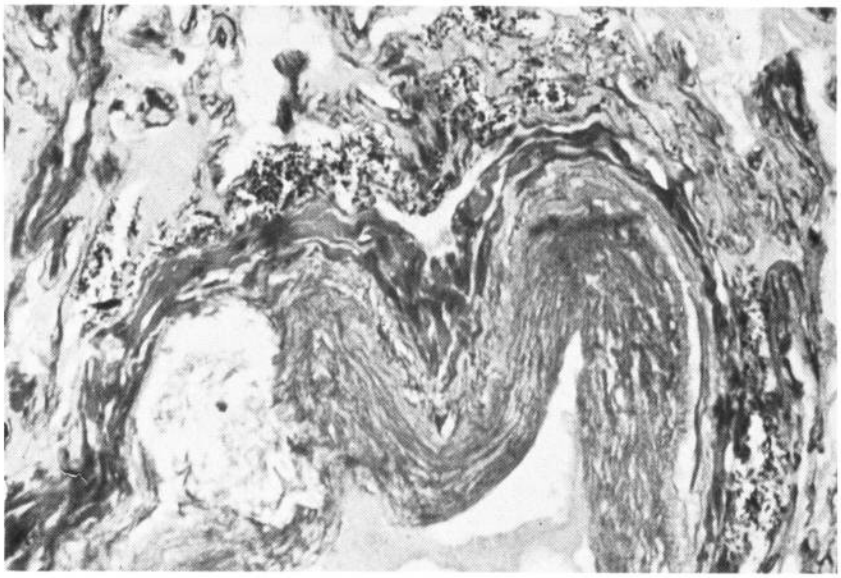
(7) The normal structure of the lung has been destroyed by fibrosis and aggregations of fine particles are seen in the top left and bottom right of the photograph.



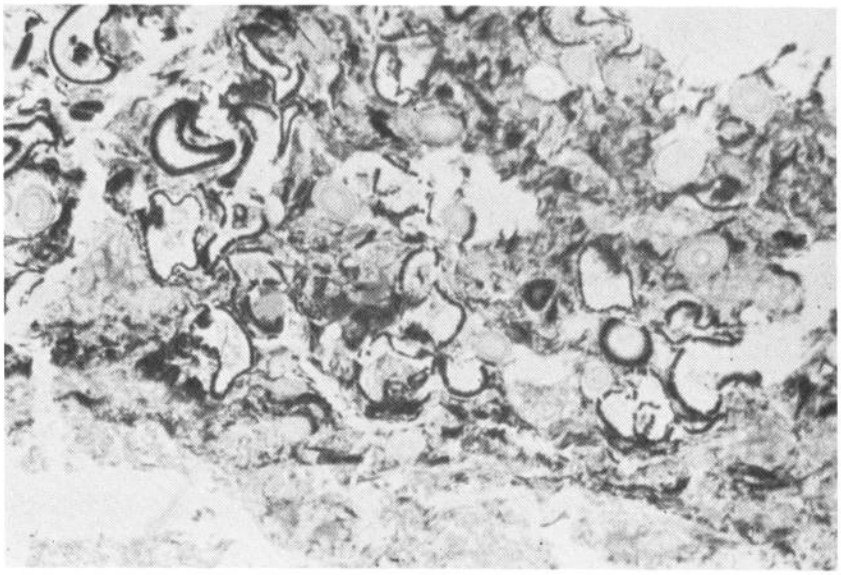
(8) A brittle piece of tissue found in the 'Hapi' jar.



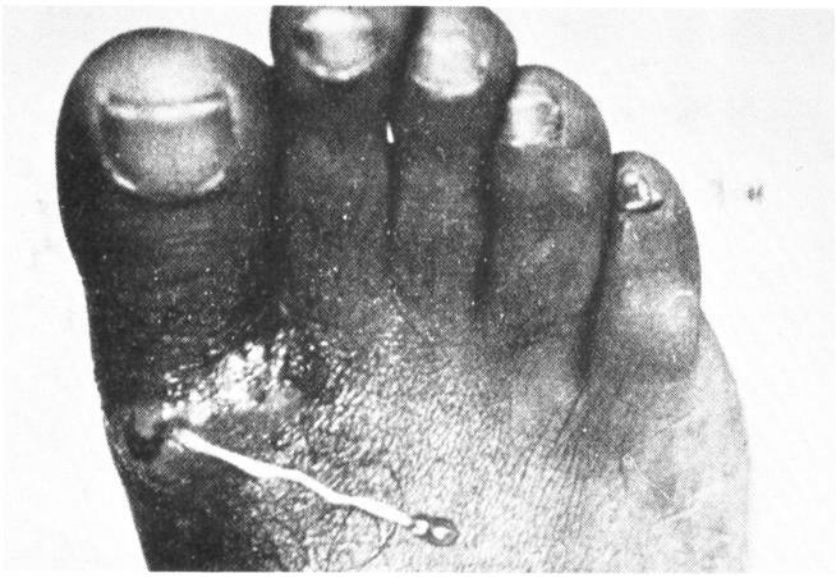
(9) A small part of the tissue from (8) rehydrated and magnified in the photograph. A large airway is seen close to the edge of the tissue on the right of the photograph.



(10) The fine dark particles are seen in the lymphatic channels around a large blood vessel in the lung.



(11) Parasitic infestation in the wall of the intestine, probably Strongyloides.



(12) An ulcer is now present and the tip of the worm has appeared through it.

worse by the occurrence of sand-storms. On the other hand the persistance of parasitic infestations such as those found in '1770' and Asru are the result of inadequate sanitation permitting continuous reinfestation of the ground. Flooding of the land for part of the year makes things worse by allowing the development and proliferation of immature forms of the parasites in the wet soil and also results in contamination of the wells from which the people draw their drinking-water. Hence the people are at risk from infections such as Strongyloides and Bilharzia whilst walking barefoot in the infected water and soil and from infestation with Dracunculosis when drinking water from their wells.

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