DIET, DISEASE AND DEATH AT DAKHLEH:

A HISTOLOGICAL EXAMINATION OF TEN MUMMIES FROM THE KELLIS 1 CEMETERY IN THE DAKHLEH OASIS, EGYPT.

A thesis submitted to the University of Manchester for the degree of Doctor of Philosophy in the Faculty of Life Sciences.

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LIST OF CONTENTS

CHAPTER TWO   **MATERIALS AND METHODS**   **82**

Final Word Count – 76 150

LIST OF FIGURES

LIST OF TABLES

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DOCTOR OF PHILOSPOHY

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ABSTRACT

Histology is a technique that has any number of diagnostic uses in modern hospital laboratories. However, as a scientific method employed in the study of ancient and mummified remains, it appears to have lost its popularity.

This project explores the advantages and limitations of histology as a technique for such studies. In order to do so, soft tissue and bone samples from ten early Roman Period mummies (30 BCE – 250 CE) from the Kellis 1 cemetery in the Dakhleh Oasis have been histologically examined.

While this project focuses on the scientific technique of histology, and its application for the study of ancient remains, it also aims to be cross-disciplinary by incorporating scientific results from the ten mummies with the historical data and archaeological remains uncovered during excavations of the Kellis site. By bringing the results of science and Egyptology/archaeology together, it hoped that a better understanding of ancient Egyptian society could be achieved.

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September 2009 - The Dakhleh Oasis Project Symposium (Lecce – Italy) – *Diet, Disease and Death at Dakhleh. (*Poster)

January 2009 – Current Research in Egyptology (Liverpool University – United Kingdom) – *The Veterinary Papyrus of Kahun.* (Presentation and Conference Proceedings)

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October 2010 - Ancient Egypt Magazine – The Veterinary Papyrus of Kahun (Article).

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DECLARATION

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CHAPTER ONE – AIMS AND INTRODUCTION

1.1 - AIMS AND PROJECT OUTLINE

While this project focuses on the scientific technique of histology, and its application for the study of ancient remains, it also aims to be cross-disciplinary by incorporating scientific results with historical data and archaeological remains. By bringing the results of science and Egyptology together, it hoped that a better understanding of ancient Egyptian society could be achieved.

In order to explore the advantages and limitations of such cross-disciplinary research, ten early Roman Period mummies (30 BCE – 250 CE) from the Kellis 1 cemetery in the Dakhleh Oasis have been histologically investigated. These mummies had been examined and autopsied in the 1990s, and at this time, no, or very few, ante-mortem pathologies could be identified. Each mummy had varying degrees of remaining soft tissue, which are, along with some bone samples (rib and femur), the subject of Chapter Four (The Case Studies).

The advantage of examining mummies from the Kellis 1, or Western, Cemetery is that Kellis is also a fairly well preserved settlement site – rare in the archaeological remains of Egypt where the best-preserved sites are necropolises. Kellis has been excavated throughout the last 30 years, and this has realised a lot of archaeological and historical (including textual) data. This data can be used with the histological results, the outcome hopefully enabling an informative cross-disciplinary study about the lives of the Kellis population.

The overarching aims of the project are threefold. These being:

- To assess histology as a scientific technique for the study of ancient human remains
- To use histology to examine ten early Roman Period mummies in terms of preservation and pathologies
- To combine histological results with historical data in order to achieve a more complete, cross-disciplinary record regarding the lives, and possibly deaths, of the ancient Egyptians from the Kellis township in the Dakhleh Oasis.

Chapter One of this project introduces the Dakhleh Oasis and Kellis Township and the excavations therein, as well as outlining the relevant historical and archaeological data (including mortuary practices) collected from the Kellis excavations over the last 30 years. Sources from outside the Dakhleh Oasis will also be briefly discussed.

Chapter Two explains the materials and methods used in the project. The materials include a description of the ten case study mummies, as well as other samples used for comparative purposes. The description of the case studies and comparative samples includes an account of the mummification techniques used and the condition of the body at the time of excavation, in order to provide an understanding of the current state of preservation of the samples examined.

A description of the stains used is also included in Chapter Two. The final part of the Section describes the histological processes used in the project. The step-by-step account of these processes is found in Appendix One.

Chapter Three focuses on an evaluation of the histological methods and results. It aims to assess the technique by investigating its advantages and its limitations, as well as the contribution histology has made, and can potentially make, to the study of ancient human remains.

Chapter Four concentrates on the ten Kellis 1 mummies. The results of the histological examination of the soft tissue and bone samples are reported and discussed, and then put into context with the available historical and archaeological data. Each mummy is treated as an individual entity due to the type of the samples available and the unique nature of the obtained.

The final Chapter (**Chapter Five**) is a brief conclusion of the overall results and how they can be used to complement the Kellis data already available.

Summary of the Aims for this Project

Overall Aims for the Project – Chapter One (Introduction)

- To assess histology as a scientific technique for the study of ancient human remains
- To use histology to examine ten early Roman Period mummies in terms of preservation and pathologies

- To combine histological results with historical data in order to achieve a more complete, cross-disciplinary record regarding the lives, and possibly deaths, of the ancient Egyptians from the Kellis township in the Dakhleh Oasis.

Aim for Chapter Three (Histology)

- To evaluate histology as a scientific method used in for the study of ancient human remains, including the advantages and limitations of the technique.

Aims for Chapter Four (The Case Studies)

- To examine soft tissue and bone samples from ten early Roman Period mummies in terms of:
    - Tissue identification
    - Preservation level
    - Pathologies.
- To combine the histological results with the historical and archaeological data in order to obtain a more complete picture of the lives, and possibly deaths, of the ten Kellis individuals.

Chapter 1.2 – INTRODUCTION

1.2.1 – Chronology

With the exception of the Late Period mummy Asru (Manchester Museum Number 1777) all Egyptian mummies studied as part of this thesis were from post-pharaonic periods (Roman and Christian Eras). However, a general chronology of the Pharaonic Period is included below because of the many elements and innovations discovered during this thesis had their origins in this time.

All dates are based on the British Museum chronology as cited in Shaw & Nicholson 2008 (reprint of 1995 version), pages 350- 352.

Predynastic		**5500 – 3100 BCE**
Early Dynastic		**3100 – 2686 BCE**
First Dynasty	3100 – 2890 BCE	
Second Dynasty	2890 – 2686 BCE	
Old Kingdom		**2686 – 2181 BCE**
Third Dynasty	2686 – 2613 BCE	
Fourth Dynasty	2613 – 2494 BCE	
Fifth Dynasty	2494 – 2345 BCE	
Sixth Dynasty	2345 – 2181 BCE	
First Intermediate Period		**2181 – 2055 BCE**
Seventh & Eighth Dynasties	2181 – 2125 BCE	
Ninth & Tenth Dynasties	2160 – 2025 (Herakleopolitan)	
Eleventh Dynasty	2125 – 2055 (Thebes only)	
Middle Kingdom		**2055 - 1650 BCE**
Eleventh Dynasty	2055 – 1650 BCE	
Twelfth Dynasty	1985 – 1795 BCE	

Thirteenth Dynasty	1795 – after 1650 BCE
Fourteenth Dynasty	1750 – 1650 BCE

Second Intermediate Period   **1650 – 1550 BCE**

Fifteenth Dynasty	1650 – 1550 BCE (Hyksos)
Sixteenth & Seventeenth Dynasties	1650 – 1550 BCE (Thebes)

New Kingdom   **1550 – 1069 BCE**

Eighteenth Dynasty	1550 – 1295 BCE
Nineteenth Daynasty	1295 – 1186 BCE
Twentieth Dynasty	1186 – 1069 BCE

Third Intermediate Period   **1069 – 747 BCE**

Twenty-First Dynasty	1069 – 945 BCE (Tanite)
Twenty-Second Dynasty	945 – 715 BCE (Libyan)
Twenty-Third Dynasty	818 – 715 BCE (Tanite/Libyan)
Twenty-Fourth Dynasty	727 – 715 BCE

Late Period   **747 – 332 BCE**

Twenty-Fifth Dynasty	747 – 656 BCE (Kushite)
Twenty- Sixth Dynasty	664 – 525 BCE (Saite)
Twenty – Seventh Dynasty	525 – 404 BCE (First Persian Period)
Twenty- Eighth Dynasty	404 – 399 BCE
Twenty-Ninth Dynasty	399 – 380 BCE
Thirtieth Dynasty	380 – 343 BCE
Thirty-First Dynasty	343 – 332 BCE (Second Persian Period)

Ptolemaic Period   **332 – 30 BCE**

Macedonian Dynasty	332 – 305 BCE

Ptolemaic Dynasty   305 – 30 BCE

Roman Period   **30 BCE – 395 CE**

Division of the Roman Empire   **395 C**

1.2.2 – The Dakhleh Oasis

Fig 1.1 – Location of Dakhleh Oasis (satellite image courtesy of NASA – http://visibleearth.nasa.gov)

The Dakhleh Oasis is the largest of Egypt's western oases and has been continuously inhabited throughout the historic period (Shaw & Nicholson 2008; 88). Currently, the Oasis basin measures 75 kilometres east to west and 25 kilometres north to south. The capital, Mut, is centrally situated within the Oasis. It is 600 kilometres southwest of Cairo, lying at 25°30′ north and 29°00′ east. A Cretaceous Period (145 to 65 million years ago) limestone escarpment, climbing up to 500 metres high, forms the northern and eastern boundaries (Mills 1999; 220).

Fig 1.2 – Looking across the Dakhleh Oasis to the Cretaceous escarpment forming the northern boundary (photograph courtesy of the Dakhleh Oasis Project)

Today, the Oasis is home to an ever-expanding population of approximately 65 000. The Oasis has no mineral or other resources, apart from ochres and a sulphurous deposit in the region of Qasr, although these were probably not

extracted until medieval times. It is completely reliant on agriculture as its economic basis, as it was during the Pharaonic Period (Mills 1999; 173).

The landscape of Dakhleh can be characterised into six categories:

1) Sand plains – Occurring throughout the Oasis.
2) Sand dunes – Mainly found in the west of the Oasis.
3) Wastelands – Usually salt-encrusted or calcrete cemented soils on old agricultural lands. They are formed when irrigation causes large quantities of salts to be brought to the surface without adequate flushing.
4) Cultivated lands – These are all irrigated from nearby wells and irrigations channels.
5) Salt marshes – Scattered throughout the Oasis and in residual drainage ditches.
6) Aquatic habitats – These consist of well pools, irrigation canals and open surfaces of reservoirs (Churcher 1999; 155).

The evidence suggests that both landscape and environment would have been similar throughout the historic period at Dakhleh (Butzer 1976; 134).

1.2.2.1 - Water Supply

That agriculture has been so successful in the western oases is down to the geology of the areas. The Dakhleh floor, lying 100 metres below the level of the surrounding desert, is known as the Taref Sandstone Member of the Nubian Formation, one of the largest ground water reservoirs in the world. This Nubian sandstone is a water-bearing stratum that underlies the whole of the Western Desert but is only accessible from the oases floors. The depth of the water-bearing sandstone varies from approximately 200 metres in the Kurayim area to 1030 metres in Dakhleh. This allows for the possibility of an almost limitless and continuous water supply and, in turn, a permanent sedentary population (Schild & Wendorf 1977; 10). Dakhleh has a line of fresh water springs following the line of the Libyan escarpment and, in addition to these, the Dakhleh dwellers would dig deep artesian wells (Dupras 2001; 1200). This means of water supply is in direct contrast with those of the Eastern Desert, which relies on springs and rock pools in the mountains or wells dug into the alluvium of the wadi floors, all of which are entirely dependent on rainfall. The yield is 'often barely sufficient for the maintenance of the nomad population and their

domesticated animals' (Ball 1939; 10). Rainfall in Dakhleh is virtually unknown, with a mean annual rainfall of 0.3 millimetres (Dupras 2001; 1200).

1.2.2.2 - Climate

The severe climate has not been a deterrent to settlement in the Dakhleh. The most impressionable climatic factor, with which the Oasis is plagued, is known as 'the curse of the Oasis', a near constant sand-laden wind from the north. While tolerable to man, it carries the invading sands, which is, and perhaps always has been, the most challenging aspect of oasis living. The engulfment by sand is a mixed blessing for the archaeologists working in Dakhleh. On one hand it has caused the wonderful preservation of the ancient township, protecting them from the interference by both man and environment. On the other hand, the unremitting build up of sand makes fieldwork very difficult (Giddy 1987; 3).

Another consequence of the arid conditions of Dakhleh is the excellent preservation of organic materials (human tissue, textiles, papyri, botanical and faunal remains) (Dupras 2001; 1201).

Temperature extremes are great; winter temperatures fluctuate from 0° to 2° Celsius before sunrise, rising to 20° to 25° by midday. It is not unknown for daily summer temperatures to average 39°. The weather pattern for Dakhleh can be summarised as long hot summers and short rainless winters. Whether this was the case in ancient times is yet to be decided. The evidence for the deterioration of conditions can be attributed to other factors, such as the inundation of sand (Giddy 1987; 4).

1.2.2.3 - Subsistence

The Western Oases have long been known for their fertility; the cultivated land at Dakhleh is extremely productive. It is probable that during the Roman Period the government introduced several agricultural policies and incentives, which were aimed at encouraging migrant farmers to settle in the Western Oases. Certainly, it was at this time there was very active construction of temples, villages, wells and irrigation systems within the Dakhleh Oasis (Dupras 2001; 1200).

Today, as in the past, the export crop of note is dates, said to be superior to any others in Egypt. They were sought after in the Nile Valley and further afield in the Mediterranean world (Mills 1999; 173). During the Roman Period, Oases-grown olives were also highly valued (Mills 1999; 173). Other produce, mainly for domestic use, includes the doum palm and acacia. The nuts and fruit of the respective trees provide food, while the trunks are used for wood. Three cereal crops are grown each year, first is rice, harvested in November, second is wheat, harvested in April and finally sorghum, which is a hot weather crop. The agriculture of Dakhleh does not contribute in any great way to the economy of Egypt; however neither does it place any great strain on its resources by using its traditional agricultural crops and farming methods (Mills 1999; 173).

Fig 1.3 – Scene of date palms in the Dakhleh Oasis (photograph courtesy of the Dakhleh Oasis Project)

The productivity of the Dakhleh Oasis, indeed of all the Western Oases, is such that practically anything can be grown there. Today, this is of fundamental importance when considering the relationship between the Western Oases and the Nile Valley. Even during the Pharaonic occupation of Dakhleh, agricultural production was frequently geared to the current demands of the Nile Valley. The relative strength and weakness of these demands at any given time, as well as the overall Egyptian control of the Oasis allows for an insight into the developments in the Nile Valley itself (Giddy 1987; 5).

1.2.2.4 – Egyptian Occupation of the Dakhleh Oasis

Between the Western Oases and the Nile Valley lies 200 kilometres of desolate and hazardous terrain and no reliable water source exists today between the two areas. A crossing of this territory needs, and needed, to be as short as possible. There are two possible routes to and from Dakhleh and the Nile Valley, firstly, via the Kharga Oasis, which lies directly to the east of Dakhleh. In

1908, Egyptologist Herbert Winlock, using the 'Ayn Amur Road, travelled from Kharga to Dakhleh on a camel. He stated that, if water was available at 'Ayn Amur, the journey could be done in two days, travelling at fifteen to sixteen hours a day (Winlock 1936; 272-6). The second route avoids Kharga by heading directly over the Libyan Plateau (Giddy 1987; 11).

Despite the distance, Nile Valley connections with Dakhleh can be dated back to the Archaic Period, based on ceramic evidence. As very few of these items have been discovered, Egyptian occupation of the Oasis cannot be confirmed at this time, however there had been an establishment of trade between the two regions (Hope 1980; 283-313).

Around 2300 BCE, the Egyptians arrived in number. As conditions were not radically different from their Valley homeland, they implemented the now centuries old agricultural practices. The farming techniques in the Oasis today are largely the result of those established during the Old Kingdom influx of new Egyptian residents (Mills 1999; 174). The large settlement site of Ain Aseel (in the area of the modern-day town of Balat) is at the entry point for the direct route from the Nile and it has been dated to this Late Old Kingdom period. It includes vast burial grounds, within which are mastaba tombs belonging to the Egyptian governors that controlled Dakhleh during the reign of Pepi II (Sixth Dynasty). There is archaeological evidence for at least 42 other Old Kingdom occupation sites spread throughout the Oasis (Mills 1999; 220). Why the Egyptians choose to relocate to Dakhleh is still unknown but it is apparent that they made a serious attempt to colonise the area.

The time spanning the First Intermediate Period to the Ptolemaic Era is not well-evidenced, although what remains suggests that there was a constant Egyptian population within the Oasis. Sometime during the Ptolemaic Period, the Dakhleh Oasis became fully occupied. From the first five centuries of the Current Era, Dakhleh increases in economic importance and almost 250 sites have been dated to this period (Giddy 1987; 168-169).
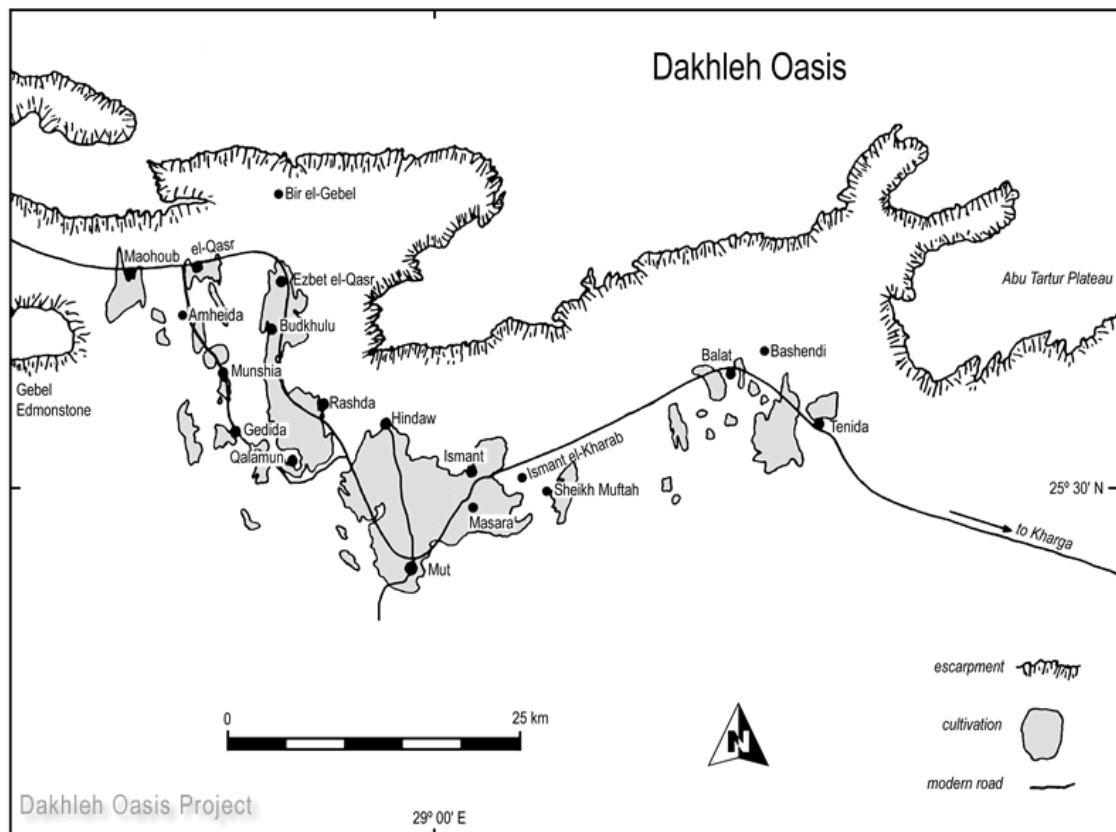
Fig 1.4 – Map of Dakhleh Oasis (photograph courtesy of the Dakhleh Oasis Project)

1.2.2.5 – The Dakhleh Oasis Project

While some prominent 19th Century Egyptologists had visited the Dakhleh Oasis, most notably H E Winlock and J G Wilkinson, there was no real interest until the 1950s when Dr Ahmed Fakhry visited the site and made some preliminary observations (http://arts.monash.edu.au/archaeology/excavations/dakhleh/index.php). The Dakhleh Oasis Project began in 1977, when A J Mills and G Freeman took a trip there; their interest raised when they could see historical remains above the ground throughout the Oasis (www.arts.monash.edu.au/archaeology/excavations/dakhleh/index.php). In 1978, a walking survey was carried out in search for:

- traces of ancient occupation
- geological features
- modern vegetation and animals.

Without searching the areas under modern cultivation, 450 sites of all periods of Egyptian history were discovered.

By 1982, the Dakhleh Oasis Project had grown to include archaeologists specialising in various subjects, photographers, botanists, geologists, palaeontologists, zoologists, architects, conservators and recording artists (www.arts.monash.edu.au/archaeology/excavations/dakhleh/index.php).

The Dakhleh Oasis Project (DOP) is a long-term regional study of the interaction between environmental changes and human activity in the closed area of the Dakhleh Oasis, Western Desert of Egypt, including the larger area of the Palaeoasis. The Project encompasses a study from the first humans in the Middle Pleistocene (approximately 400 000 years ago) up to the twenty-first century residents of the Oasis; it includes all human activity and changing environmental conditions for which there is evidence within this time period. The data gathered from the Pharaonic Period sites will assist the current understanding of trade, influences, migration and long-distance communication of this time (www.dakhleh.com/trust.htm).

The DOP is important because the Dakhleh Oasis is both an isolated unit and a microcosm of much wider trends. No such large oasis area of the eastern Sahara has yet been so broadly examined and in such great detail. What occurs in the Dakhleh Oasis, will, in all probability, also occur in other places, with local variations. For example, because of human interference and natural destruction, early adaptation in the Nile Valley is imperfectly understood. The Dakhleh Oasis is isolated but not too distant from the Nile and one of the aims of the DOP is to shed light onto this area of research. Through an understanding of the cultural development in the oasis, and in the variety of ways people have had to adapt and accommodate themselves to their changing world, and also how they have influenced or created change in their world, it should become easier to understand the present-day problems of life in an hyper-arid environment, with fertile soils but with a finite water supply (http://arts.monash.edu.au/archaeology/excavations/dakhleh/index.php).

The DOP is supported by a number of universities and organizations, including Monash University, The University of Durham, the University of Toronto, Columbia University, the Royal Ontario Museum, the Society for the Study of Egyptian Antiquities, the American Research Centre in Egypt and the Egyptology Society of Victoria.

The author of this thesis must acknowledge all the research of the Dakhleh Oasis Project, which has contributed so much to the understanding of the ten Kellis mummies examined here. Many of the photographs and maps are also the product of the ongoing work of the DOP.

1.2.3 – Kellis – Ismant el-Kharab (Ismant the Ruined)

The ancient town of Kellis or Ismant el-kharab (Ismant the Ruined) lies approximately 2 ½ kilometres east of the modern village of Ismant (given the Dakhleh Oasis Project designation of Site 31/420-D6-1). It had been previously visited and described by renowned early visitors, such as H E Winlock and J G Wilkinson, who were attracted to the prominent ruins visible above the sands. The town covers an area of approximately 1050 x 650 metres, standing four to six metres above the floors of two wadis to the northwest and southeast borders. The settlement area is clearly defined by the mud-brick and stone remains of buildings including temples, one of which, the Main Temple, is the earliest structure (Knudstad & Frey 1999; 189). It has been under the excavation of the Dakhleh Oasis Project since 1981(see Chapter 1.2.1.5).

Fig 1.5 – The mud-brick remains of Kellis (photograph courtesy of the Dakhleh Oasis Project)

The temple itself is a small sandstone structure, dedicated to the protective deity, Tutu, who is first attested in the Twehty-Sixth Dynasty in the town of Sais.

His popularity spread throughout Egypt during the Ptolemaic Period. He became associated with well-known Egyptian female goddesses such as Neith and Bastet. The temple at Kellis is the only surviving temple known to be dedicated to him, and the related inscriptions and images have provided much specific information about this god (Kaper 2003; 319). The temple appears to have been initiated during the first century CE, based on an inscription of the Roman Emperor Nero (54-138 CE) and the discovery of some demotic papyri, which is probably of this date. It probably continued to be used throughout the life of the city (Hope 1999; 223-224).

Fig 1.6 – The baked-brick columns of the Temple of Tutu, probably added in the third century CE (photograph courtesy of the Dakhleh Oasis Project)

The northern area of Kellis is dominated by three large building complexes; the southern most of which consists of 216 rooms, courts and corridors, some preserved to a second floor level. It was probably the centre of administration for the town; however, during the fourth century CE, it appears to have ceased this function, now being used for domestic purposes, including the stabling of animals (Hope 1999; 224).

The east and central areas of the town are residential sectors, the houses of which are single story, some preserved to roof level. Most of the wooden roof beams, doorframes and doors have been removed, probably at the time the town was abandoned. However, numerous artefacts, such as clothing,

jewellery, coins, furniture, pottery and documents were left behind. The documents have enabled an incredible insight into the lives of the Kellis population; written in Coptic, Greek and Syriac, they include private letters, economic statements and literary texts. Translation of these documents reveals that Kellis was the centre of a regional economy that was agriculturally based. It traded with other villages and towns in the Dakhleh Oasis, as well as with those in the Kharga Oasis (Hope 1999; 225).

The site was occupied from the late Ptolemaic Period, based on the discovery of burials and demotic inscriptions from this time. It was abandoned in the final years of the fourth century CE; the latest text that can be dated is a horoscope drawn up in the year 392 CE (Hope 2002; 205-206).

1.2.3.1 – Food in Kellis
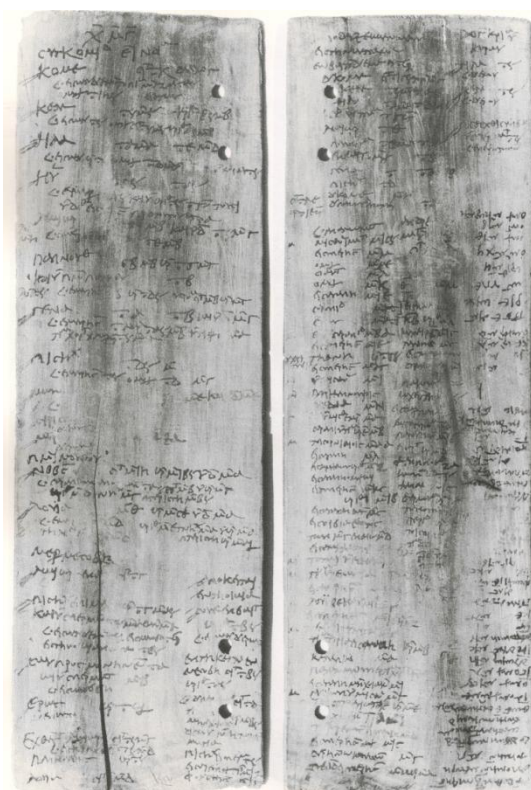
Fig 1.7 – The wooden boards of the Kellis Agricultural Account Book (Bagnell 1997; pl 6)

Kellis was a town based on agricultural production and most of inhabitants were not of high status (Mills 1999; 173). A lot of information, in the form of botanical and faunal remains and written documents, is available regarding diet, suggesting the population of the town had access to a wide range of produce.

Our knowledge of the agricultural products of the Kellis' past is greatly assisted by the 1988 discovery of the Kellis Agricultural Account Book (KAB). This remarkable codex consists of eight acacia boards, on which 1700 lines of accounts relating to agricultural production, estate management and tenancy agreements over a three-year period dating to the second half of the fourth century CE. The 'income crops' listed in the KAB include grapes (used to make the renowned Oasis wine), hay, figs, dates, jujubes, cotton, turnips, and the so-far unknown tiphagion. Crops, which were produced on a lesser scale, include sesame, onions, legumes (lentils and beans are not mentioned), cumin, safflower and fenugreek. Animal products of cheese, butter and chickens are also cited (Bagnall 1999; 115-116). A summary of the agricultural products is produced in Table 1.1 below.

In addition to the products listed in the KAB, numerous botanical and faunal remains have been discovered. Not only do these remnants provide evidence of other agricultural products available within the Oasis, they can also allow species identification of the items cited in the KAB. For example, three species of wheat have been recorded as part of the botanical assemblage – bread wheat being the most common, followed by hard wheat and only rare finds of emmer wheat, which, up until the Graeco-Roman Era, was the only wheat crop harvested by the Egyptians. Table 1.2 below lists the main plants that have thus far been excavated and identified in Dakhleh.

The faunal assemblage also sheds light on the diet of the ancient population of Kellis. The four most common taxa are pig, cow, goat and chicken, with less regular finds of rabbit and dorcas gazelle bones, all found with evidence of butchery marks and some charring. Chicken eggshells have also been found in rubbish dumps; however, it is not known whether these were eaten or just the remains of hens' nests. Surprisingly, the finds show that fish (Nile perch and Nile catfish) was a fairly common item on a Kellis menu, in dried form, imported from the Nile Valley (Churcher 2002; 105-106).

The evidence in the Kellis Agricultural Account book as well as the archaeological botanical and faunal remains, suggests that the inhabitants of Kellis enjoyed a wide range of produce, which should have provided them with all the necessary nutrients needed for a healthy life. However, a study of the human remains from the Kellis 2 Cemetery by Fairgrieve & Molto (2000), found

that the population suffered from widespread anaemia, suggesting there was a lack of iron (found in protein-rich foods) in the diet. Pulses were certainly missing from the botanical assemblage, however, there appears to be access to protein in the form of meat, fish, milk and possibly chicken eggs. The Kellis 1 mummies, including the sub-adults, do not show signs of the widespread anaemia and the reason for it is unknown.

Plants	Processed Foods	Animals
Wheat	Olive oil	Cows
Chaff	Wine	Chickens
Barley	Vinegar	Pigs
Hay	Honey	Donkeys
Green fodder	Butter	Pigeons
Arakia (legume)	Cheese	Sheep
Fenugreek	Stagma	Horses
Safflower	Oregmos	Camels
Sesame	Porridge	
Cotton		
Turnips		
Tiphagion		
Onions		
Vetch		
Figs		
Dates		
Date stones		
Doum palm		
Olives		
Jujubes		
Cumin		

Table 1.1 – Plants, Processed Food and Animals cited in the Kellis Agricultural Account Book (Bagnall 1999; 122)

Field crops	Garden plants	Fruits and nuts	Other plants
Einkorn	Fenugreek	Pine	Pepper
Emmer wheat	Bottle gourd	Hazelnut	Myrrh
Hard wheat	Sesame	Fig	Nile acacia
Bread wheat	Celery	Walnut	Camel thorn
2-rowed barley	Anis	Apple	Clover
4- and 6- rowed barley	Coriander	Almond	Tamarisk
Barley	Rosemary	Apricot	Sedge
Lentil	Safflower	Peach	Papyrus
Broad bean	Artichoke	Carob	Club-rush
Linseed	Onion	Pomegranate	Wild oat
Flax	Garlic	Citrus sp.	Halfa grass
Cotton		Pistachio	Common reed
		Nabakh	Foxtail millet
		Grape	
		Olive	
		Doum palm	
		Coconut	
		Date	

Table 1.2 – Botanical Assemblage from Kellis (Bagnell 1999; 122)

1.2.3.2 – The Ruin of Ismant

Kellis, it appears, was abandoned at the end of the fourth century CE, for reasons as yet unknown.

The current condition of the site suggests that it is the result of a particular sanding situation involving rapid burial followed by gradual deflation. Whether this process contributed to Kellis' abandonment is unknown but it appears to have been the dominant cause of the town's extremely impressive preservation. Once abandonment occurred, burial by wind-blown sand quickly followed, preserving structures up to four metres high. On the negative side, the combination of sand and wind has also caused the erosion of the tops of walls in a process called deflation, which still continues today. Like many Roman Period sites, the mud-bricks used to construct Kellis were a mixture of mud and pottery sherds, the eroding wind and sand depleted the mud matrix

leaving the sherds scattered on the surface in ever-increasing numbers (Knudstad & Frey 1999; 191).

In spite of these eroding forces, today the town remains in remarkable preservation, enabling all accessible architecture to be traced and recorded. There has been a wealth of material excavated from the site. In residences, temples and churches, detailed decorations remained, as well as ostraka, coins, worked wood, statuettes, textiles, rope, baskets and sandals, many of which were still intact.

Figs 1.8 & 1.9 – Decorated wall and pottery excavated in the Kellis settlement site (Photographs courtesy of Dakhleh Oasis Project)

An architectural survey carried out by Kundstad and & Frey (1999) reveals that Kellis grew to a major local size and stature, enjoying religious and administrative importance. The abandonment of the town cannot be confirmed but environmental conditions most likely played a large part. As well as the constant accumulation of sand that would have plagued Kellis, it is possible that this coincided with the over exploitation of water resources (Knudstad & Frey 1999: 200). During the Roman Period, there was a considerable expansion of agriculture in the Dakhleh Oasis thanks to the introduction of the water wheel (saqiya). Over a number of centuries, the increase of the agricultural demands being placed on the land may have lead to soil depletion and salination. Only continued research could confirm or deny this suggestion.

The extraordinary preservation of the Kellis settlement site has allowed an exciting opportunity to investigate life in a Saharan town during a time when the traditional practices of Egypt were mixing with classical ones. The occupation of the town through the transition to Christianity is another fascinating facet added to an already rich history.

How people lived in Kellis becomes more apparent with each season of excavation of the town, similarly, the adjoining cemeteries and their occupants, who also display exceptional levels of preservation, can enlighten us on how they died.
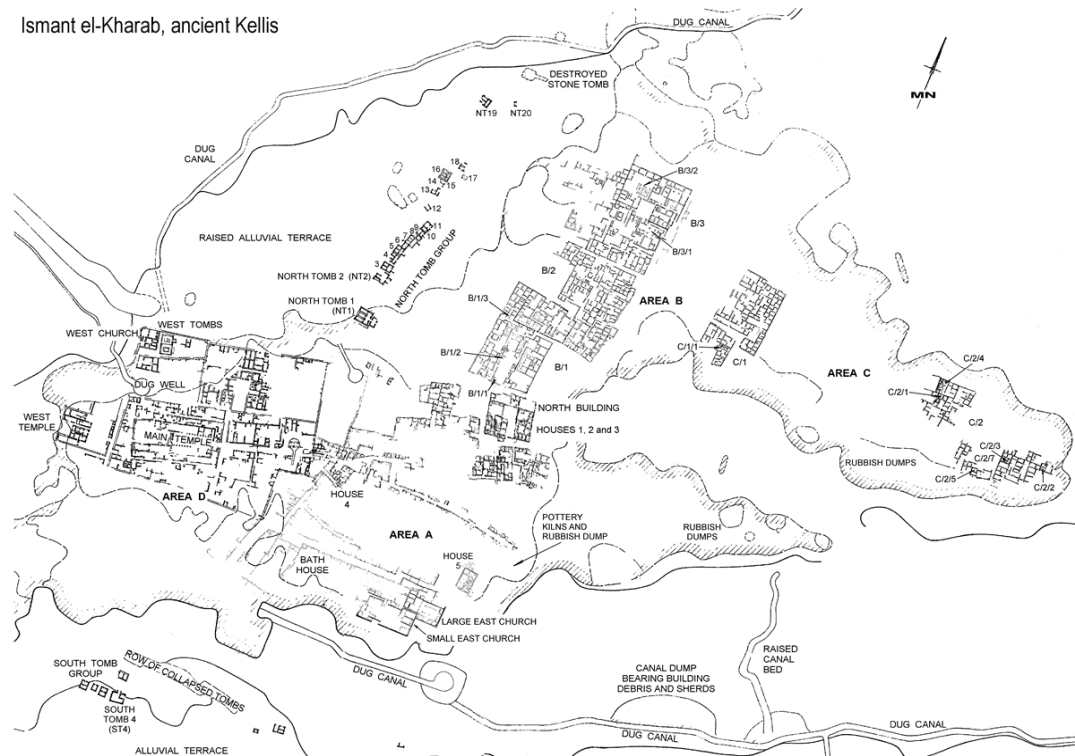
Fig 1.10 – Map of Kellis – Western Cemetery not shown (photograph courtesy of the Dakhleh Oasis Project)

1.2.4 – The Cemeteries

While many tombs are associated with the township of Kellis, there have been two main cemetery sites located to the North of the settlement site, either side of the wadi, which runs from the north-east to the west of the town. Both have been the subjects of excavation by the Dakhleh Oasis Project during the 1992-1993 and 1998-1999 seasons (Birrell 1999; 29).

The West Cemetery, designated as Kellis 1 (31/420-C5-1), was discovered in 1992, during a walking survey of the area. Scraps of textile and skeletal remains alerted the excavators of its contents (Dupras 1999; 150). On the basis of ceramic material and other artefacts, the Kellis 1 cemetery has been assigned a date range of late Ptolemaic to the early Roman Period (Birrell 1999; 29).

The Cemetery is situated in a progression of low hills to the northwest of Kellis Township. The hills are relatively steep, rising six to eight metres above the wadi

bed to a height of 126 metres above sea level. The geology of the area is made up mainly of red Nubian clay. The 21 tombs that have thus far been excavated have either been cut entirely into the red Nubian clay or dug into clay of a higher sandstone level (Birrell 1999; 31). All tombs have very low ceiling and are mostly single chambered. One to 42 individuals have been interred in each tomb; the latest inhumations frequently placed on the top of previous burials (Dupras 1999; 150).

The tombs that have been dug entirely into the red clay hills are situated in close proximity, taking advantage of all the available space. They follow the contours of the hills with no particular orientation. Each tomb has a deep narrow entrance passage, for example, Tomb 9's entry passage is 130 centimetres long and 70 centimetres wide. Some tombs had a mud-brick arch placed over the entrance; others show evidence of once including wooden doors. The shape of these tombs is similar to those excavated in 'Ein Tirghi dated to the Ptolemaic Period based on the ceramic finds at the site (Birrell 1999; 32).

Fig 1.11 – Tomb entrance in the Kellis 1 Cemetery (photograph courtesy of the Dakhleh Oasis Project)

The Kellis 1 tombs that were cut into a sandstone terrace are less regularly spaced, displaying no regular orientation, rather following the shale stratum. The entrance to each tomb was blocked by a sandstone slab positioned against the outer face of sandstone doorjambs, or a block inserted into a

groove in the doorjambs. The entry passages consist of a circular or roughly squared pit up to 80 centimetres in diameter and usually about 30 centimetres deep. The tomb chambers are very small, consisting of roughly carved rectangular rooms. A typical example of size is Tomb 8, measuring only 370 by 220 centimetres, with a ceiling height of 98 centimetres (Birrell 1999; 33).

All of the Kellis material examined as part of this project came from the Kellis 1 Cemetery.

The East or Kellis 2 Cemetery (31/420-C5-2) was also discovered as part of a walking survey in 1991. Archaeologists could see that the extensive wind erosion had exposed several graves and many human bones were visible on the surface in the western part of the Cemetery. Radiocarbon results date the Kellis 2 Cemetery to 250-450 CE, the Romano-Christian Period (Dupras 1999; 156).

The East Cemetery is situated on a low-rise approximately 200 metres north east of the township. So far, 450 burials have been excavated, however it is believed that the Cemetery could contain up to 5000 individuals. The burial style differs from those in Kellis 1, demonstrating the shift in the population from pagan (Kellis 1) to Christian (Kellis 2). There may have been some overlap in the dates of the two cemeteries, however, if so, these would have been in the minority. Each burial is a single interment of an east-west orientation, with head facing toward the West. The bodies would have been simply wrapped, although much of the textile material did not survive except for some loose linen bandages around the feet of some adult skeletons. The action of the ground water has reduced the bodies to skeletons but they many are undisturbed. None of the bodies appeared to have been decorated with jewellery or amulets (Birrell 1999; 41).

Three types of burial have been identified within the Kellis 2 Cemetery. The first type makes up the majority of interments and consists of a plain grave in which the individual had been placed in an extended supine position; the hands are placed over the pubic region or beside the thighs. In the majority of female burials, the former position is the most common. A single grave good was found in these burial types (grave 24), a rectangular green glass bottle placed in the burial of an adult female. Several of the graves had been disturbed,

suggesting that tomb robbers knew where to strike. None of the undisturbed graves contained grave goods of any kind (Birrell 1999; 41).

The second type of Kellis 2 burial consists of a mud-brick super structure, on the top of which is a false bottom. After the body had been placed in the grave, a layer of mud-bricks with an A-frame roof structure would have been built around it. This was then covered with a mixture of dirt, stones and gypsum, imitating the actual grave bottom and giving the appearance of hard bedrock. It was probably hoped that this would put off would-be thieves, as bedrock would be hard to penetrate. However, several of these structures had been damaged, a further indication that the tomb robbers had prior knowledge, which assisted them to focus their actions (Dupras 1999; 160).

The final type of burial of the Kellis 2 Cemetery was marked by the inclusion of pigeon pots (used for raising pigeons) and water jars (used to hold different types of liquid and dry goods) near the surface of the grave. These were most commonly found as single items placed near the top of the burials of infants or children (near or over the face), however, one adult female (grave 55) had large fragments of three pigeon pots and a large painted jar covering her torso and legs. A lower section of a fifth container was placed upright, covering the face of the deceased (Birrell 1999; 41).

The cemeteries were not the only burial spots connected to the town of Kellis. Burials have been uncovered in the church complexes and there are two other major tomb groups designated as the North Tomb Group and the South Tomb Group.

The North Tombs are grouped along a major approach to the northwest area of the town, while the South Group is located immediately to the southwest. Nineteen of the North Group mausolea are still in a good state of preservation and traces of a further seven can be made out, while many of the mausolea from the South Group are poorly preserved, leaving the exact number of them unknown (Knudstad & Frey 1999; 208-213). The artefacts found in the tomb (and others in the North and South Tomb Groups) attest to its use from late first to fourth century CE (Hope 2003; 284).

The North Group Tombs vary in size and plan but collectively represent a basic structure type as well as a burial tradition common to a relatively affluent social

group. Tomb 1 is the largest of these measuring approximately twelve metres^2, to a height of five metres. It includes an elaborate free-standing forecourt, in which the remains of ten columns can be seen. It was plastered and painted in reds and yellows.

While the human remains within the North and South Tombs were mostly in disarray, the difference between these tombs compared to the Kellis 1 Cemetery is clear, and it is likely that these tombs represent the more elite members of society and the Kellis 1 was reserved for the common people of the town.

1.2.5 – The Mummies

All tombs within the Kellis 1 Cemetery had been looted in antiquity.

When sand was removed from a number of tombs located within the Kellis 1, or Western Cemetery during the 1993 and 1998 excavation seasons, a substantial number of bodies, distributed chaotically, were discovered. Many of the bodies had been placed on small sandstone blocks or large pottery sherds. In total, 150 bodies were found however only 49 of these could be termed 'mummy', the remaining 100 only skeletally preserved in various levels of articulation. The 49 mummies (partial and complete) were examined by A C Aufderheide, L Cartmell and M Zlonis in the field and samples obtained for further study at a later date (Aufderheide et al 2003; 141).

Most of the Kellis 1 tombs had been sealed with a sandstone slab, which proved to have not been secured with sufficient effectiveness and had allowed the drifting sand to fill much of the tomb space. The bodies had not been placed in coffins or other forms of container, although most had been simply wrapped and some had evidence of cartonnage coverings. This means that when the bodies were placed in the tombs, there was little between them and the hot dry sand. Therefore, desiccation should have been quick and effective; however, the majority of the bodies that have thus far been excavated consist of skeletal remains, suggesting that putrefaction or decomposition had taken place, possibly even before the deceased were placed in the tomb. It is also possible that the poorly preserved individuals died during the winter season when the sands would not have been as hot, and the fluctuations in temperature vary greatly, or, these tombs may have been

sealed efficiently, not allowing the sand to blow in and cover the body. According to M Birrell (1999; 35), the field archaeologist of the Kellis cemeteries, some of the bodies showed evidence that they had been desiccated in the tombs and the best-preserved bodies had been treated with resin painted onto the skin's surface. Some of the very poorly preserved bodies had been stabilised by the insertion of palm ribs down the spinal column. It is possible this was carried out after looting in antiquity.

The pattern of disturbance to the bodies suggests that looting was carried out in order to appropriate any jewellery or amulets that had been placed with the deceased. Many of the heads had been exposed as though the looters were searching for necklaces. Many of the heads had actually been twisted off the body, judging by the appearance of the soft tissues at the separated edges of the neck (Aufderheide et al 2003; 137). While some heads remained attached to their related bodies by only a thin band of soft tissue, other bodies had been completely separated from their heads, making identification of the correct head and body configuration impossible. It was also common for hands, feet and other extremities to be disarticulated, as the robbers searched for valuables (Aufderheide 2003; 137). No jewellery or amulets have been discovered in either of the Kellis cemeteries so it cannot be confirmed whether the looters were successful or if the Kellis deceased were buried without such adornments.

The application of resin was the most common feature of the Kellis 1 mummies. During the 1993 and 1998 autopsies, the dissectors noted that all mummies showed evidence of resin having been painted onto the skin's surface (autopsy reports 1993 & 1998). Some bodies had also had resin poured into the internal cavities (cranial, thoracic and abdominal). Aufderhiede et al (2003; 149) believed that this resin had been applied sometime after mummification had taken place, possibly as part of an attempt to reconstruct the bodies after looting. It is not possible to confirm or deny this suggestion; the mummies from Kellis 1 could have been originally buried with resin applied or at a later date. It is also clear that resin had been used to hold the wrappings in place.

The dependence on abundant applications of resin is a characteristic of the Roman Period. During the Middle and New Kingdoms, for artificial mummification, the desiccation of soft tissue was achieved by the packing of

the sodium carbonate-derived ore, natron, around the body after evisceration. By the Late Period, and especially during the Roman Era, the use of natron subsided as the dependence on resin took over (Ikram & Dodson 1998; 95). At Kellis, the desiccating effect of natron was unnecessary, due to the hot sun and dry sand; resin may have been used for its anti-bacterial effects or as a moisture-repellent to prevent rehydration of the already desiccated deceased, or simply as a means to secure bandages during wrapping (Aufderheide et al 2003; 149).

A study by Maurer et al (2002) analysed samples of the resinous material from four of the Kellis 1 mummies (see below):

Mummy Identification	Sample Used
Mummy A3	Resin-soaked cloth from chest
Mummy A5	Resin lump and dark material from cranial cavity
Mummy A7	Dark material from cranial cavity
Mummy A9	Dark material from chest cavity

The samples were analysed for soluble lipids with the aim to identify the materials used for embalming. The results showed that the dark material was an inhomogeneous mixture of soluble and insoluble matter. The insoluble residue consisting of carbonised plant material (Mummies A5 and A7) or sand (Mummies A3 and A9). The soluble material consisted of plant-derived material, mainly that of coniferous trees. Mummy A3 contained evidence of palmitic acid, possibly originating from bees wax. Based on these findings, the embalming material used on Mummies A9 and A3 (chest samples) is identical as is that used on Mummies A5 and A7 (cranial samples) (Maurer et al 2002; 761). This suggests that the resin used in the mummification of the Kellis 1 mummies must have come from limited sources, which is unsurprising, given the location of the cemetery.

The textiles used to wrap the Kellis 1 mummies varied in shape - from band-like strips (four to eight centimetres wide) to broad sheets the size of the body, some of which had been patched together in order to achieve the large size. None of the wrappings were of any uniform size. Many of these larger pieces had utilitarian purposes before being employed on the deceased as evidenced by the numerous patches. All wrappings were linen. The textiles

closest to the skin were more likely to be coarser than the surface layers. Variation in wrapping, especially around the head was not uncommon. During the wrapping, resin was periodically applied, the amount varying from a thin layer to large amounts, able to soak through many bandage layers. Unlike many other Roman Period site burials, no evidence of geometric patterns or other wrapping patterns could be identified. No inscriptions were found on any of the Kellis 1 textiles (Aufderheide 2003; 141).

All mummified bodies had their cranial cavity pierced by a trans-nasal craniotomy through the ethmoid bone (for further discussion, see Chapter 4.1) (Birrell 1999; 35).

Of the 49 mummies examined, Aufderheide et al (2003) identified seven distinct mummification patterns. These are described below:

Type One bodies were little more that disarticulated bones with no soft tissue preservation. No human intervention to arrest decay had been undertaken and the environmental conditions were ineffective to cause rapid desiccation. No Type One bodies were used in this project.

Fig 1.12 – Type One (photograph courtesy of A C Aufderheide)

Type Two bodies were also disarticulated bones with no soft tissue preservation; however, these bones had been tied to a wooden rack and then wrapped to give the appearance of a mummified adult body. There is only one body of this type (Mummy A15), which actually is made from parts of four different bodies, the femur of which was used in this project.

Fig 1.13 – Type Two (Mummy A15) wrapped (photograph courtesy of A C Aufderheide)

Fig 1.14 – Type Two (Mummy A15) unwrapped (photograph courtesy of A C Aufderheide)

Type Three bodies retain varying degrees of soft tissue preservation and some visceral organs were present. There is no evidence of resin applied either externally on the skin's surface or internally over the body cavities. No effort had been taken to preserve the body and the preservation that occurred was entirely due to the effect of the environmental conditions at the time of burial. No Type Three bodies were used in this project.

Fig 1.15 – Type Three (photograph courtesy of A C

Type Four bodies are identical to Type Three bodies except in these a thin layer of resin had been applied to the skin surface. It is not possible to know whether the resin was applied at the time of burial or later. It is possible that the resin layer was used to hold the first layer of wrappings in place as it would have no effect on assisting body preservation. There is no evidence on resin on the visceral organs and the presentation pattern is that of spontaneous mummification. It is possible that these bodies have spontaneously mummified in favourable environmental conditions and then, at a later date, perhaps after

looting, have been painted with a thin layer of resin. The majority of the samples (nine) used for this project are Type Four mummies.

Fig 1.16 – Type Four before autopsy (photograph courtesy of A C Aufderheide)

Fig 1.17 – Type Four after autopsy (photograph courtesy of A C Aufderheide)

Type Five mummies have both external and internal resin application although the visceral organs display the pattern of spontaneous mummification patterns. These mummies demonstrate the contradiction of the evidence of burial with no human effort in the form of evisceration in order to retard decay. There is, however, evidence of anthropogenic mummification in the form of extensive resin application. The suggestion by Aufderheide et al (2004) is that the body was interred, placed in the usual supine position and without any human effort to preserve it, spontaneous mummification took place.

Fig 1.18 – Type Five (photography courtesy of A C Aufderheide)

Fig 1.19 – Cranial cavity of Type Five with evidence of resin application (photograph courtesy of A C Aufderheide)

Some time later, probably after the looting of the tomb had taken place, the mummies of Type Five were 'repaired' by the extensive application of resin via atypical port of entry. These atypical ports included defects in the back, the mouth and the anterior chest wall. Five Type Five mummies were used in this project.

Type Six bodies had been anthropogenically mummified, that is, they were eviscerated at the time of death and extensive applications both externally and internally in an effort to preserve the body's soft tissue. The mummification methods used in both Types Six and Seven are indistinguishable from those employed by the contemporary Nile Valley embalmers. The Type Six bodies remained undisturbed until the time of excavation, except for some violation of the external wrappings. Both Type Six and Type Seven bodies had been prepared with a high level of professional skill; evisceration was via an abdominal incision and resin was generously painted on the skin surface and poured into internal cavities.   This resin was comprised mainly of sap from coniferous trees such as cedars or pine with small amounts of beeswax and fossil hydrocarbons (bitumen) (Aufderheide et al 2004; 91). One Type Six mummy was used in this project.

*Fig 1.20 – Type Six (photograph courtesy
of A C Aufderheide*

Type Seven mummies were prepared identically to those of the Type Six pattern; however, unlike the Type Six bodies they had been extensively looted some time after interment. When this looting was discovered in antiquity, attempts were made to reconstruct the dismembered bodies by rejoining their various components by splinting them together with wooden sticks and then rewrapping them. In some of these reconstructions, it would appear that heads had been returned to their original bodies and are therefore, better termed composite mummies (Aufderheide 2003; 150). Two Type Seven mummies are used in this project.

*Fig 1.21 – Type Seven (photograph
courtesy of A C Aufderheide)*
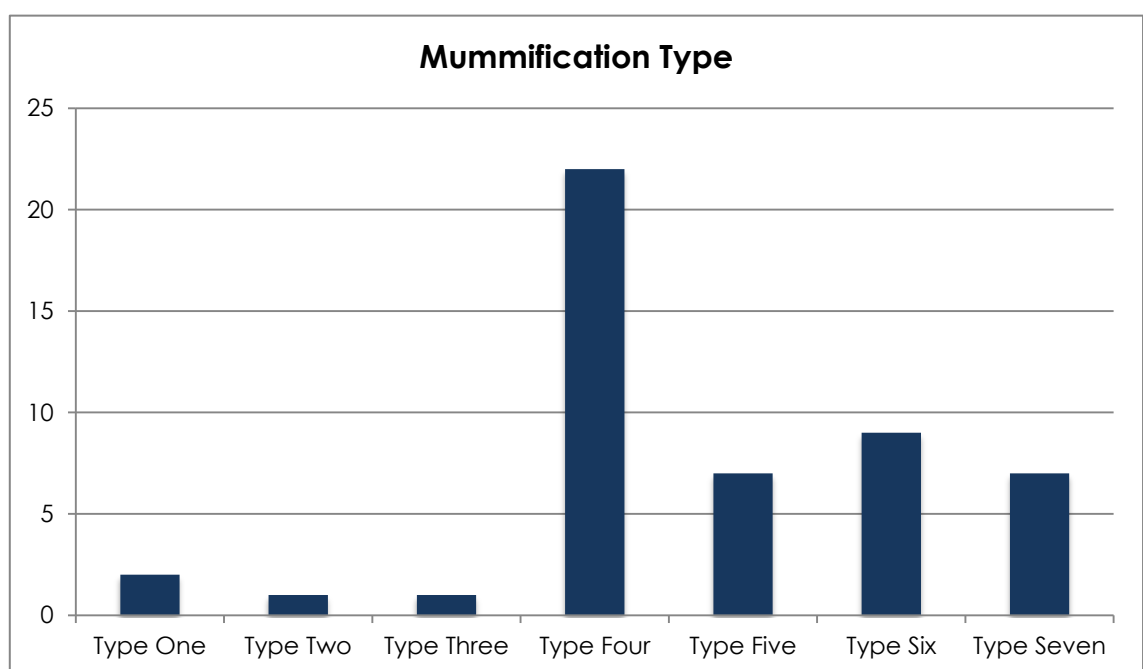
*Fig 1.22 – Chart of the types of mummification in the Kellis 1 Cemetery
(N = 49)*

1.2.5.1 – Cultural Objects

There were cultural objects of some sort placed within all the tombs. Each tomb had the remains of painted and gilded cartonnage fragments, including some complete chest and foot covers. These were decorated with images of *ba* birds, as well as the god Tutu, the main deity of Kellis. A number of wooden statues were found; one depicted a jackal, probably Anubis and more *ba* birds. Two sandstone offering tables were discovered in the entrance of one tomb, on which reliefs of loaves of bread were depicted. Ceramic items were also found in four of the tombs, mainly jugs. Each tomb contained small bouquets of rosemary (Birrell 1999; 36). A study of these objects suggest that

these tombs were in use from the Ptolemaic Period, however the body position and mummification types are much more like those of the early Roman Period. No objects, other than textiles, were associated with the ten mummies chosen for this project as case studies and therefore could offer no clues to the social status of the individuals.

1.2.6 – Data Sources

The information relating to the mummies of the Kellis 1 Cemetery is vast. Research has been undertaken on the human remains from both the Kellis 1 and Kellis 2 Cemeteries and excavations of the settlement and cemetery sites have been ongoing since 1985 involving a wide range of disciplines including zooarchaeology, archaeobotany, architecture, ceramics, osteoarchaeology, and textual analysis. Despite its desert location, Kellis had substantial contact with the Nile Valley and therefore, with a degree of caution, sources from the Valley (tomb scenes, archaeological artefacts, texts, etc) can be used as comparison or to inform the results of this project.

1.2.6.1 – Excavation Reports

The town and cemetery site of Kellis (Ismant el-Kharab) has been under intense archaeological investigation by the Dakhleh Oasis Project (DOP) since 1981. This has included mapping, architectural surveys, excavations of both settlement and cemetery sites, analysis of the faunal assemblage (ancient and modern), recording of the botanical finds, translation of written material and examination of the human remains. The DOP aim to have their results published and available in the public domain as soon after excavation as possible, therefore, there is a large amount of information on the site, the population and the environment available.

Being able to access such a variety of excavation data is an advantage when histologically examining the human remains, for example, the plant material in the coprolite samples, such as the remains of cereal seeds, can be broadly identified due to the recorded ancient botanical assemblage and the available translation of the Kellis Agricultural Account Book.

1.2.6.2 – Human Remains

One of the most important sources of information used in this project has been that of the reports filled out during at the time of autopsy. These reports have been an invaluable tool recording information including:

- position of the body in the tomb
- state of the body at the time of excavation and autopsy
- cultural objects connected to the bodies
- age at death estimations
- sex
- samples taken at autopsy
- skeletal pathology
- dental pathology
- evidence of excerebration
- resin application patterns.

The first fifteen autopsies took place in 1993, the final 34 in 1998. The reports from the 1993 autopsies are particularly useful as they include tomb and body numbers, however, recording of these does not continue with the second group.

Being able to go back to the autopsy reports has been especially useful when, for example, the epidermis no longer remains on a skin sample, however the sample itself is in a good state of preservation; the report records whether the body was wrapped at the time of burial, and later unwrapped at excavation or autopsy. The removal of the textile bandages from the body is one explanation for the epidermis to be absent, as it adheres to the wrappings and is removed accordingly.

The human remains from both the pagan Kellis 1 and the Christian Kellis 2 Cemeteries have been the subjects of much previous study. For example, Dupras (2001; 1199-1208) investigated the stable light isotope values for a number of samples from both Kellis1 and 2 samples, however, the Kellis 1 samples proved to be too degraded to be successful. The Kellis 2 results demonstrated that migration from the Nile Valley into the Oasis had occurred. Dupras et al (2001; 204-212) investigated the weaning habits of the population, finding that infants were breastfed for six months and fully weaned by the age of three, however, again only Kellis 2 samples were used. Fairgrieve & Molto (2000; 319-331) undertook a study of the Kellis 2 skeletal material in order to

investigate the condition cribra orbitalia, a clinical sign of anaemia, and finding it to be widespread within the Kellis 2 population. Studies such as these are useful for comparing and contrasting results from the current project.

Aufderheide et al (2003; 137-151) and Birrell (1999; 29-41) give descriptions of the bodies at the time of excavation and the mummification methods used, useful information when assessing the possible reasons for the preservation levels of the samples used in the histological examination.

1.2.6.3 – Nile Valley Sources

The Dakhleh Oasis lies approximately 350 kilometres from Luxor (Thebes) and 800 kilometres from Cairo (Memphis). However, the substantial contact between the Nile Valley and the Oasis throughout Egyptian history means that information from Valley sources can, and should, be used in the study of the Kellis population.
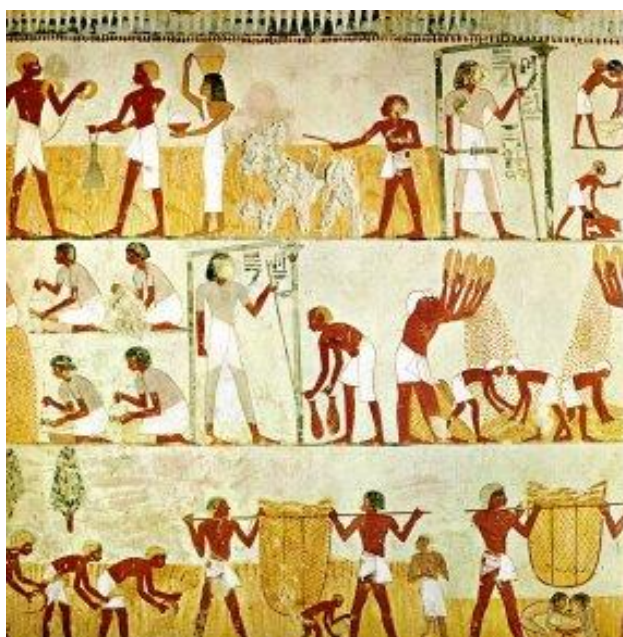
Fig 1.23 – Tomb scene of grain production – tomb of Menna (18th Dynasty) (www.mennaproject.com)

The magnificent scenes on the tomb and temple walls in the Nile Valley provide information on how ancient Egyptian society was constructed, what people did, what they ate, how they celebrated, mourned and interacted with each other and their environment. While the scenes need to be viewed with a certain degree of caution as they mostly depict the lives of the ancient

Egyptian elite, scenes, such as those of agriculture and food production, have enabled insight into these, and many other processes.

The human remains from the Valley necropolises are also useful for comparative and contrast purposes in terms of burial customs, mummification techniques and disease patterns.

While the excavations at Kellis have uncovered a vast amount of written material covering nearly every facet of the lives of the inhabitants, there has been little found in the way of medical prescriptions or processes, only two short descriptions of illness have been uncovered thus far; both for amulets to be worn as protection against a fever (Worp 1995; 214-218). The medical papyri found in the Nile Valley are useful resources when investigating diseases of the soft tissues, such as anthracosis. While the diseases are not directly named in the papyri, the frequency the related symptoms are mentioned and the treatment thereof, gives valuable insight into the commonality of certain ailments and what beliefs the Egyptians attached to them.

All these available resources enable a fairly full picture of the lives and deaths of the people from the Roman Period town of Kellis in the Dakhleh Oasis. The question is – can a histological examination of the mummies from the Kellis 1 Cemetery add anything to this picture? And, is it possible for histological and archaeological results to combine for this to occur?

1.3 – The Use of Histology in Mummy Studies

Gross examination of mummies provides the basis for palaeopathological studies; however, palaeohistology can extend such observations substantially, as well as adding many new ones, many of which would be undetectable by any other means. Before the discovery by Marc Almond Ruffer of a way to return the hard brittle mummified soft tissue to a form as close to fresh tissue as possible, no cellular analysis of human remains was possible (Benson 1995; 67).

1.3.1- Mummy Studies before Marc Armand Ruffer

Occasional examinations of mummies were carried out in the eighteenth century; however most of these went unrecorded and it was not until the nineteenth century that mummy studies became more common and added the element of scientific investigation (Halioua & Ziskind 2005; 53).

The English physician Dr Augustus Granville performed the first recorded autopsy and examination of an Egyptian mummy in 1825. The mummy was thought to be from Thebes belonging to the Ptolemaic Period, which Granville had purchased in Thebes for four dollars in 1819. As part of the autopsy, Granville undertook a careful macroscopic study; a result of which was a diagnosis of a large ovarian cyst, which he concluded was the cause of death, although this diagnosis is now thought to be wrong and the tumour was benign (Sandison 1955; 81). For all his errors (Granville also believed that the greasy substance found on the surface of mummies was related to the type of embalming materials used, when it fact, it was adipocere produced by the body), using such a detailed examination technique and recording, Granville greatly advanced the scientific study of mummies (Brier 1998; 60).

In the same era as Granville, another English physician, Thomas Pettigrew, was conducting the unrolling of mummies in London; the first being in 1833 in front of a packed audience at the Charing Cross Hospital (David 2008; 3). While these unrollings had a large element of public entertainment, Pettigrew connected his unrollings to a series of six lectures of two to three hours in length. The first five lectures covered a variety of aspects regarding ancient Egypt, while the final one was reserved for the unrolling (Brier 1998; 140).

The first microscopic study of ancient Egyptian human mummified tissue was in 1852 by Johan Czermak, a distinguished Viennese laryngologist, who studied two Egyptian mummies. He used a simple but effective method by teasing out mummified tissue (tendon, cartilage, nerve, muscle and fat) in a caustic soda solution and then made detailed drawings of the tissues' microscopic structure (Sandison 1967; 151). Czermak was also the first person to use a micrometre in a study of this kind. A micrometre is an instrument used to make very precise linear measurements of dimensions, such as diameters, thickness and lengths of solid bodies. It consists of a C-shaped frame with a movable jaw operated by a screw (MacAdam & Sandison 1969; 81).

The study of ancient Egyptian mummies was quick to make use of the advances in scientific technology. Within four months of the discovery of x-rays by Wilhelm Roentgen in 1895, Walter Koenig produced radiographs of an ancient Egyptian cat mummy (Adams & Alsop 2008; 21).

In 1898, the famous Egyptologist, Flinders Petrie, applied x-rays on the mummies he had excavated from the site of Deshasheh (south of Cairo) (Aufderheide 2003; 2-3). The first royal mummy to be x-rayed was performed by the famous Australian anatomist Grafton Elliot Smith (assisted by Howard Carter) in Cairo, in 1904, of the Eighteenth Dynasty pharaoh, Thutmose IV (Adams & Alsop 2008; 21).

Imaging, including x-ray and now computed tomography, is still a much-used technique in the modern scientific study of ancient Egyptian mummies. Information such as skeletal abnormalities (acquired ante- or post-mortem), number of textile layers and inclusion of amulets within the bandages, can be provided without any disruption to the mummy under investigation, whether wrapped or unwrapped (Adams & Alsop 2008; 40).

Fig 1.24 - Radiograph produced by Koenig in 1896 of a cat mummy (Aufderheide 2003; 13)

During the same time period that Elliot Smith was radiologically investigating the mummies of Egypt, Alfred Lucas was analysing the natron and other

preservatives used to embalm the mummies by using chemical processes (Lucas 1948; 307-377).

In the first decade of the twentieth century, techniques were being explored, with the aim of being able to examine mummified human remains at a cellular level. In 1904, Harris Hawthorne Wilder began to experiment with desiccated skin samples, discovering that using a solution of one to three percent caustic potash was able to restore dry tissue to a more hydrated state, closer to that of fresh tissue (Wilder 1904; 1-17). He first started experimenting with frogs, and then moved onto immersing parts of, or complete bodies in the solution and examining the results (Wilder 1904; 1-2). Wilder met with reasonable success, after rehydration, he embedded, sectioned and stained samples of skin. Many areas of the samples were decomposed and the only identifiable features were blood vessels and connective tissues (Wilder 1904; 5-17).

Fig 1.25 – Head of a prehistoric female mummy from Utah, before and after the potash treatment by Wilder (1904; 17).

In 1909, the same year as Ruffer discovered his rehydration technique, Samuel George Shattock (the Pathological Curator of the Museum of the College of Surgeons) prepared frozen sections of the aorta of the Nineteenth Dynasty Pharaoh, Merenptah (given to him by Grafton Elliot Smith). While the frozen sections were not completely successful, Shattock was able to visualise elastic fibres within the sample (Sandison 1962; 77).

The histology of ancient bone samples has a much longer history than that of mummified tissue. Even though for the best results, bone still needs to be rehydrated and fixed, bone retains much of its original state despite mummification and desiccation.

In 1849, the founder of the Royal Microscopic Society, John Thomas Queckett, was able to observe gross historical details of animal fossils (Stout 1978; 601). In 1878, Dr Chr Aeby demonstrated that the characteristic birefringence seen in fresh bone remained in ancient bones (Aeby 1878; 371-381).

It appeared that bones were impervious to the ravages of time; however a study in 1967 examined the histology and histomorphology of bone samples from a number of sites in Israel and discovered that exposure to moisture was the least favourable condition for bone preservation however, the length of time a bone has been dead seem to have little effect (Salomon & Hasse 1967; 747-54).

Despite this experimental work by Wilder and Shattock and the long history of histological studies of ancient bone samples, it is only with Marc Armand Ruffer can the discipline of palaeohistology be said to have truly begun (Halioua & Ziskind 2005; 60).

1.3.2 – Mummy Studies and Histology

The first major histological study of ancient Egyptian human remains was the now famous undertaking by Marc Armand Ruffer in 1909, and it was he that more than anyone else that is responsible for the advancement of histological knowledge.

Ruffer was born in France in 1859, and his early education was in France and Germany before he moved to England and achieved an Arts Degree at the University of Oxford and then one in Medicine in London. After this, he briefly went to study with the famous Louis Pasteur at the Pasteur Institute (Sandison 1967: 150).

 After contracting diphtheria, Ruffer moved to Egypt to recuperate and fell in love with country, stayed and became a professor at the Cairo Medical School. He was in Egypt at a time when large numbers of mummies were being excavated and as he was a friend of the then director of the Antiquities Service, Gaston Maspero, he was asked to apply his medical knowledge to the examination of the mummies (Sandison 1967; 150).

Ruffer joined the American archaeologist George Reisner and Elliot Smith for the scientific examination the mummies from the extensive excavations in

Nubia in anticipation of the raising of the Aswan Dam (Brier 1998; 140). While Elliot Smith was interested in the skeletal information the mummies provided, Ruffer wanted a way to investigate the bodies at a cellular level.

Ruffer recognised that in order to study the minute structure of mummified tissue, he needed to restore it to as close to the form of modern tissue as possible. Once he discovered a rehydration and fixation solution (see Chapter 2, Table 2.2) that allowed effective results, he stained the tissues using 'ordinary dyes' or those, which were used routinely in modern histology laboratories (Ruffer 1909; 1005). Under microscopic examination, he identified muscle striations, intestinal glands, tubules and glomeruli of kidneys and various layers of the skins of samples from two mummies from the Twenty First Dynasty (1069 – 945 BCE) (Ruffer 1909; 1005).

Fig 1.26 – Sir Marc Armand Ruffer
(Sandison 1967; 153)

Ruffer was not only respected for his pioneering work within the study of Egyptian mummies; he was a bacteriologist and hygienist of international repute. One of his greatest achievements was to rid Egypt of Cholera. Ruffer received a knighthood in 1916, only a year before he died at sea returning to Egypt from Greece, where he had been asked to reorganise the Sanitary Service of the Provisional Greek Government (Sandison 1967; 151).

In 1921, after his death, a collection of articles written by Ruffer was published by his friend and colleague, Roy L Moodie and from that time onwards, nearly every palaeohistological study has referenced this work (Sandison 1967; 151).

After the publication of Ruffer's work in 1921, the study of mummies in the second quarter of the twentieth century lost momentum. This can be put down to a number of reasons; firstly the death of many of the pioneers of this work including Grafton Elliot Smith in 1937, George Reisner, the American

archaeologist in 1942 and, as stated above, Ruffer himself in 1917 (Aufderheide 2003; 16). Secondly, the two world wars, the subsequent economic depressions, and the political and social instability of the time, severely limited the advancement of research into mummies from ancient Egypt. Finally, the few studies that were undertaken at this time concentrated on skeletal remains. Two exceptions to this was the histological study of the Eighteenth Dynasty mummy, Harmose, carried out by A F B Shaw (1937; 115-123) and the histological investigation of mummies found in Thebes by Gürtler and Langegger (1942: 185).

The second half of the twentieth century saw a renewed interest and remarkable advances in the study of ancient Egyptian mummies including the use of such scientific techniques such as blood antigen serology; using such an attempt was made to establish relationships between Tutankhamen and other possible family members (Connolly & Harrison 1969; 325-326) and, electron microscopy on bone and soft tissue (Lewin 1967; 416-417). The first major example of the use of electron microscopy in palaeopathology is Lewin's study of a mummified ancient Egyptian hand (dated to approximately 600 BCE). After rehydrating, fixing and embedding samples of skin and muscle, Lewin was able to photograph nuclear and cytoplasmic membranes, possible nuclear pores and mitochondrial organelles and tonofilaments (Lewin 1967; 416-417).

Despite being a technique employed in mummy studies since Ruffer's work in 1909, the term 'palaeohistology' was first employed by Wilhelm Graf in 1949, when he was examining the preservation of histological structures of both Egyptian and Swedish mummies (MacAdam & Sandison 1969; 85).

In 1955, Sandison improved on Ruffer's original rehydration and fixation technique (see Chapter Two, Table 2.2), and with this became a leading light in the histological studies of ancient Egyptian mummies and as such, much of his work will be cited throughout this thesis (Sandison 1955; 70).

In the 1970s, histology still had an important role to play in the study of ancient Egyptian mummies; however, the important histological work done during this period was usually as part of a multidisciplinary collaborative research project.

While it is not possible to reference all histological studies of mummified material at this time (many of them will be cited during this thesis), two examples must

be discussed in some detail; the Manchester Museum Mummy Project (MMMP) and the work done by the team assembled by Dr Aidan Cockburn at the Wayne State Medical School and the Pennsylvania University Museum.

The Manchester Museum Mummy Project, under the leadership of Dr Rosalie David, the then Curator of Egypt and Sudan at the Manchester Museum, made headlines with their multidisciplinary mummy research and the autopsy of one the badly damaged mummies (museum number 1770) in 1975 (David 1992; 96). The autopsy of Mummy 1770 was the culmination of the study of seventeen of the Museum's human mummies and 34 animal mummies undertaken from 1973 to 1975. A range of scientific techniques were utilised for the study of the Manchester mummies, including radiography, electron microscopy, dental examination, facial reconstruction, fingerprinting and histological examination (David 1992; 97); the findings of which will be discussed throughout this thesis. The autopsy of 1770 was the first, and last, of its kind at Manchester, with less destructive techniques being favoured for all future mummy research.

Fig 1.27 – Dr Rosalie David during the autopsy of Mummy 1770
(www.archaeology.org/online/features/mummies/jpegs/mummies2.jpeg)

The autopsy of 1770 was used to establish two main aims for the Manchester Museum Mummy Project as a whole. Firstly, to discover more about the life, death and disease of the ancient Egyptian population and secondly, to establish a methodology for examining mummified remains that could be followed by other institutions wishing to undertake similar research (David 1992; 97).

The 1970s investigations were not the first multidisciplinary work to be carried out by Manchester Museum. In 1908, the then Curator, Dr Margaret Murray, assembled a team including a physician, three chemists and two textile specialists, for the public unwrapping of the mummy of one of the Museum's Two Brothers – Middle Kingdom mummies found in a small but well provided tomb in the town of El Rifeh (David 1992; 17). In 1908, palaeohistology was still in its infancy and was not useful in this context but it played a major role in the 1970s investigation (David 1992; 95-96). The findings of both examinations have contributed much to the field of mummy studies and will be discussed in the following chapters of this thesis.

Fig 1.28 – Margaret Murray in 1908 unwrapping one of the Two Brothers
(www.knhcentre.manchester.ac.uk/images/knh/murray.jpg)

In 1979, Manchester hosted the first international symposium entitled 'Science in Egyptology', at which scholars from many countries discussed the application of scientific techniques in the area of mummified remains. Papers from this and a second symposium held in 1984 were published in 1986 (ed. A R David). In 1992, the World Congress of Mummy Studies was first established and held in Tenerife, and is still an important date in the palaeohistologist's calendar, being held every three years in various international locations (the eighth Congress is set to be held in Rio de Janeiro in 2013) (Aufderheide 2003; 19).

In 1991, The Manchester Museum Mummy Project was asked to carry out an investigation into a mummy from the Leeds Museum (United Kingdom). Like the mummies of the Two Brothers from Manchester Museum, an earlier examination, involving specialists from a number of scientific fields, had been undertaken in 1828 by the Leeds Society (David 1992; 59). In 1991, the Manchester Museum Mummy Team were able to compare the findings of the earlier autopsy and include techniques such as histology, which could not be incorporated in the study in 1828, nearly 90 years before Ruffer's work.

The Manchester Museum Mummy Team remain active today under the name of the KNH Centre for Biomedical Egyptology (www.knhcentre.manchester.ac.uk/).

Simultaneously to the early work of the Manchester Museum Mummy Project, was the study in America and Canada led by a British epidemiologist, Dr Aidan Cockburn, based in Detroit. Cockburn, in the 1960s, concentrated on the evolution of infectious diseases, publishing two books in the area (Cockburn 1963 & 1967). In the mid 1970s, Cockburn organised the dissection of a number of Egyptian mummies by a multidisciplinary team that included more than 75 scientific experts (Cockburn et al 1998). From a meeting with the Egyptian Curator at the Pennsylvania University Museum, three mummies were studied by Cockburn and his team, the first of which (PUM II) led to the formation of the Paleopathology Association, which still exists today, with more than 300 members in 25 countries (Cockburn 1978; xviii). Cockburn et al also autopsied and examined the Twentieth Dynasty mummy Nakht, housed at the Royal Ontario Museum, the findings of which were presented in no less than seventeen publications (Zweifel et al 2009; 408).

Other important work in the field of palaeopathology in the second half of the twentieth century includes that of pathologist Dr Michael Zimmerman, whose doctoral studies in 1972 compared experimentally mummified material to that of ancient Egyptian remains (Zimmerman 1972; 271-280). Since then, this has been used as a model for many palaeohistologists when instituting laboratory techniques for the study of mummified material. However, in this thesis, the protocols and methods have been established based upon former histological studies by the Manchester Museum Mummy Project and especially the work of Mr John Denton (2008; 71-82).

Through the second half of the twentieth century, numerous histological studies were undertaken on ancient organic material, provided informative results, which has led to a better understanding of how cultures of old lived and died. However, with the advent of biomolecular techniques, such as ancient DNA recovery and Stable Light Isotope analysis, histology has been utilised much less in the twenty-first century. Histological investigation by the KNH Centre for Biomedical Egyptology continues, unfortunately, much of it unpublished. Zimmerman and David have recently published an article on the lack of cancer in ancient Egypt, using the results of histological examination and analysis of the ancient Egyptian literature (David & Zimmerman 2010; 728-733). However, the histology was done in the 1970s and the paper itself was not well received.

The reason for this decline in the use of histology in the study of ancient mummified material is most likely due to two aspects of the work. It is a destructive technique and, in the past, samples for histological examination were obtained from autopsies of mummies, a practice that is now seen as unnecessary and unethical, especially with the advances made in x-ray and CT scanning. Also, histology requires a laboratory set-up; it is not a technique that can be successfully done in the field. That said endoscopy is now able to obtain samples for histological examination with limited to no damage to the mummies. Also, other sources, such as the contents of canopic jars and embalming caches have the potential for valuable and informative histological work. Histology laboratories are available in hospitals and universities; of course, protocols must be established and the examination of ancient material should never take priority over fresh samples but once these procedures in place, the results of histological examination of ancient material have the potential to provide so much valuable information about the life, and death, of ancient populations.

1.3.3. – The Ethics of Mummy Studies

An understanding of the ethical concerns surrounding the study of ancient Egyptian human remains is imperative for any scholar working in the area.

While there has been much debate in the United Kingdom regarding the use of human tissue from the living or recently deceased, an outcome of which was the release of the Human Tissue Act 2004 (UNESCO 2009; 270). There has been

a lot less analysis when looking at human tissue associated with ancient human remains, especially the moral questions raised.

In 2005, the Department of Culture, Media and Sports (DCMS) released a nonstatutory report giving the legal and ethical guidelines for the museums in the United Kingdom that house collections of human remains. The report acknowledges that ancient human remains have the potential to contribute to research and teaching in higher education; however consideration must be taken because of the personal, cultural, symbolic, spiritual or religious significance of the human remains to individuals or groups (DCMS 2005; 7).

Where sampling of human remains is a factor, the guidelines state that there must be good scientific justification for taking the samples. The guidelines also assert that students working with the human remains must be made aware of their legal and ethical obligations (DCMS 2005; 20-21).

The guidelines also discuss the call for the repatriation of certain human remains. Theses guidelines have been particularly successful in cases such as the return of the bodies of indigenous Australian and the royal mummies of Egypt (DCMS 2005; 3.3.2). Non-royal ancient Egyptian mummies are housed throughout the world and there has not, thus far, been any official talk of repatriation these bodies and, appropriate research on these remains is generally accepted, including in Egypt itself, for example, at the National Research Centre in Cairo, where a number of scientists are currently examining a number of Egyptian human remains (www.nrc.sci.eg/).

The samples used in this thesis were obtained during 1993 and 1998 autopsies of 49 mummies from the Kellis 1 cemetery in the Dakhleh Oasis, Egypt. The autopsies were performed in the archaeological field house in the Oasis and once examined, photographed, recorded and samples taken, the bodies were reburied in their tombs (Birrell 1999; 35). The scientific study of these samples has provided information on aspects of life in Kellis such as diet and disease, as well as mummification processes employed in the Oasis. The author of this thesis remained aware throughout the research that mummified human remains are finite and therefore as little of the material was used as possible. The resulting paraffin and resin blocks of the samples examined have been returned to the International Tissue Bank housed at the University of Manchester for research by

future scholars. One advantage of the work done in this thesis is that the returned samples have all been correctly identified (see Chapter 3.4.1).

CHAPTER TWO – MATERIALS AND METHODS

2.1 - MATERIALS - SAMPLES

The majority of the samples chosen for this project are from the early Roman Period (30 BCE – 250 CE) Kellis 1 Cemetery in the Dakhleh Oasis and currently housed in the International Tissue Bank (University of Manchester, United Kingdom). While accessibility to the samples was an advantage, there were other reasons for the sample choice. Most importantly, Kellis was not just a cemetery site but also an extremely well-preserved settlement site, which has been the subject of ongoing excavations since 1986 by the Dakhleh Oasis Project (Hope 1998: 1). The two connected cemeteries - Kellis 1 and 2 - have been excavated throughout the 1990s (Birrell 1999; 29). This means that there is much available data on how the Kellis inhabitants lived, what they ate, how they worked and thanks to the plethora of written material, even how they thought.

With so much information already available, the results from this project do not have to be viewed in isolation but can be triangulated with historical and archaeological data, hopefully leading to a more complete picture of life, and possibly death, in Kellis.

Thus far, approximately 150 bodies have been excavated from Kellis 1. The majority of these bodies were preserved only as skeletal remains, however also uncovered were 49 complete or partial mummies. These mummies were examined and autopsied in 1993 and 1998. It was at these times that the soft tissue and bone samples used in this project were collected (Aufderheide et al 2003; 141).

At the time of autopsy, the dissectors assessed the level of soft tissue preservation visually as a percentage. They did this by giving five areas of the body (head, chest, abdomen, arms and legs) a score out of five, and then turning the combined score into a percentage. For example:

Head	Chest	Abdomen	Arms	Legs	Final score	Percentage
5	4	5	5	4	23/25	92%

Histology will be a useful tool to see if the visual assessment of preservation levels is accurate.

2.1.1 - Mummification Patterns in Kellis 1 Cemetery

The 49 mummies examined from the Kellis 1 cemetery can be categorised into two major groups:

1) Bodies in which no effort had been made to preserve the soft tissue at the time of burial (Types One to Five - See Chapter 1.2.5)
2) Bodies that had undergone major human effort in order to prevent soft tissue decay, using methods very similar to those of the Nile Valley embalmers (Types Six and Seven – see Chapter 1.2.5).

The account of the mummification methods, recorded in the autopsy reports, for each mummy indicates that there was no pattern regarding age, gender and mummification type; these have been included in the description of the all the Kellis 1 samples because an understanding of the mummification practices performed on each mummy is useful when analysing the microscopic preservation level of the samples. Alternatively, histology may be able to give insights into the mummification processes used at Kellis.

The tables at the beginning of the description of each of the ten mummies that have been used as case studies comply to the minimum standards recommended by Zweifel et al (2009; 416) for case reports, established by Nerlich et al (2000).

2.1.2 – The Case Studies

Although samples were available from all 49 of the Kellis 1 mummies, this project focuses on ten of these. Mummies A1, A4, A5, A8, A13, A101, A102, A108, A126 and A129 were selected for the following reasons:

- Complete or near complete bodies
- Mix of ages and gender
- Very few ante-mortem pathologies had be identified
- No cause of death was recorded.

All samples available from these mummies were examined.

2.1.3 - Comparative Samples

As well as the samples from the ten mummies used as case studies, other samples were utilised for comparative purposes. These samples were taken from the remaining mummies from the Kellis 1 cemetery as well as from the Christian Period cemetery of Kulab Narti (Nubia), a Roman Period settlement site in York (United Kingdom), a Peruvian mummified body and a well-preserved Late Period female mummy (Asru – Museum Number 1777) currently on display at Manchester Museum (United Kingdom).

The comparative samples were chosen for specific reasons; lung samples were chosen to add weight to the general discussion regarding lung disease (Kellis mummies A105, A110, A111, A132), and the intestinal contents and conglomerate samples from Asru, Peru, York and Kulab Natri were compared to the coprolite samples analysed from the Kellis 1 mummies. Other samples from Kellis 1 (for example, A15) were utilised in the Histology Chapter (Chapter Three) of this project.

Samples	From where samples were procured
Kellis samples	International Tissue Bank (United Kingdom)
Kulab Natri	International Tissue Bank (United Kingdom)
Peru	International Tissue Bank (United Kingdom)
Asru	International Tissue Bank (United Kingdom)
York	York Archaeological Trust (United Kingdom)

Table 2.1 – The institutions where samples are currently housed

2.1.4 - Case Study One – Mummy A1

*Fig 2.1 - Mummy A1 before autopsy (photograph
courtesy of A C Aufderheide)*

Mummy Identification Number	A1
Historical Age	Early Roman (30 BCE – 250 CE)
Individual Age	13 – 17 years
Sex	Male
Place of Excavation	Tomb Number 3, Body Number A
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	96
Samples Used	Scalp, Rib, Liver, Femur, Muscle, Skin (ear)
Previous Palaeopathological Findings	None Found
Cause of Death	Not Known
Mummification Type	Four

Table 2.2 – Minimum Standards Case Report – Mummy A1
The first of the mummies from the Kellis 1 cemetery was labelled A1. It was that

of an adult male[*], aged thirteen to seventeen of age at the time of death. Sex was determined by the presence of preserved visible genitalia (penis and scrotum) and age was based on dentition patterns (all permanent dentition present). Height during life was estimated, by long bone measurement, at 157.4 centimetres (Aufderheide 1993; 8).

The body was found in an extended position with arms straight along the sides with the palms towards the legs. The body was unwrapped at autopsy, when ears and the eyes, still with eyelashes, were identified (Aufderheide 1993; 2).

Many teeth had cracked or been lost post-mortem although few ante-mortem pathologies could be identified; these included dental caries on two teeth and the left mandibular canine rotated 45 percent clockwise (Aufderheide 1993; 9).

The chest cavity was intact with the pericardium present; however the heart had not been preserved. Both the lungs and the liver were evident, with no obvious pathology (Aufderheide 1993a; 6).

At the time of autopsy, the soft tissue preservation score was 96 percent (Aufderheide 1993a; 3).

There was no evidence of resin use internally (chest, abdominal and cranial cavities). However, the skin had been painted with a thin layer of resin. Mummy A1, therefore, was of the Type Four mummification pattern.

The samples examined from Mummy A1 were scalp, rib, femur, liver, muscle and skin.

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[*] In this project, sub-adult is those mummies less than 12 years of age at the time of death.

2.1.5 – Case Study Two – Mummy A4

Fig 2.2 – Mummy A4 before autopsy (photograph courtesy of A C Aufderheide)

Mummy Identification Number	A4
Historical Age	Early Roman (30 BCE – 250 CE)
Individual Age	20 – 22 years
Sex	Female
Place of Excavation	Tomb Number 4, Body Number E
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	56
Samples Used	Breast, Liver, Lung, Muscle Scalp, Skin, Rib, Femur
Previous Palaeopathological Findings	None Found
Cause of Death	Not Known
Mummification Type	Four

Table 2.3 – Minimum Standards Case Report – Mummy A4

Mummy A4 is an adult female, aged approximately twenty to 22 years at time of death. Age was determined by femoral epiphysis fusion and sex by external genitalia. According to the excavator, Dr Michael Birrell (1999; 35), the body had good skin preservation and had a head of abundant hair. She was buried in the Kellis Western Cemetery (Kellis 1) in tomb number 4. The body was found supine with arms extended and hands placed over the lateral portion of the

upper thighs. No cultural objects were found connected to the body, as the tomb had been looted in antiquity, if cultural objects were present, their context had been lost (Cartmell 1993; 2). The body showed no evidence of resin on any of the internal cavities; however, it would appear that a thin layer had been applied to the external surfaces (Cartmell 1993; 2).

Her body was excavated in 1992 and was autopsied in the field by the University of Minnesota, Duluth on December 5, 1993 under the direction of Larry Cartmell. The body had been opened in modern times and the ventral portion of the anterior abdominal wall had been entered with a defect measuring 16 by 10 centimetres. All internal organs appeared to be present; the lungs were flat and posteriorly placed and when the pericardial sac was opened it revealed the heart as a dark mass of approximately 6 centimetres. The liver was also identifiable, measuring 10 x 6 x 2 centimetres, dark brown to black in colour. Other organs were present but unidentifiable Cartmell 1993; 6-7).

At autopsy, the soft tissue preservation score was 56 percent (Cartmell 1993; 3).

Samples used from Mummy A4 were breast, femur, liver, lung, muscle, rib, scalp and skin (ear).

Mummy A4 was mummified in the pattern of Type Four.

2.1.6 – Case Study Three – Mummy A5

Fig 2.3 – Mummy A5 before autopsy (photograph courtesy of A C Aufderheide)

Mummy Identification Number	A5
Historical Age	Early Roman (30 BCE – 250 CE)
Individual Age	Approximately 48 years
Sex	Male
Place of Excavation	Tomb number 2, body number D
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	96
Samples Used	Liver, skin (ear), Rib, Heart, Muscle
Previous Palaeopathological Findings	None Noted
Cause of Death	Not Known
Mummification Type	Five

Table 2.4 – Minimum Standards Case Report – Mummy A5

Mummy A5 was that of a well preserved, complete adult male aged approximately 48 years at the time of death. Sex was determined by the presence of external genitalia (circumcised penis and scrotum), and age was based on the patterns of symphysis fusion. Using the long bones, stature could be estimated at 164 centimetres (Aufderheide et al 2003; 140).

Unfortunately, the autopsy report for Mummy A5 was not available so a lot of contextual information is lacking, including the recording of any ante-mortem pathologies found at the time of gross anatomical examination. However, it was decided to include A5 in the ten case study mummies due to firstly, the number of soft tissue and bone samples available and, secondly, the high soft tissue preservation score given at autopsy.

At autopsy, the soft tissue preservation score was given as 96 percent (Aufderheide et al 2003; 140).

Resin was found in the cranial cavity as well as being painted on the external surfaces (Aufderheide et al 1999; 203). No evisceration wound could be identified, which strongly suggests that Mummy A5 was mummified according to the Type Five pattern.

The samples used from Mummy A5 are heart, liver, muscle, rib and skin.

2.1.7 – Case Study Four – Mummy A8

Figs 2.4 – Mummy A8 before autopsy (photographs courtesy of A C Aufderheide)

Mummy Identification Number	A8
Historical Age	Early Roman (30 BCE – 250 CE)
Individual Age	8 – 11 years
Sex	Undetermined
Place of Excavation	Tomb Number 3, Body Number C
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	32
Samples Used	Liver, Scalp, Skin (ear), Rib
Previous Palaeopathological Findings	None Found
Cause of Death	Not Known
Mummification Type	Four

Table 2.5 – Minimum Standards Case Report – Mummy A8

Mummy A8 is a spontaneously mummified body of a sub-adult, aged approximately eight to eleven years at time of death. Age at death was based principally by dentition. The first molars had erupted, however the second molars had not. It was not possible to determine sex of the mummy as no genitalia had been preserved (Aufderheide 1993b; 1).

The legs of the body were largely absent, although several of the disarticulated bones were associated with the body. Hands and feet were also absent as was the right forearm. Both eyes and ears were present and intact. The skin over the thorax was intact; however the diaphragm and abdominal wall were absent, leaving the chest open to the environment. Heart, lungs and other viscera were not present within the chest. The liver was present, measuring 10 x 6 x 2 centimetres. The brain had been removed by transnasal trephination (Aufderheide 1993b; 6-7).

Several strands of black hair, up to 8 centimetres in length, were attached to the scalp at the vortex of the skull surrounded by shorter hair up to two centimetres in length over an area of about eight centimetres in diameter. The rest of the scalp was hairless.

At the time of autopsy, the soft tissue preservation score was given as 32 percent (Aufderheide 1993b; 3).

The skin of the face strongly suggests the external application of resinous material, which confirms the Type Four mummification pattern.

The samples examined from Mummy A8 were liver, femur, scalp, skin, rib and bowel.

2.1.8 - Case Study Five - Mummy A13

Fig 2.5 - Mummy A13 before autopsy (photograph courtesy of A C Aufderheide)

Mummy Identification Number	A13
Historical Age	Early Roman (30 BCE – 250 CE)
Individual Age	55+
Sex	Male
Place of Excavation	Not Recorded
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	99
Samples Used	Colon, Liver, Lung, Muscle, Skin (ear), Rib
Previous Palaeopathological Findings	Osteoarthritis, Osteoporosis, Dental Caries, Ante-mortem Loss of 18 Teeth
Cause of Death	Not Known
Mummification Type	Four

Table 2.6 – Minimum Standards Case Report – Mummy A13

Mummy A13 is that of an adult male aged over 55 years at time of death. Sex was determined by external genitalia; the penis and scrotum being very well preserved and confirmed that the deceased had not been circumcised. Age at death was based on dentition patterns, the degree of osteoarthritis and the morphology of the pubic symphysis (Zlonis 1993b; 1).

The skin of A13 was black, coated with either resin or bitumen, which was mainly concentrated on the face, particularly around the nose and mouth. No resin, however, was present in the mouth or cranium. There was also no evidence for resin in any of the other internal cavities and therefore matching the Type Four pattern of mummification. The body had been wrapped with linen bandages and transnasal cranial trephination had been performed. The body appears to have been previously unwrapped and strips of 3 to 6 centimetres wide woven linen bandages were adherent to some areas of the skin. Bandages were present in most areas, one or two layers thick (Zlonis 1993b; 2).

A 9 by 6 centimetre defect was present in the left anterior abdominal wall, most probably inflicted in modern times by previous excavators. Many small insect holes were present on the posterior surfaces of the body (Zlonis 1993b; 2).

The lungs were present, presenting as a thin plate against the posterior thorax, however the heart was preserved only as a collection of stringy material. The diaphragm was in place but contained many holes. The liver was preserved as a dense sticky dark brown mass measuring 14 x 6 x 2 .5 centimetres (Zlonis 1993b; 6-7).

At autopsy, the soft tissue preservation score was assessed as 99 percent (Zlonis 1993b; 2).

The samples examined from Mummy A13 were muscle, rib, lung, colon, liver and skin (ear).

2.1.9 – Case Study Six – Mummy A101

Fig 2.6 – Mummy A101 before autopsy (photograph courtesy of A C Aufderheide)

Mummy Identification Number	A101
Historical Age	Early Roman (30 BCE – 250 CE)
Individual Age	20 – 30 years
Sex	Male
Place of Excavation	Tomb 16
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	100
Samples Used	Colon, Coprolite, Liver, Muscle, Skin (ear), Rib
Previous Palaeopathological Findings	Some Dental Caries
Cause of Death	Not Known
Mummification Type	Four

Table 2.7 – Minimum Standards Case Report – Mummy A101

Excavated in the 1998, Mummy A101 was a male aged between twenty and 30 years at time of death. Sex was determined by the presence of external genitalia; in this case, a circumcised penis measuring 8 x 1.5 x 0.4 centimetres was easily recognisable. Age at death was based on the pattern of attrition and symphyses fusion. In life, Mummy 101 would have stood at a height of 185 centimetres. The body had been unwrapped in antiquity (Cartmell 1998a; 8).

No ancient inflicted defects were evident; however, there were several small excavation defects of the skin and underlying tissue up to 8 centimetres diameter in the right chest wall. Other than these defects, the skin was intact and had been covered with a resinous substance (Cartmell 1998a; 6-7).

While the body displayed no evidence of ante-mortem pathologies other than some minimal dental caries on the first molars, the seventh thoracic vertebrae was completely fragmented, creating an acutely angled gibbus. No blood or tissue stains or any apparent tissue reaction could be identified; strongly suggesting this was a post-mortem injury, occurring shortly after death. This fracture deformed the soft tissues sufficiently to produce the tissue protrusion of about 3 to 4 centimetres at the base of the neck. The chest cavity, due to the abovementioned excavation defects, contained abundant sand. Neither lungs nor heart could be identified. The liver, measuring 5 x 4 x 3 centimetres, was found in place, as were numerous flattened loops of bowel, containing generous quantities of coprolite material (Cartmell 1998a; 6-7).

Transnasal craniotomy had been performed (Cartmell 1998a; 9).

At autopsy, the soft tissue preservation score was assessed as 100 percent (Cartmell 1998a; 3).

There was no evidence of resin within the internal body cavities; however, a resinous substance had been applied to the skin's surface, which complies with the mummification pattern of Type Four bodies.

The samples examined from Mummy A101 were labelled as liver, skin (ear), colon, rib, muscle and coprolite.

2.1.10 - Case Study Seven – Mummy A102

Fig 2.7 - Mummy A102 before autopsy (photograph courtesy of A C Aufderheide)

Mummy Identification Number	A102
Historical Age	Early Roman (30 BCE – 250 CE)
Individual Age	8-11 years
Sex	Male
Place of Excavation	Not Recorded
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	72
Samples Used	Skin, Rib, Lung, Bowel, Liver
Previous Palaeopathological Findings	Dental Abscess
Cause of Death	Not Known
Mummification Type	Four

Table 2.8 – Minimum Standards Case Report – Mummy 102

Mummy A102 was that of a eight to thirteen-year old sub-adult male. Sex was determined by the presence of external genitalia and age at time of death was based on dentition patterns. The body, at the time of excavation, was complete except for the third and fourth distal bilateral phalanges. This was judged by the excavators to be post-mortem loss. There were irregular fragmented wrappings over most of the body. The scalp was covered by short reddish brown resin-soaked hair. The skin was intact other than the rectal area. Fingernails were present but all toenails were missing (Cartmell 1998b; 6-7).

The only pathology identified at the time of autopsy was a dental abscess. Transnasal craniotomy had been performed; however, a minimal amount of brain tissue remained in place (Cartmell 1998b; 6-7).

The entire body was covered in resin and the remaining wrappings were resin-soaked. However, there was no evidence of resin in the cranium or other internal cavities so the body complied with the Type Four pattern of mummification.

At autopsy, the soft tissue preservation score was assessed as 72 percent Cartmell 1998b; 3).

The samples used from this Mummy were bowel, liver, lung, rib and skin.

2.1.11 – Case Study Eight – Mummy A108

Fig 2.8 – Mummy A108 during autopsy (photograph courtesy of A C Aufderheide)

Mummy Identification Number	A108
Historical Age	Early Roman (30 BCE – 250 CE)
Individual Age	21-23 years
Sex	Male
Place of Excavation	Not Recorded
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	90
Samples Used	Heart, Colon, Lung, Muscle, Rib, Liver
Previous Palaeopathological Findings	None Found
Cause of Death	Not Known
Mummification Type	Four

Table 2.9 – Minimum Standards Case Report – Mummy A108

Mummy A108 was that of a young adult male, aged twenty to 25 years at time of death. Sex was determined by the presence of intact external genitalia (penis and scrotum) and age at death was based on dentition patterns. A108's stature in life would have been approximately 167cm. The body was found supine, arms extended with hands resting over the pubis. The head was attached, but the right lower leg was detached, located near to the body and

the left lower leg was missing. The skin appeared to have been painted with a very thin layer of resin (Aufderheide 1998b; 6-7).

At autopsy, the pericardial sac was found to be intact and the heart was present, measuring 7 x 3 .5 centimetres. The collapsed lungs had no lesions but were incompletely preserved. The liver was found in place and was extremely brittle, measuring 8 x 3.5 x 2 .5 centimetres. The stomach was mildly dilated but empty, as were the several loops of small and large intestine that were present and in place (Aufderheide 1998b; 6-7).

At autopsy, the soft tissue preservation score was assessed as 90 percent (Aufderheide 1998b; 3).

No evidence of resin could be detected within the abdominal, chest or cranial cavities. Due to the thin layer of resin on the external body surface, Mummy A108 was mummified according to the Type Four pattern.

The samples used from Mummy A108 were colon, heart, liver, lung, muscle and rib.

2.1.12 – Case Study Nine – Mummy A126

Fig 2.9 – Mummy A126 before autopsy (photograph courtesy of A C Aufderheide)

Mummy Identification Number	A126
Historical Age	Early Roman (30 BCE – 250 CE)
Individual Age	30-40 years
Sex	Male
Place of Excavation	Not Recorded
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	52
Samples Used	Skin, Muscle, Lung, Rib, Liver
Previous Palaeopathological Findings	None Found
Cause of Death	Not Known
Mummification Type	Five

Table 2.10 – Minimum Standards Case Report – Mummy A126

Mummy A126 is that of an adult male aged approximately 35 years at the time of death. Sex was determined by the presence of preserved external genitalia (circumcised penis and scrotum) and age at death was based on pubic symphysis morphology and the absence of osteophytosis (Aufderheide 1998f; 6-7).

The body was discovered in an extended position with arms parallel to the trunk and hands against the lateral thighs. The head was absent as were both legs below the knee. The left arm below the elbow was also absent. However, the measurement of the long bones determined stature during life to be 167.7 centimetres (Aufderheide 1998f; 8).

No evisceration wound could be identified. The skin had been stained black by resin application and a portal of 4 centimetres in diameter had been created in the lower left quadrant of the back in order for resin to be poured into the internal cavities. The chest cavity was largely intact although there was no evidence of any cardiac tissue. Both lungs were present in the form of flat membranes covered in resin on each side of the chest. The liver was identifiable and weighed 44 grams; however this weight included a layer of resin (Aufderheide 1998f; 6-7).

At autopsy, the soft preservation score was assessed as 52 percent (Aufderheide 1998f; 3).

Due to the use of resin, both externally and internally, as well as no evident evisceration wound, the mummification pattern is Type Five.

The samples examined from Mummy A126 were skin, muscle, lung, liver and rib.

2.1.13 - Case Study Ten – Mummy A129

Fig 2.10 - Mummy A129 before autopsy (photograph courtesy of A C Aufderheide)

Mummy Identification Number	A129
Historical Age	Early Roman (30 BCE – 250 CE)
Individual Age	6 years
Sex	Male
Place of Excavation	Not Recorded
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	100
Samples Used	Skin (leg), Muscle, Bowel, Rib, Skin (ear), Liver
Previous Palaeopathological Findings	None Found
Cause of Death	Not Known
Mummification Type	Six

Table 2.11 – Minimum Standards Case Report – Mummy A129

Mummy A129 was that of a sub-adult male of approximately six years of age at time of death. Sex was determined by the presence of visible external genitalia (penis and scrotum) and age was based on dentition patterns and by the length of the long bones. Full primary dentition was present with minimal

attrition and no caries. The first molar was fully erupted in all four positions (Aufderheide 1998g; 1).

This mummy was 94 centimetres in length. The body was largely intact, although the head was detached. The body was enveloped in approximately 20 layers of partly shredded linen wrappings. Most of these wrappings were elongated pieces of closely woven linen (some patched), up to 56 centimetres long and 20 centimetres wide. Many of the textile layers have been saturated with resin. The detached head was intact with abundant unstyled hair (Aufderheide 1998g; 2).

No heart or lung tissue was present and there was a small amount of resin in some areas of the chest cavity. The liver was present and identifiable, measuring seven by 5 x 4 centimetres, coloured black and grey with an irregular surface. No abdominal or perineal evisceration wound could be identified.   All extremities were present, including finger and toenails. There was evidence of transnasal craniotomy but no resin was found in the cranial cavity (Aufderheide 1998g; 6-7).

At autopsy, the soft tissue preservation score was assessed as 100 percent (Aufderheide 1998g; 3).

As resin was present in varying amounts in the chest and abdominal cavities, Mummy A129 was mummified according to the Type Six pattern.

The samples examined from Mummy A129 were skin (ear), skin (leg), muscle, bowel, liver and rib.

2.1.14- Comparative Sample – Mummy A9

Fig 2.11- Mummy A9 before autopsy (photograph of A C Aufderheide)

Mummy A9 was that of a male child aged approximately five and a half years at the time of death. Sex was determined by the presence of preserved external genitalia and the age at death was based on the dental eruption pattern (Zlonis 1993a; 1).

The body appeared to be in a good state of preservation and, although the lungs and heart could not be identified, the liver was present in its normal anatomical position (Zlonis 1993a; 6-7).

At the time of autopsy, the soft tissue preservation score was assessed as 100 percent (Zlonis 1993a; 3).

Resin was present on both the external and internal body surfaces and there was no evidence of an evisceration wound, therefore this mummy was of the Type Five mummification pattern.

The sample examined from Mummy A9 (for comparative purposes) was liver.

2.1.15 – Comparative Sample – Mummy A15

Figs 2.12a & b – Mummy A15 before and after unwrapping (photograph courtesy of A C Aufderheide)

A15 was a composite mummy and the only one of the Type Two mummification pattern. The mummy is actually made up of four different bodies:

1) The head was that of a twenty – 25-year old woman (based on dentition)

2) The torso belonged to a 45 – 50-year old women (pubic symphysis)

3) The disarticulated left leg and both feet belonged to a seven-year old child

4) The right leg was that of a three and half-year old child.

The body had been wrapped and the only remaining soft tissue was in contact with these wrappings (Aufderheide 1993c; 2).

The sample used from Mummy A15 was the femur from the seven-year old child, which showed no obvious pathologies at the time of autopsy.

2.1.16 - Comparative Sample – Mummy A105

Fig 2.13 - Mummy A105 before autopsy (photograph courtesy of A C Aufderheide)

Mummy A105 was that of a young male, aged approximately 22 years at time of death. The body is only an upper torso, separated at the mid-abdominal wall. Due to this separation, no abdominal contents were present. The left forearm and hand were also detached however were present close to the body in the tomb. It was estimated that during life Mummy A105 stood at 188.4 centimetres (Cartmell 1998c; 2).

At the time of autopsy, the tissue preservation score was assessed as 48 percent (Cartmell 1998c; 3).

The remaining body and head, including hair, had been coated with a thin layer of black resinous material. There was no evidence for the application of resin within the body cavities, suggesting that the body was that of the Type Four pattern of mummification (Cartmell 1998c; 6-7).

No wrappings or other cultural objects were found.

The sample available from Mummy A105 was lung.

2.1.17 - Comparative Samples - Mummy A106

Fig 2.14 - Mummy A106 before autopsy (photograph courtesy of A C Aufderheide)

Mummy A106 is that of an adult female, aged between thirteen and seventeen years at time of death. Sex was determined by the presence of external genitalia and age at death was based on the non-fusion of the greater trochanter as well as the condition of the pubic symphysis. The body was supine with no external wrappings or cultural objects found in relation to it. About ten percent of the reddish-brown hair remained (Cartmell 1998d; 2).

The body was virtually intact, except for the left lower leg, which was missing. The diaphragm was in place; however, neither the heart nor the lungs could be identified. The liver was found in place and weighed 54 grams. The small intestine was present, while the large intestine could not be specifically identified, however, large quantities of coprolite material was present in the pelvis. One flat bone (2 x 3 centimetres), probably a small rib was also found in the pelvic region, possibly foetal remains. No major pathologies could be identified at the time of autopsy (Cartmell 1998d; 6-7).

At autopsy, the soft tissue preservation score was assessed as 90 percent (Cartmell 1998d; 3).

Resin had been applied to the hair and body, but was not present in any of the internal cavities. The mummification pattern is therefore that of Type Four.

Sample used from Mummy A106 was coprolite.

2.1.18 - Mummy A107 – Comparative Sample

Fig 2.15 - Mummy A107 before autopsy (photograph courtesy of A C Aufderheide)

Mummy A107 was that of a headless sub-adult male, aged approximately eight years at the time of death. Sex was determined by the presence of preserved external genitalia (penis and scrotum), and age at death was based on the length of the long bones. The lower legs were missing (Aufderheide 1998a; 2).

While the diaphragm was intact, there was no evidence of the lungs. In the abdominal cavity, the liver (weighing 155 grams) and several loops of bowel were preserved. No other organs, linen or other foreign material were discovered (Aufderheide 1998a; 6-7).

At autopsy, the soft tissue preservation score was assessed as 90 percent (Aufderheide 1998a; 3).

Resin had been applied to the external and internal surfaces of the body and there was no evidence of an evisceration wound. Mummy A107 has therefore been categorised as the Type Five mummification pattern.

The samples examined from Mummy A107 (for comparative purposes) were bowel and liver.

2.1.19 - Mummy A110 – Comparative Sample

Fig 2.16 - Mummy A110 before autopsy (photograph courtesy of A C Aufderheide)

Mummy A110 was that of an adult male, aged approximately 35 years at the time of death. Sex was determined by the presence of external genitalia (penis and scrotum) and age was based on the fusion of the symphyses (Aufderheide 1998c; 1).

The body was headless and missing the extremities below the knees. It had been wrapped in numerous layers of linen bandages and sheets, with resin used to hold them in place. Resin had been introduced to the abdominal cavity via a posterior defect, and it had spread through the thoracic cavity and diaphragm, leaving all remaining organs affected (Aufderheide 1998c; 6-7).

At the time of autopsy, the soft tissue preservation score was assessed as 54 percent (Aufderheide 1998c; 3).

Due to both internal and external resin application, Mummy A110 was of the Type Five mummification pattern.

The samples used (for comparative purposes) from Mummy A110 were lung and rib.

2.1.20 - Mummy A111 – Comparative Sample

Fig 2.17 - Mummy A111 before autopsy (photograph courtesy of A C Aufderheide)

Mummy A111 was that of a young adult male aged approximately twenty to 25 years at time of death. Sex was determined by the presence of external genitalia (penis and scrotum) and the age at death was based on the condition of the pubis symphysis. The body was found in an extended position with the arms placed along the trunk and hands on the lateral aspect of the thighs. During life, A111 would have stood at a height of 183.2 centimetres (Aufderheide 1998d; 8).

When the chest cavity was opened, there was no evidence of identifiable cardiac tissue. Lungs were in place as was the liver, which measured 8 x 5 x 3 centimetres. Transnasal craniotomy had been performed; however there was no evidence of any evisceration wound (Aufderheide 1998d; 6-7)

At autopsy, the soft tissue preservation score was assessed 100 percent (Aufderheide 1998d; 3).

Resin was only present on the external body; therefore, despite the care of wrapping, the body was mummified according to the Type Four pattern.

The samples examined from Mummy A111 (for comparative purposes) were lung and liver.

2.1.21 - Mummy A112 – Comparative Sample

Fig 2.18 - Mummy A112 before autopsy (photograph courtesy of A C Aufderheide)

Mummy A112 was that of a sub-adult, approximately seven years old at the time of death. The body is very incomplete (head, arms and lower legs were missing), which rendered determination of sex impossible. Age at the time of death was based on the length of the femurs. Soft tissues remained attached to the pelvis and proximal femurs (Aufderheide 1998e; 1).

At autopsy, the soft tissue preservation score was assessed as four percent (Aufderheide 1998e; 3).

Resin had been painted on the external surface of the body; however, there was no evidence of resin in the remaining internal cavities. Mummy A112, therefore, was that of Type Four pattern of mummification.

The sample examined from Mummy A112 (for comparative reasons) was rectum.

2.1.22 - Mummy A132 – Comparative Sample

Fig 2.19 - Mummy A132 before autopsy (photograph courtesy of A C Aufderheide)

Mummy A132 was that of a sub-adult of approximately four years of age at time of death. The sex of the child could not be determined at either the time of excavation or during autopsy. This was due to the body being incomplete, with only the trunk, arms and head remaining. Age at death was based on dentition patterns; a completely erupted primary dentition was present with minimal attrition as well as a well-formed first molar crown in all positions (Aufderheide 1998h; 1).

The head had been separated from the trunk but was held in place by linen wrappings. Other extremely worn wrappings covered the remaining body. On the head, brown unstyled hair was well preserved. Eyes and ears were present (Aufderheide 1998h; 6-7).

Mummy A132 can be termed a composite mummy as it had been reconstructed from parts of at least two bodies. The head, as stated, was present, as were the left and right humeri, the length of which suggests the body age of four to four and a half years. Also confirming this age range were the remaining radius and ulna. These bones were all covered with muscle and skin. Some separate fingers with dried skin attached are present on each hand. A third, foreign, humerus of 14 centimetres (1.6 centimetres less than the two humeri that form the arms) was found lying loose in the thoracic cavity. The body has been extensively reconstructed with the cervical vertebrae having been splinted by a 20.6 centimetre segment of palm leaf rib (Aufderheide 1998h; 6-7).

At the time of autopsy, the soft tissue preservation score was assessed as 32 percent (Aufderheide 1998h; 3).

Despite its complicated state at the time of excavation, the mummification pattern of A132 complies with that of Type Seven. This was due to the presence of resin in the internal cavities and the absence of many of the visceral organs. However, it must be noted that the absence of viscera could very well be due to the fragmented state of this mummy.

The sample examined from Mummy A132 was labelled lung.

2.1.23 – Asru – Manchester Museum Number 1777 – Comparative Sample
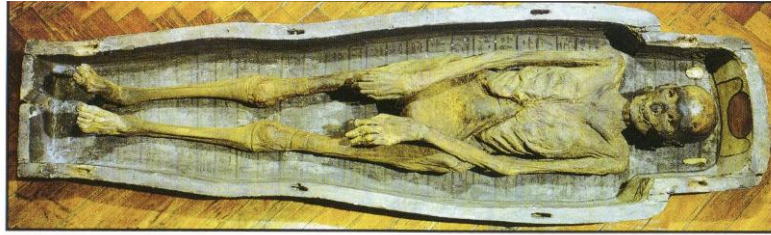
Fig 2.20 – The chantress Asru housed at Manchester Museum (David & Archbold 2000; 135)

Asru is currently housed at the Manchester Museum (United Kingdom). Her mummy arrived at the Museum in 1825, having been previously completely unwrapped. Although provenance had not been recorded, her treatment after death, including the coffin decoration, strongly suggests she lived, and died, in Thebes (modern day Luxor) in the Twenty-Fifth Dynasty. She was approximately 60 years at the time of death.

Asru is in an excellent state of preservation, having clearly being well mummified. No evisceration opening could be found so Asru's internal organs were most likely removed *per ano*. A visceral package was found in the coffin at her feet, this included the extremely degraded intestinal contents that were analysed as part of this project.

Asru had been previously studied as part of the Manchester Mummy Project in 1972. At this time, she was found to have suffered from osteoarthritis, a slipped disc and strongyloides, a parasitic infection (Tapp 1979; 99, Isherwood et al 1979; 31).

2.1.24 – Comparative Sample - Peruvian Mummy (Coprolite Material)

Fig 2.21 – Peruvian Mummy (International Tissue Bank, Manchester)

A coprolite sample from a Peruvian mummy was included in the project as a means of comparing the plant material found within the intestinal contents of the Dakhleh mummies. The Peruvian sample, housed at the International Mummy Tissue Bank (Manchester University, United Kingdom), came from Townley Hall (Burnley, United Kingdom). W T Taylor donated the mummy to the Museum; however, he provided no information regarding its provenance. In 2007, the York Mummy Research Group (United Kingdom) conducted an investigation and, with the use of radio carbon dating, concluded that the mummy could be dated to approximately 1100 CE. This date corresponded to the Charcay culture in Peru, who made mummies from 1000 to 13000 CE (York Mummy Research Team 2007; 7).   This strongly suggests a provenance of an area close to the Pacific Coast, a suggestion backed up by the preservation state of the intestinal tract, which was intact to the point of yielding coprolite material. From any other region of Peru, the internal organs and their contents are reduced to a fine brown powder (Vreeland 1998; 155).

The York Mummy Research Team also discovered the mummy was a male in his early 20s, and due to the evidence of head binding, he was of high status. Although samples were taken from the intestinal tract, at the time of the York investigation no evidence of diet or parasites was found (York Mummy Research Team 2007; 8).

2.1.25 – Comparative Sample -York Conglomerate

The samples from York were collected from the York Archaeology Trust (United Kingdom) and were, like the Peruvian sample (Chapter 2.1.22), used to compare the plant material found in coprolite samples. The samples had not been mummified but fossilised, which meant that histological techniques had to be tested in order to achieve the most effective result for the examination of the sections under the microscope. The samples had been labelled 'conglomerate' and thought to contain coprolite material within it, which is the reason they were chosen to be part of the project. The samples are dated to the Roman Period, being found in Romano-British settlement sites within the city of York.

2.1.26 – Comparative Sample – Kulab Narti Material

Samples were used from a mummy from the early Christian cemetery (600-850 CE) at Kulab Narti in North Sudan (Nubia).

Lung samples were chosen to compare particulates such as carbon and silica. However, the samples proved to be coprolite material.

2.1.27 – Summary of Samples

MUMMY AUTOPSY NUMBER	SEX male female indeterminate	AGE AT TIME OF DEATH (in years)	MUMMIFI CATION TYPE (1-7)	SAMPLES
A1	Male	13-17	4	Femur, liver, muscle, rib, scalp, skin
A4	female	20-22	4	Breast, femur, hair, liver, lung, muscle, rib
A5	Male	48	5	Heart, liver, muscle, rib, skin
A8	indeterminate	8-11	4	Bone, femur, hair, liver, rib, skin
A13	Male	55	4	Colon, liver, lung, muscle, skin(e)
A101	Male	20-30	4	Colon, coprolite, liver, muscle, rib, skin(e)
A102	Male	9-13	4	Bowel, liver, lung, rib, skin
A108	Male	21-25	4	Colon, heart, liver, lung, muscle, rib
A126	Male	30-40	5	Liver, lung, muscle, rib and skin
A129	Male	6	6	Bowel, liver, muscle, rib, skin(e), skin(l)
A15	indeterminate	7	2	Femur
A106	female	13-17	4	Coprolite, bowel
A107	Male	7-9	5	Bone, lung
A110	Male	35	5	Brain, skin
A112	Indeterminate	7-8	4	Rectum
A132	unknown	3-5	7	Lung
Asru	Female	50-60	7	Intestinal contents
S82 & 85 (Kulab Narti)				Lung
Peru	Male	20s	Smoked	Coprolite
YAT1&2			Fossilised	Conglomerate

Table 2.12 – Summary of Samples

2.1.28 – Summary of Blocks and Slides Produced

The table below describes the number of paraffin and resin blocks and slides produced as part of this thesis. Ancient Egyptian mummies are not renewable resources and care was taken not to use any more organic material than was necessary for the best-expected results and while the number of blocks and slides appear to be a lot, the samples themselves were extremely small (the average sample was <1 sq mm.

MUMMY IDENTIFIC-ATION AND SAMPLE	NUMBER OF WAX BLOCKS	USED	NUMBER OF RESIN BLOCKS	USED	TOLUIDINE BLUE SLIDES	USED	MSB SLIDES	USED
Mummy A1								
Skin	2	2	0	0	2	1	1	1
Liver	1	1	0	0	1	1	1	1
Muscle	1	1	0	0	3	2	3	1
Femur	1	1	1	1	2	2	2	1
Rib	1	1	1	1	2	2	2	2
Mummy A4								
Skin	2	1	0	0	4	3	5	5
Breast	2	1	0	0	2	2	1	1
Liver	1	1	0	0	2	1	2	2
Lung	2	1	0	0	2	2	2	2
Muscle	1	1	0	0	2	2	2	2
Rib	1	1	0	0	2	2	2	2
Mummy A5								
Skin	1	1	0	0	2	1	2	2
Heart	1	1	0	0	2	1	2	2
Liver	1	1	0	0	4	4	4	4
Muscle	1	1	0	0	2	2	2	2
Rib	1	1	0	0	2	2	2	2
Mummy A8								
Skin	1	1	0	0	2	2	2	2
Scalp	1	1	0	0	2	2	2	2
Liver	2	1	0	0	3	2	3	2
Femur	1	1	0	0	2	2	2	1
Rib	2	1	0	0	2	2	2	2
Mummy A13								
Skin	1	1	0	0	2	2	2	2
Colon	1	1	0	0	2	1	2	1
Liver	2	1	0	0	4	2	2	1
Lung	1	1	0	0	3	2	3	2
Muscle	2	1	0	0	2	1	2	2

Rib	2	1	1	1	6	4	3	2
Mummy A101								
Skin	3	2	0	0	2	2	5	4
Coprolite	3	3	0	0	5	5	5	5
Liver	2	2	0	0	4	4	4	2
Muscle	2	1	0	0	2	2	2	1
Rib	1	1	1	1	4	3	2	1
Mummy A102								
Thigh Skin	2	1	0	0	2	1	4	1
Colon	1	1	0	0	3	3	3	2
Liver	2	1	0	0	3	3	3	3
Lung	2	2	0	0	4	4	6	6
Rib	1	1	0	0	3	2	3	3
Mummy A108								
Bowel	2	2	0	0	2	2	2	2
Heart	2	1	1	1	5	5	5	5
Liver	1	1	1	1	4	3	4	4
Lung	1	1	0	0	3	3	2	1
Muscle	2	2	0	0	3	3	3	2
Rib	1	1	1	1	3	3	3	3
Mummy A126								
Skin	1	1	0	0	3	3	2	1
Lung	2	2	0	0	4	2	4	1
Muscle	1	1	0	0	3	2	3	2
Rib	1	1	1	1	5	2	3	3
Mummy A129								
Skin	2	2	0	0	3	3	3	3
Bowel	2	2	0	0	3	3	3	3
Liver	1	1	1	1	5	5	3	3
Muscle	1	1	0	0	3	3	3	3
Mummy A15								
Femur	1	1	0	1	3	2	3	2
Mummy A106								
Bowel	1	1	0	0	3	2	3	1
Coprolite	2	2	0	0	5	5	5	5
Mummy A107								
Bone	1	1	0	0	3	2	3	1
Lung	1	1	0	0	3	3	3	3
Mummy A110								
Brain	1	1	0	0	3	1	3	2

Lung	1	1	0	0	3	3	3	3
Mummy A112								
Rectum	1	1	0	0	3	1	3	1
Mummy A132								
Lung	1	1	0	0	3	3	3	3
Asru Intestinal Contents	1	1	1	1	4	3	5	3
Kulab Narti Lung	2	1	0	0	4	3	4	1
Peruvian Mummy Coprolite	1	1	1	1	3	3	3	3
YAT Conglomerate	0	0	2	1	6	3	0	0
TOTALS	**91**	**77**	**14**	**14**	**198**	**162**	**184**	**146**

Table 2.13 – Number of blocks and slides produced for this thesis

2.2 – METHODS – PARAFFIN WAX

Below is a flowchart outlining the steps undertaken to rehydrate and fix bone and soft tissue samples in order for their embedding in paraffin wax blocks so they can be sectioned, stained and examined microscopically.

```
┌─────────────────────────┐
│ Rehydration and         │
│ Fixation                │
└─────────────────────────┘
           ↓
┌─────────────────────────┐
│ Processing              │
└─────────────────────────┘
           ↓
┌─────────────────────────┐
│ Embedding               │
└─────────────────────────┘
           ↓
┌─────────────────────────┐
│ Sectioning              │
└─────────────────────────┘
           ↓
┌─────────────────────────┐
│ Mounting                │
└─────────────────────────┘
           ↓
┌─────────────────────────┐
│ Pre-stain Procedures    │
└─────────────────────────┘
           ↓
┌─────────────────────────┐
│ Staining                │
└─────────────────────────┘
           ↓
┌─────────────────────────┐
│ Post-stain Procedures   │
└─────────────────────────┘
           ↓
┌─────────────────────────┐
│ Mounting                │
└─────────────────────────┘
           ↓
┌─────────────────────────┐
│ Examination             │
└─────────────────────────┘
```
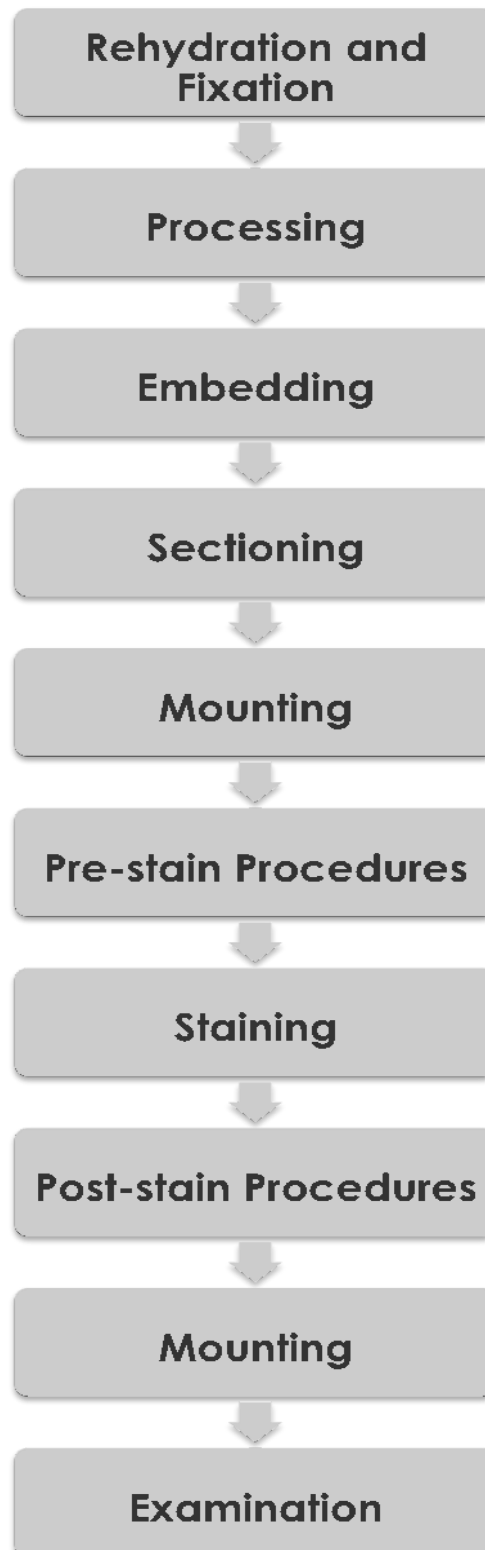
Derived from the Greek *histo* – meaning tissue and *logos* – meaning treatise, histology is one of the older techniques utilised for the examination of ancient material. The first microscopic studies of Egyptian mummified tissue was undertaken by Czermack, published in 1852, however it was in 1909 that Sir Marc Almond Ruffer developed rehydration techniques and protocols that were still used, with modifications, as the basis of histological mummy studies until recently. Today, the current rehydration techniques are quite unlike Ruffer's, which relied on alkali and alcohol, while the current solutions are detergent based (Denton 2008; 72).

The preservation of organic mummified remains can be affected by five factors, which in turn, affect the results of a histological examination. These are:

- Autolysis

- Putrefaction

- Mode of mummification

- Oxidation, and

- Insect attack (Denton 2008; 72).

The effect of these factors can result in visual identification by gross anatomical examination often being impossible. Staining techniques coupled with microscopy enable recognition of the cellular architecture, cellular type and matrix, which means not only can samples be indentified however, when compared to modern counterparts preservation levels of the ancient samples can be assessed (Denton 2008; 77, Currie 2006; 330). Once samples have been correctly identified and the level of preservation is known, there is more likely to be a successful outcome if they undergo further analysis by molecular techniques such as DNA sequencing (Denton 2008; 77).

Histological and microscopy techniques are capable of highlighting the biological changes that affect human and animal tissue. This means that diseases such as pneumonia and liver cirrhosis (Aufderheide 2000; 369) can be identified along with many parasites such as *Schistosoma* sp, *Taenia* sp (tapeworm), *Ascaris* sp (roundworm), *Strongyloides stercoralis* and *Dracunculus medinensis* (guinea worm) (Ruffer 1910; 16, Cockburn et al 1998; 101, Tapp 1979; 101).

2.2.1 - Rehydration

Ancient tissue has intrinsic problems that must be addressed before any histological techniques can be applied. The foremost of these problems, and the main difference between modern and mummified samples, is that dehydration and time have rendered ancient tissues hard and brittle. In this condition, the tissue is impossible to manage, especially when it comes to sectioning. The tissue must be softened before any further processing; this is achieved by a process known as rehydration.

An ideal rehydration solution must include:

1)   An emulsifying agent, which will decrease the surface tension of water and is able to occupy the sample homogeneously. This can be a product such as Comfort® fabric softener, sodium carbonate or sodium laurel sulphate
2)   A solvent, which both moisturises the sample and removes the mummifying agents. Solvents used include dilute acetic acid and water.
3)   A stabilising agent, which gives the tissue strength to ensure it does not collapse. Stabilising agents include ethanol and formaldehyde.
4)   A strong preservative, which will inactivate bacteria and arrest decomposition. This can be achieved by ethanol and formaldehyde (Mekota & Vermehren 2004; 12).

2.2.2 - Fixation

In modern histology, when rehydration is not necessary, all tissue samples still require fixation before they can be examined microscopically. Fixation is the foundation for all subsequent phases of preparation of the sections through to the diagnosis stage.

The aims of fixation is to block all autolytic enzyme activity and inactivate bacteria and fungi, which result in putrefaction, in order to preserve components of the tissues as they were in the living state (Sacrano et al 2003; 159).

When preparing ancient tissue samples, the stage of rehydration and fixation can occur concurrently while immersed in the same solution. If mistakes occur

during these two processes, it can lead to problems with the subsequent infiltration of the wax or resin (Bancroft & Stevens 1996; 23).

Method	Ingredients
Ruffer 1 – 1909	5 parts distilled water, 3 parts absolute ethanol, 2 parts 5% aqueous sodium carbonate
Ruffer 2 – 1909	97 parts tap water, 2 parts 5% aqueous sodium carbonate, 1 part 4% formaldehyde
Graf – 1949	5 parts glycerin, 5 parts 10% acetic acid
Sandison – 1955	5 parts 1% aqueous formaldehyde, 3 parts 96% ethanol, 2 parts 5% aqueous sodium carbonate
Giacometti & Chiarelli – 1968	0.9% sodium chloride
Gordon & Bradbury – 1979	70ml ethanol (70%), 30ml glycerin, 1g dithionite
Turner & Holtom – 1981	0.2% solution of 'Comfort' fabric softener (Lever Bros.) in normal saline
Kleiss & Simonsberger – 1984	2% aqueous sodium carbonate
Fulcheri et al – 1985	Undiluted, inactivated human blood serum at 4 Deg. C
Piepenbrink & Herrmann – 1988	15% glucose solution
Wiest et al – 1994	9.5 parts formaldehyde (2%), 0.5 parts Brij solution
Grupe et al – 1997	5% DMSO in Tris buffer, pH 7.6
Mekota & Vermehren 1 – 2002	4 parts undiluted inactivated human blood serum at 4 Deg. C, 1 part 5% sodium carbonate
Mekota & Vermehren 2 – 2002	5 parts distilled water, 3 parts 15% saccharose solution, 2 parts 2% sodium carbonate
Mekota & Vermehren 3 – 2002	8 parts 0.2%solution of "Comfort" fabric softener (Lever Bros.) in 5% sodium carbonate, 2 parts aqueous formaldehyde (4%)
Currie – 2006	1% sodium laureth sulphate in neutral buffered formol saline

Table 2.14 – Summary of different rehydration methods used for mummified tissue
All tissue samples used in this study were rehydrated and fixed for 48 hours using a solution of one percent sodium laureth sulphate and formol saline (step-by-step instructions, see Appendix 1).

The methods described below were evaluated using scientific principles and experimentation by Currie (2006) and it was established that the solution of sodium laureth sulphate in neutral buffered formol saline was the most

successful rehydration agent for mummified remains. Currie's protocol is used for this project.

2.2.3 - Processing

As Egyptian mummified tissue is often contaminated by sand, it is important that prior to processing that this sand is removed. Immersion of the samples in twp percent hydrofluoric acid removes sand easily and leaves little to no damage to the original sample (Denton 2008; 74), however this procedure is exceptionally hazardous and must only used by trained and experienced personnel. Then the mummified tissue can be processed using conventional techniques. A typical processing schedule is:

- four changes of industrial methylated spirit (IMS), each of five hours duration. This removes the fixative and water from the sample.

- three changes of xylene, each of five hours duration, which allows the removal of alcohol prior to its replacement by paraffin wax.

- three changes of molten paraffin wax (60° C) (Denton 2008; 72).

This process is fully automated.

2.2.4 - Embedding and Sectioning

The main embedding media used in histology, especially for soft tissue, is paraffin wax; the advantage of which being that it is cheap, the embedding process is simple and it provides a strong enough support for the soft tissue to achieve good sections of varying thickness.

After the tissue has been processed, the cassettes are stored in a vacuum oven set at 65°C. The low vapour pressure and high temperature of the oven ensures that any volatile substances left over from processing are boiled off.

The cassettes are removed from the oven and placed in a docking station, where the samples are then placed in metal cassettes, filled with molten wax and set onto a cold plate to quickly cool sample so that the wax crystals formed are small, as slow cooling will result in large crystals making the subsequent sectioning difficult. Once solid, the wax cassette is stored in a freezer for at least thirty minutes to further cool the wax and aid sectioning.

After thirty minutes, the samples, now positioned in wax blocks, can be sectioned using a microtome (in this case, a rotary microtome has been used). Sections are cut at a thickness of five microns.

2.2.5 - Mounting Wax Sections

Once sections are cut, they are mounted on to glass microscope slides, which support the sections in order for the staining process to take place (Denton 2008; 75).

First, the slides must be labelled for ease of identification. A ribbon of sections is placed onto the surface of water heated to 30°Celcius in a water bath. This relaxed the compressed sections removing any small creases. Individual sections are separated by the use of forceps or scalpel and a glass slid used to pick up the section by placing the slide in the water and slowly removing it attaching the wax section to its surface. After blotting the slide and section are placed on a hot plate, set at 50°C. After twenty minutes, the slides are moved to a second hot plate, set at 70°C, this combination initially dries the wax section which following the 70°C hotplate melts the wax and the tissue fuses to the slide.

2.2.6 - Pre-Stain Slide Preparation

As most of the staining techniques occur in an aqueous environment, wax must be removed from the section prior to staining (Denton 2008; 75).

The sections, on a metal slide carrier, are first placed in a container of xylene for two minutes to soften and remove the wax. Then, the slides are dipped ten times in each of a further three containers of xylene, to wash off any residues. Next, the sections are dipped ten times in each of four containers of Industrial Methylated Spirits (IMS) to remove any xylene and provide a medium mixable with water. Finally, the slides are taken to water.

The slides are ready for staining.

2.2.7 - Staining

Staining is required in order to visualise the thin, transparent sections of tissue which have no inherent contrast and colour and to selectively colour tissues in order to identify them. It is important when studying ancient remains that a

panel of stains be used to collect as much information as possible from the damaged tissue. The panel of stains employed for this project are discussed in Section 3.1.

2.2.8 - Dehydration, Clear and Mount

After staining, dehydration of the sections with alcohol and xylene (reversal of the pre-staining sequence) must occur so that the section can be encapsulated with a protective coverslip and so that the refractive index of the encapsulation medium is identical to that of glass, which aids microscopic examination. Once stained, the sections are fully immersed in water to wash off any excess stain. The sections are then dipped ten times in each of four containers of Industrial Methylated Spirits (IMS) to remove water.   Next, the sections are dipped ten times in each of four containers of xylene so that all alcohol is removed and the section is in the same solvent as the encapsulation medium.

 Then, the final step before microscopic visualisation is the application of a thin glass coverslip, which has been treated with a small amount of a mounting medium, in this case, Xam. The mounting medium is designed to have the identical refractive index as the microscope slide and coverslip. This provides a transparent conduit for light having a refractive index identical to the glass slide which minimises refraction, which is a cause of microscopic resolution loss (Denton 2008; 77).

2.2.9 - Microscopy

Light microscopy is then used to visualise the histologically stained sections. Light microscopy is one of the oldest methods used in the investigation of mummified remains (Jeziorska 2008; 87). For the sections produced for this report, both standard transmitted light, polarised light microscopy and Differential Interference Contrast sometimes known as Normaski microscopy was used. Polarised light microscopy uses plane polarised light to analyse the structures of the section that are birefringent (double refractive). Birefringent structures (including numerous crystals, fibrous structures, pigments, lipids, proteins, bone and amyloid) have two different refractive indices at right angles to each other. Polarised light microscopy is used to measure the amount of retardation that occurs in each direction, which in turn provides

information about the molecular structure of the section (Finzi & Dunlap 2001; 1-5). The magnifications quoted with each image are in objective lens magnification. See below for the corresponding actual magnifications.

Objective lens magnification	Final image magnification
x1.6	x48
x2.5	x75
x5	x150
x10	x300
x20	x600
x40	x1200

Table 2.15 – Magnification

2.2.9.1 – Focus Stacking Microscopy

For microscopes (particularly at high magnification) that have a small depth of field, information outside the focal plane becomes blurred and less defined, leaving the subject of the image not entirely in focus. Using extended depth of field techniques, such as focus stacking, allows a single, fully focussed image to be extracted from the combination of a series of images focussed at a range of depths. The resulting, or stacked, image has a greater depth of field than the individual images the technique often known a Z Stacking (Hovden et al 2011; 75).

When examining mummified tissues under a microscope, the above phenomenon of some subject elements being blurred due to differing focal lengths is not uncommon. Areas of degradation can have differing focal lengths than the surviving tissue or components, such as cartilage, can fold at the time of sectioning due to the rehydration process. In such cases, the focus-stacking programme – CombineZ (http://hadleyweb.pwp.blueyonder.co.uk) – a series of images of a section of intercostal ligament from the Kellis 1 Mummy, A4, were combined (see Figures 2.21 to 2.31) to produce a single, completely focussed image (see Figure 2.32).
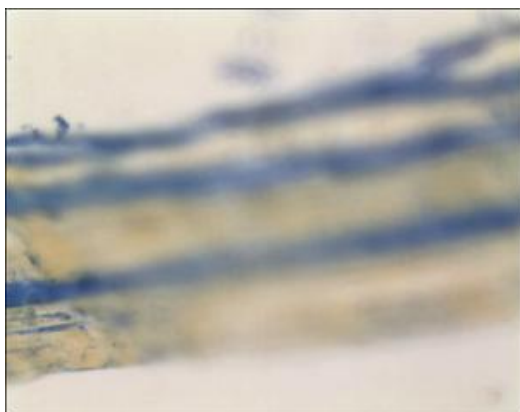
Fig 2.22
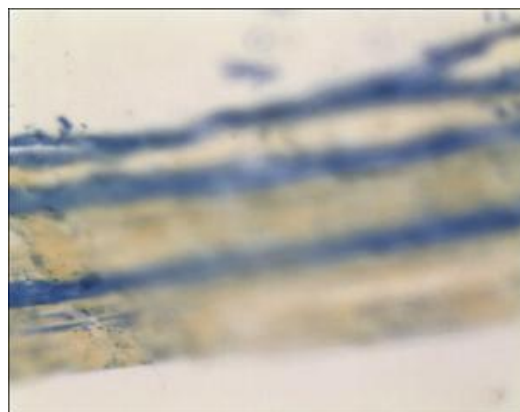
Fig 2.23
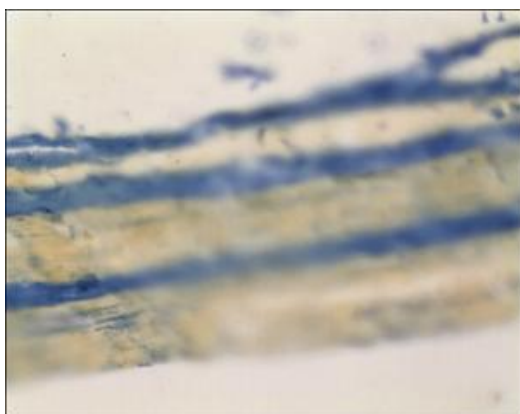
Fig 2.24
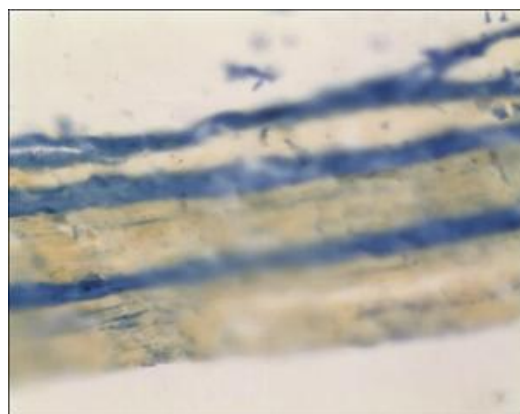
Fig 2.25
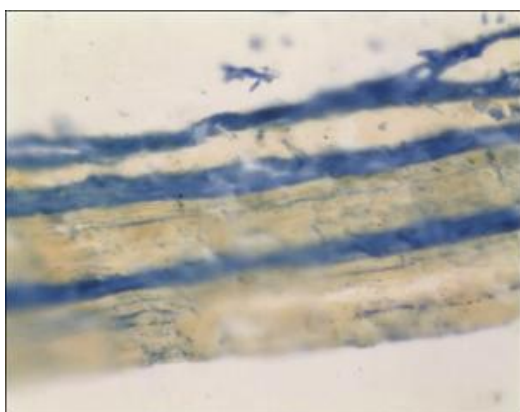
Fig 2.26
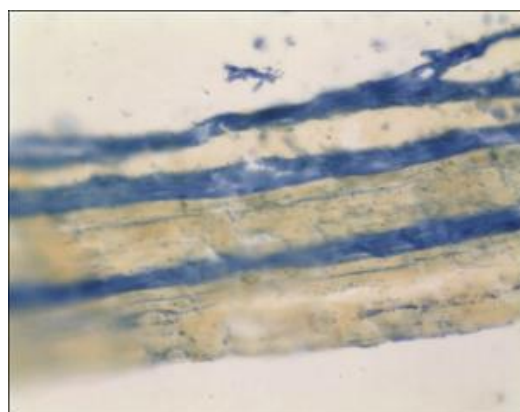
Fig 2.27
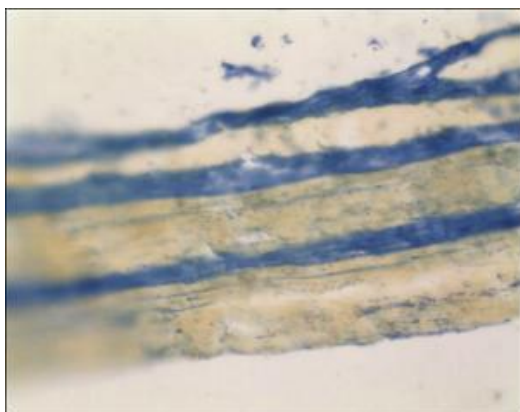
Fig 2.28
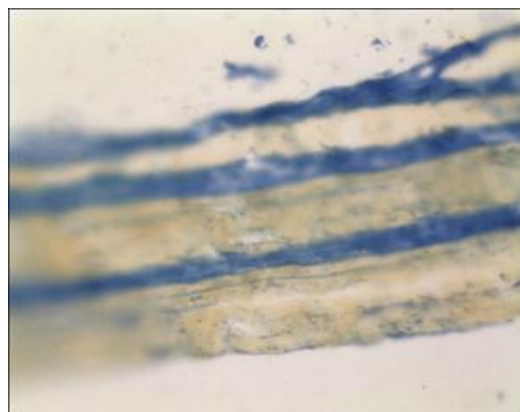
Fig 2.29
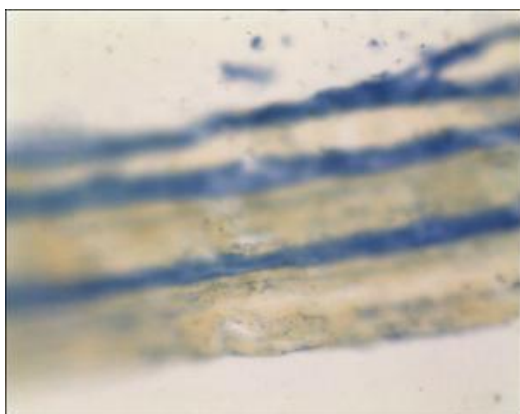
Fig 2.30
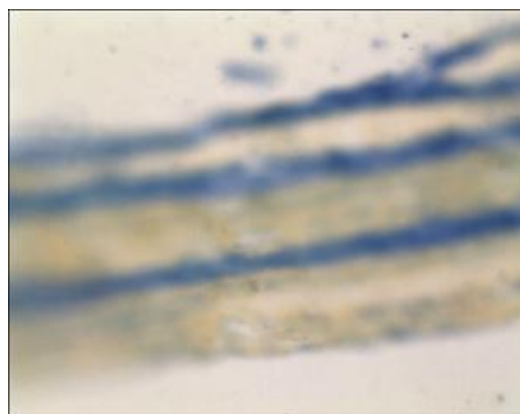
Fig 2.31
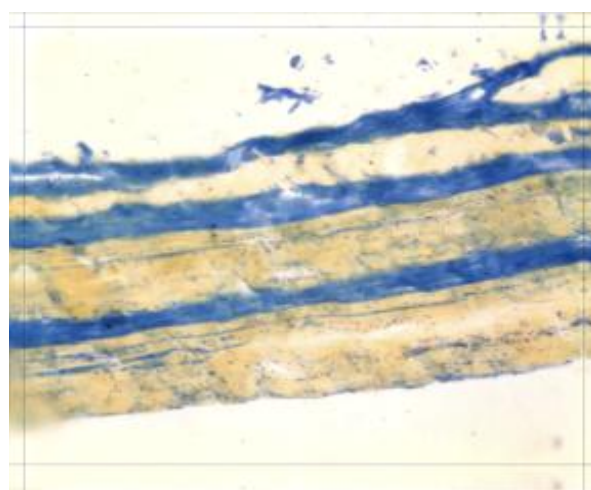
Fig 2.32

2.2.9.2 – Differential Interference Contrast Microscopy

Differential Interference Contrast microscopy (DIC), also known as Nomarski Interference Contrast microscopy (NIC), is an optical microscopy illumination technique, which enhances the contrast in sections, particularly those unstained giving a three dimensional appearance to the otherwise invisible elements (Hovden et al 2011; 79). DIC was utilised in this project for samples that for some reason, most commonly degradation, did not take up the staining procedure (see Fig 2.33 below).

By working on the principle of interferometry, DIC obtains information about the optical path length of the sample, allowing the viewing of otherwise invisible features.

Its resolution and clarity in conditions such as these is unrivalled among standard microscopy techniques.

Figure 2.33 shows a sample of rib bone from Kellis 1 Mummy A101. It is clear that the section has not taken up the stain, probably due to poor preservation of the sample. Using ordinary transmitted light microscopy, an osteocyte within bone can be difficult to visualise. To overcome this, Differential Interference Contrast Microscopy (DIC) can be applied, giving its characteristic three-dimensional appearance. Micro-components (osteocytes and their related canaliculi) of the bone become recognisable, despite not being stained (Figure 2.34).
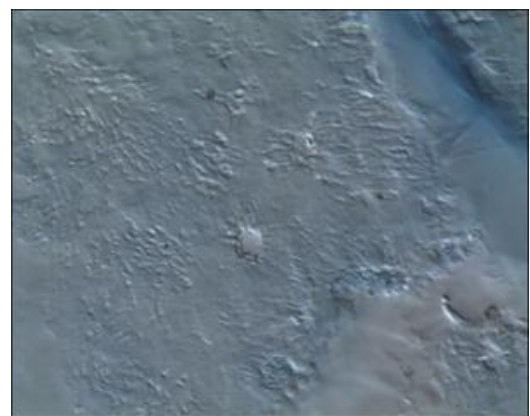
| Fig 2.33 | Fig 2.34 |

2.3 – METHODS – ACRYLIC RESIN

Below is a flowchart describing the steps undertaken in order to rehydrate, fixate and decalcify (bone only) ancient organic samples, in order for their embedding in resin blocks and then sectioned and stained before microscopic examination.

Rehydration and Fixation

↓

Decalcification (Bone Only)

↓

Processing with LR White Resin

↓

Blocking Out

↓

Mounting onto Chucks

↓

Sectioning

↓

Staining

↓

Mounting

↓

Examination
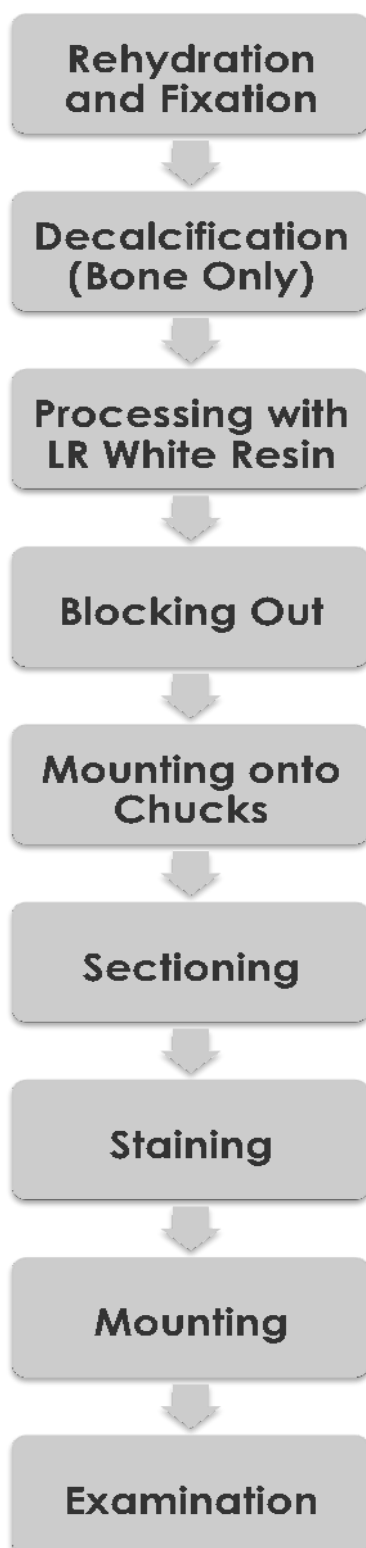
2.3.1 - Bone

At the time of autopsy, bone samples were collected from twelve of the mummies, which are under analysis in this project. These samples consisted mainly of rib; however, two femur samples were also examined.

In human skeletons, bone is a highly active calcified connective tissue, forming the articulating structure to which the muscles (through the tendons) are attached (Denton 2008; 80).
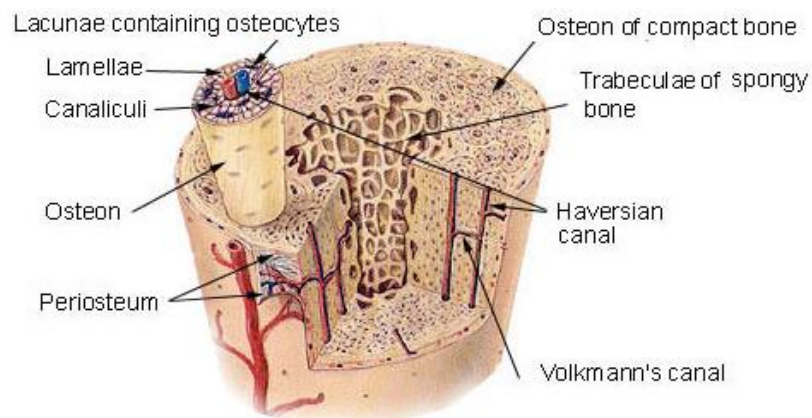
Fig 2.35 - Compact and spongy bone (www.daviddarling.info/images/bone.jpg)

There are two types of normal bone. These are:

- Cortical or compact bone which surrounds the outside of all bones but with varied thickness. It forms the shafts of the long bones and much of the exterior surfaces of the flat bones. It appears solid and is immensely strong.
- Trabecular, cancellous or spongy bone which is found in extremities and marrow cavities of the long bones, the vertebrae and centres of the flat bones. Although much less solid that compact bone, the arrangement of the trabecular bone forms an almost ideal weight bearing structure.
- Another configuration of bone is that of woven bone produced as a consequence of bone damage and rapid repair. This type is particularly seen in fracture repair. It differs from the normal bone types in that the collagen does not have a regulated structure of either plates as seen in trabecular bone or tubes as seen in cortical bone. The collagen seems to have a somewhat random pattern. When able to, the woven bone is

134

undergoes osteoclastic resorption and is replaced by either of the normal bone types (Bancroft & Stevens 1996; 309).

Bone is composed of a variety of cells with specific functions:

- Osteocytes – The most abundant of bone cell types and have two main functions. Firstly, they monitor and help maintain the mineral and protein content of the surrounding bone matrix and secondly, they are involved in bone repair.
- Osteoclasts – Bone cells that remove the mineralised matrix of bone in a process called bone resorption (osteoclasis).
- Osteoblasts – These carry out the function of bone formation.
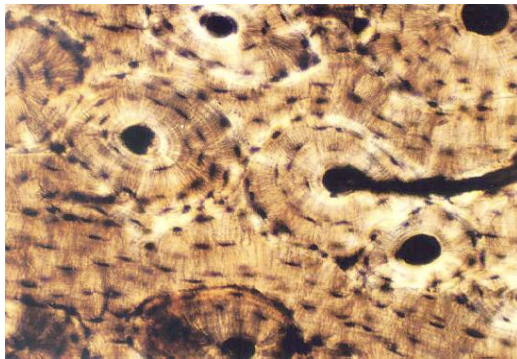
Fig 2.36 - Compact bone (www.cytochemistry.net/microanatomy/ bone/bone1.jpg)
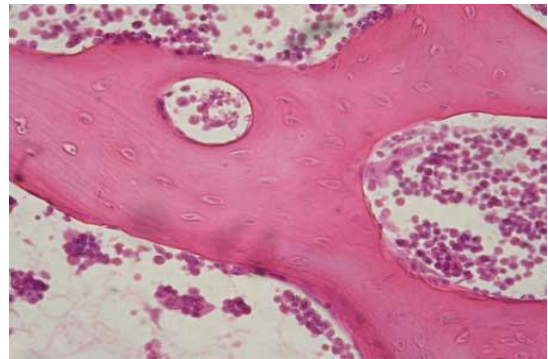
Fig 2.37 – Trabecular or Spongy bone (www.cytochemistry.net/microanatomy/b one/spbone.jpg)

Bone also contains a large vascular network and a matrix of collagenous fibrils and inorganic salts (Young et al 2007; 196).

During life, bone cells die and are replaced cells, particularly osteoblasts and osteoclasts maintain bone integrity and composition — areas of bone containing collagen and minerals are eroded and formed continually. These processes are called remodelling. Remodelling consists of resorption and deposition, taking place in equilibrium so that the shape and volume of the bones is more or less constant and adaptive to mechanical stress.

As aging progresses, the remodelling process slows down and sometimes deposition cannot keep up with resorption. This increases the porosity and brittleness of the bone. In more extreme cases, this becomes the debilitating condition osteoporosis (Bancroft & Stevens 1996; 309).

In modern tissue, polymer resins are mainly utilised when examining mineralised bone because of the additional support needed when sectioning either hard tissues or fully calcified bone, while the cheaper and more convenient paraffin wax is used for bone samples that have been demineralised, rendering them much softer (Skinner 2003; 167).

When bone is decalcified, only information gained from cells and the organic matrix can be assessed. Any information about the distribution and degree of mineralisation is lost.

For this project, the bone samples were first fixed using the same methods as that for soft tissue (see Chapter 2.2.1 & 2.2.2). After fixation, all samples were decalcified using the chelating agent ethylene diamine tetra-acetic acid (EDTA).

2.3.2 - Decalcification (Bone only)

One of the main components of bone is collagen; however, over 70 percent of the weight of dried bone is the mineral element hydroxyapatite.

Bone is a highly mineralised strong tissue, in which calcium salts are fixed in an organic osteoid matrix; the main component of which is the crystalline element hydroxyapatite. Hydroxyapatite is composed mainly of calcium, phosphate and hydroxyl ions with small amounts of potassium, fluoride, carbonate and magnesium (Bancroft & Stevens 1996; 310).

In modern bone histology, the choice of decalcify agent is determined by the type of analyses that will be undertaken on the final slides. If it is of primary importance to make the bone sample soft enough to acquire a section to be stained by haematoxylin and eosin, then any decalcifier can be used. If, however, the sample needs extremely fine intracellular detail, special stains or immunohistochemical procedures, a decalcifying solution must be chosen with care (Skinner 2003; 173).

The ancient bone tissue from the Dakhleh mummies proved to be extremely brittle and the choice of decalcifier needed to be effective but gentle enough to limit the damage to the fragile structure of the bone.

With any decalcification process there are two main techniques. These are;

1) The Acid Method

In this method, acids are used to ionise and dissolve the calcium salts in the mineral hydroxyapatite forming a soluble salt of the acid.

a. Strong Acids – the strong decalcifying acids, such as nitric and hydrochloric, when used in the dilute form, are utilised when the speed of decalcification is the primary concern. These are considered to give adequate results when the decalcification end point needs to be less than 48 hours (Skinner 2003; 173). When decalcification is obtained by strong acids damage to tissue and its cellular components can occur, which in turn will influence the range histological techniques undertaken. One such problem can be the production of carbon dioxide bubbles on the sample. These are the result of carbonate ions present in the crystal lattice hydroxyapatite reacting with the acid. This can cause damage to the cells by causing the tissue to expand and break apart.

b. Weak Acids – Taking into account the balance between optimal quality of the stained section and time of decalcification endpoint, it is generally considered the best decalcifying agent is aqueous formic acid in concentrations between five and fifteen percent. This delivers excellent morphological detail with little to no tissue damage (Skinner 2003; 174).

2) The Chelating Method

Chelating agents, such as ethylene diamine tetra-acetic acid (EDTA), are one of a group of organic compounds that bind to certain metals to produce a very stable compound called a metal chelate. When it is used to decalcify bone, EDTA binds with the calcium ions from the water of hydration shell of the crystal lattice and gradually removes them from the outer layer of hydroxyapatite (Skinner 2003; 169), when removed the crystal atomic lattice becomes unstable. To achieve stability, phosphate ions are shed from the crystal forming soluble phosphate molecules. As chelating agents are used near to, or at, neutral pH, they are much less harmful to tissue than the acid decalcifying agents. This is because hydrogen ions that effect enzymes and nucleic acids, do not

take part in the chemical reaction (Bancroft & Stevens 1996; 316). EDTA was used for the decalcification of the Kellis 1 samples.

2.3.3 - Decalcification Endpoint (Bone only)

The most important concept, regardless of the decalcifying agent used is the precise endpoint when the best sectioning and staining will be obtained. Decalcification is complete when there are no calcium ions present in the solution. To realise an accurate endpoint, different decalcifying agents require different tests.

By adding a strong ammonia solution followed by a saturated aqeous solution of ammonium oxalate the decalcifying fluid, a white precipitate (calcium oxalate) will form if calcium ions are present in the fluid. If no white precipitate forms, decalcification is complete. This method is only useful for acid decalcifying agents and not for EDTA based solutions

Radiography is also used to determine decalcification endpoint. However, it is necessary to compare the radio-opacity of the sample with control specimens (one that is calcified and one that is decalcified). This additional step and the process of developing the film causes radiography to be time consuming and expensive, however it is considered to be the "gold standard" for determining the endpoint (Skinner 2003; 169-70).

2.3.4 – Processing and Embedding

Paraffin wax embedding is generally the method of choice for embedding both decalcified bone and soft tissues; however some of the mummified tissues were so hard and difficult to section that was decided to embed some of the more difficult tissues in resin in order to obtain better quality sections. As the bone samples used were all of a poor level of preservation, there was a need for the embedding medium to be an approximate hardness to the bone sample being sectioned. Some soft tissue samples were also embedded in resin; these soft tissues were so degraded that paraffin wax could not support them. Resin embedding can give thinner and better quality sections but can limit the staining techniques as the resin itself can stain or the staining solution cannot penetrate the resin. There are two types of resin most commonly employed in histology. These are:

1) Epoxy Resins

These are hard cross-linked solids containing two or more epoxy groups in their structure. In a polymerised state, the epoxy resins have excellent physical properties such as strength, toughness and thermal stability; this means the resin has the necessary strength to support the tissue during sectioning. The epoxy resins are used mostly for electron microscopic studies since the polymerised resin is hard enough to allow sections as thin as 30-40nm to be cut with a glass or diamond knife. The disadvantages of epoxy resins include being hydrophobic and any oxidation of peroxide to correct this may cause tissue damage. The components of many epoxy resins are toxic and extreme care must be taken when handling them. For light microscopy the biggest disadvantage is the unpolymerised resin is very viscous and with samples larger than 1mm^3 it is nearly impossible to infiltrate the tissue with resin Formulations of epoxy resins include Spurr's and Araldite CY212 (Bancroft & Stevens 1999; 556-7).

2) Acrylic Resins

These are a group of vinyl polymers; acrylites are made of acrylate monomers and these monomers are esters that contain vinyl groups. Its subsequent user determines the polymerising method of acrylic resin. When acrylic resins are polymerised quickly at high temperatures, many radicals are produced, these collide with each other as well as the polymer chains resulting in a highly branched microstructure that expands only a little in water and will reduce infiltration of stains. Slow polymerisation produces very few radicals, the polymer chains grow longer with little interference from free monomers and the resulting blocks are tough and easy to section, swell more in water and therefore, stain more easily (Bancroft & Stevens 1999; 559).

It was decided to embed the decalcified bone samples from the Dakhleh mummies in LR White acrylic resin. While it is decidedly more expensive than using a paraffin wax medium (500ml for approximately £110 and 50ml needed per block), it is readily available, minimal care is needed and can be used in a fully automated processor so no manual changing of solutions was necessary.

As LR White has a viscosity slightly greater than that of water, infiltration into the bone samples occurs quite easily (Karlsen 2006; 140).

The embedding process for LR White takes eleven days to complete and is done by an automated processing machine housed in a cold room to avoid the premature polymerisation of the LR White monomer. The bone and soft tissue samples are placed in a basket where they are immersed firstly in five changes of ethanol to remove water, then two changes of chloroform, and finally, three changes of pre-catalysed LR White resin containing the catalyst 0.9 percent benzoyl peroxide (Newman 1987; 118). There is automatic agitation of the reagents, which ensure better infiltration.

2.3.5 - Blocking Out the Resin

Once the samples have been removed from the processor, they are placed in the separate compartments of an ice cube tray, which are then half-filled with pre-catalysed LR White resin, the opposite side of the tray containing the identification label.

The trays are placed in a vacuum oven at room temperature and which is taken to a pressure of -2 bar, and left overnight so that any air bubbles or residual reagents can be removed. The pressure is then returned to atmospheric pressure. Once this is completed, the trays are placed in a pressure chamber (pressure of 2 bar). The pressure chamber is a sealed compartment with an O^2 free, dry nitrogen environment. The chamber is purged with O^2 free nitrogen to remove any air in the chamber and the pressure increased to 2 Bar after which the chamber valves are closed. The whole pressurised chamber is placed in an oven overnight at 42°C where the LR White polymerises.

Once taken out of the oven and cooled, the hard resin blocks can be removed from the ice cube tray.

2.3.6 - Mounting the Resin Blocks onto Chucks

In order for the blocks to be sectioned on the microtome, they need to be mounted onto chucks. To do so, a strong adhesive typically another setting resin is used to attach the block onto a chuck. Once done, the block can

remain in place when the large force of the microtome is applied with no damage to the resin block.

2.3.7 - Sectioning the Resin Blocks

A microprocessor-controlled LKB macrotome was used to section the resin blocks equipped with a tungsten carbide tipped "D" profile knife. The mounted chuck is placed in the microtome holder and the desired section thickness (10micron) and cutting speed (3mm/second) is programmed into the microtome. The sections are then cut automatically and manually collected from the knife. The knife is placed at an angle to the block so that it starts cutting from the corner of the block with the piece of tissue at the trailing edge of the block. If the knife was to be placed parallel to the block edge, a large amount of pressure would be created when they came into contact, which could affect the quality of the sections, crack the block or damage the knife. By cutting at an angle, the pressure starts gradually builds so the section cuts smoothly and there is no damage to the block or knife.

As with the paraffin blocks, the top layers need to be cut away to expose the sample and then the desired sections can be removed with tweezers and placed onto a slide tray, ready for staining.

2.3.7.1 – Adhesive Tape Methods (Ball 1956 – adapted by J Denton for Use In-House)

The adhesive tape method was originally developed to aid the sectioning of undecalcified bone embedded in paraffin wax. In this project, it was useful for very hard samples, such as the York conglomerate material.

Before sectioning, a strip of adhesive tape (e.g. sellotape) is stuck to the top surface of the resin block. The block is then sectioned; the resulting section has the tape attached. The tape prevents impaction, crumbling and curling of the sections (Ball 1956; 281).

A part of the tape with one or more sections fixed to it, is then placed, adhesive face downwards onto albuminised microscope slide and dried on a hot plate. The tape is then removed by dissolving the adhesive by immersion in xylene for 30 minutes, followed by a wash in alcohol and then stored in water prior to staining

2.3.8 - Staining with Toluidine Blue

Set a single section in a shallow container of ethanol until it curls up and relaxes. The section is then transferred to a shallow container of deionised water by collecting the section onto stainless steel mesh; the surface tension flattens it. Once the section has flattened, it can be placed in the stain for five minutes.

The section is then removed from the 0.005% toluidine blue and set into another container of deionised water, until the excess stain has washed off.

Using mylar graphic film, the stained section is picked up on the matt side and set on a hot plate for 30 minutes to dry. Now the sections are ready to be mounted.

2.3.9 - Mounting Stained Resin Sections

Once dried, the resin sections need to be mounted onto glass slides. Firstly, the mylar graphic film containing the stained section is placed on an overhead projector (OHP) film in an ultraviolet (UV) exposure unit. A small drop of Loctite Glass Bond glue is put onto the section; Loctite is a glass adhesive is a UV polymerising resin. A glass slide is placed on the top of the glued section. The slide is then turned over and another piece of OHP film is placed over the top; the OHP film stops the slide sticking to the UV unit.

The lid of the UV unit is fastened and left for 30 seconds, applying pressure to the slides. The UV is turned on for two minutes. The slides are then taken off the UV and the mylar film removed (mylar is used because the Loctite glue will not stick to it). The section will remain on the glass microscope slide.

A further drop of Loctite is put onto the section and a glass cover slip placed over this. The mounting medium used in the mounting of paraffin wax, Xam, cannot be used with resin because it reacts with it, leaving the section folded, creased and/or swollen. This is due to the xylene and toluene within the Xam. The slides are set back onto the UV unit, covered with OHP film. The lid of the UV unit is fastened and left for 30 seconds, applying pressure to the slides. The UV is turned on for two minutes.

The slides are removed and any excess glue around the sides is removed. The slides are now ready to be examined under a microscope.

2.3.10 - Microscopy

See Chapter 2.2.9.

2.3.11 – Summary of Methods used in this Project

Method	This Project
Rehydration & Fixation	1% sodium laureth sulphate in neutral buffered formol saline
Decalcification (bone only)	Ethylenediamine tetra-acetic acid
Processing	Fully automated (see Sections 2.2.3 & 2.3.4))
Embedding	Both Paraffin Wax and LR White resin embedding media
Sectioning	Rotary Microtome and LKB Microtome
Staining	Toluidine blue, One Step MSB (see Section 3.1)
Microscopy	Light, Polarised, Focus Stacking, Differential Interference Contrast

Table 2.15 – Summary of Methods

CHAPTER THREE - HISTOLOGY

The aim of histology is the production of thin sections of tissue that can be stained and examined under a microscope, rendering informative data of the subject of the examination (Denton 2008; 71).

Histology has been used for over a century for the study of ancient Egyptian mummies, with advancements throughout this time enabling detailed information on a number of aspects of Egyptian life and death, including diet, disease and mummification processes. While the technique is not utilised as much today as it was it the second half of the twentieth century (see Chapter 1.3), it has the potential to provide insights into the preservation and pathology of human remains that no other techniques currently has the ability to do.

The aim of this project therefore, is to re-evaluate histology as a scientific technique for the study of ancient, especially mummified, material.

Aims

The main aim of this section is:

- To evaluate the use of histology as a forensic method in mummy studies, including the advantages and limitations of the technique

Fig 3.1 – Endoscopy of ancient Egyptian mummies is one way of obtaining tissue for histological study (http://emhotep.net/wp-content/uploads/2011/12/mfor04-mummy-endoscope.png)

3.1 STAINS AND STAINING METHODS

Stains are used on sections in order to facilitate the elucidation of structured details (Kiernan 1981; 2). In modern histology, one stain is usually sufficient to afford the information required. However, when dealing with ancient tissue, a panel of stains is needed to answer the three main questions that should be asked of all palaeohistological studies:

1)   What is the tissue being examined? (Identification)
2)   What condition is the tissue in? (Preservation)
3)   Are there any anomalies? (Pathology) (Denton 2008; 76).

Once samples have been rehydrated, fixed, processed and embedded, they are then sectioned.   For the examination of ancient material, sections are usually cut at a thickness of five microns, which is the optimum thickness enabling visualisation of most cell components. However, at this point, the sections have no inherent colour or contrast for the individual tissue elements to be visualised, and therefore need to be stained (Denton 2008; 75).

A dye or stain is a coloured compound that can be bound by a substrate. In histology, dyes/stains are used to import colours to the various components of tissues (Kiernan 1981; 38). In the pilot stage of this project, a panel of five stains was tested in order to find out which combination would be provide the most useful for the information in terms of this study. These stains were:

1)   Hameatoxylin and Eosin (H&E) – The most useful and common staining procedure employed in hospital laboratories today provides disappointing outcomes when used on ancient material. While some scholars still recommend that H&E be the main stain used in palaeohistology (Lepidi 2008; 69, Mekota & Vermehren 2004; 10), others have reported less than promising results (Denton 2008; 76, Shaw 1938; 117, Sandison 1955; 278, Sandison 1963; 419).

Haematoxylin, a natural stain, when counterstained with the dye eosin, is most effective when used to demonstrate nuclei (stained blue) in contrast to other tissues (stained red).   The degradation of ancient tissue however, results in a loss of nuclear staining as well as the contrast given by eosin (Denton 2008; 76).

2)   Giemsa – In modern histology, Giemsa is often used as a blood stain, allowing the identification of the various types of cells occurring in the blood and haemopoietic (formation of blood and blood cells) tissue. Blood stains also reveal abnormalities in the cells and the presence of pathogenic organisms, for example, malarial parasites (Kiernan 1981; 88). The detection of microorganisms, such as bacteria, is a challenge, especially in ancient material as many are too small to be seen clearly with light microscopy, and the larger organisms such as fungi may not be easily recognisable with the use of many of the well-known stains as they can be obscured by surrounding tissue components (Lepidi 2008; 70). While there are a variety of stains that can be employed to overcome these problems (for example, Gram, Periodic acid-Schiff and Grocott-Gomori methenamine silver), the Giemsa stain is purported to be most sensitive, enabling palaeopathologists to identify most microorganisms and study their morphology (Lepidi 2008; 70).

3)   Miller's Elastic Stain – There are three types of fibre found in connective tissue are collagen, reticulin and elastin. These fibres have certain physical and chemical properties, which enable them to be stained. Elastic fibres are made of elastin, a fibrous protein different to that of collagen or reticulin. It is rich in glycine, alanine, proline and other non-polar amino acids that are cross-linked. Elastin is particularly resistant to digestion by most proteolytic enzymes, which helps explain its preservation in ancient material. Elastic fibres are abundant in blood vessel walls, ligaments, lungs and the heart. Elastic fibres stain quite intensely with the Millers elastic stain but are not often stained by other methods such as toluidine blue (Kiernan 1981; 92).

4)   One Step MSB – One of the most useful, and most common, staining techniques in the histological examination of ancient tissue is that of the trichrome stain. Like Haematoxylin and Eosin, trichrome stains are connective tissue stains. The term 'trichrome' is a general name for a number of techniques used for the selective demonstration of red blood cells (erythrocytes), fibrin, collagen and muscle. As the name suggests, three dyes utilised together (although the term still applies to as few as two dyes), one of which may be a nuclear stain.

Trichome stains, such as van Gieson's and Mason's trichrome, have been used extensively and successfully in previous studies on mummified material.

Examples include Walker et al's (1987) examination of lung tissue from Egyptian mummies, A F B Shaw's (1937) histological study of the mummy Har-mose, a singer from the Eighteenth Dynasty and Sandison's (1955) investigation into Late Period Egyptian mummies from two Scottish museums. Trichrome stains have also been employed for non-mummified ancient remains such as Post and Daniels (1969) study of American Indian scalps.

Stains, such as Masson's trichrome, are multi-step techniques, in which dyes are applied sequentially over a period of time. For this project, however, a one-step trichrome staining method was used (One Step MSB). One step staining methods combine all of the dyes and other reagents into a single solution. This solution results in the various factors interacting simultaneously, resulting in various tissue components staining with different dyes. One step methods are most effective when everything (rehydration, fixation, processing and section thickness) is standardised (www.stainsfile.info/StainsFile/theory/theory.htm). In this project, any variation in results was due not to any changes to the standardised procedures but was due to the preservation level of individual tissues.

5)   Toluidine Blue – One of the easiest, cheapest and most useful stains utilised in this project was the general architecture stain, toluidine blue. It allows for considerable cellular detail including the matrix, nuclei and microorganisms. In modern histology, toluidine blue is most commonly used for the high-resolution investigation of the structure of the glomerulus in health and disease, and for the high-resolution light microscopy of nerves. As they are in modern samples, all of the ancient tissue components are coloured in shades of blue, including any surviving nuclei so identification of the tissue must be done through morphology alone (Denton 2008; 76).

3.1.1 – Staining Results

Haematoxylin and Eosin

Haematoxylin and Eosin (H&E) is the standard stain used in modern clinical pathology, however, when applied to ancient tissue, it yields disappointing results because of the degradation of the cell nuclei. The main reason for the use of H&E is for the differentiation it displays between staining nuclei and the other tissue elements. The haematoxylin stains nuclei, ribosome's and rough endoplasmic material a purplish blue; these tissue elements have a strong affinity for this dye due to their high content of RNA and DNA. Eosin, an acidic dye, stains the basic tissue structures red or pink.

In Figures 3.2 and 3.3 below, two ancient samples, coprolite and lung respectively, have been stained with H&E. The sections are clear although it is obvious that the differentiation has not been successful.
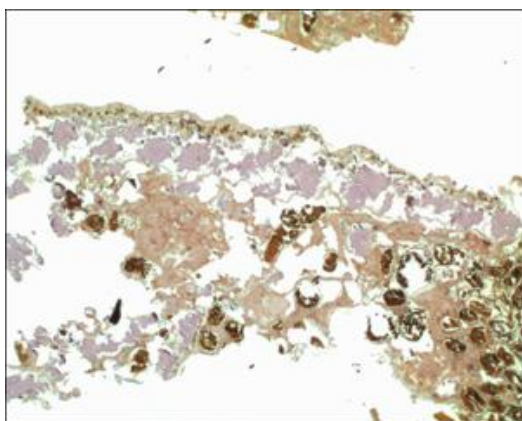
| Fig 3.2 – Coprolite sample stained with H&E (Mummy A101) | Fig 3.3 – Lung sample stained with H&E (Mummy A126) |
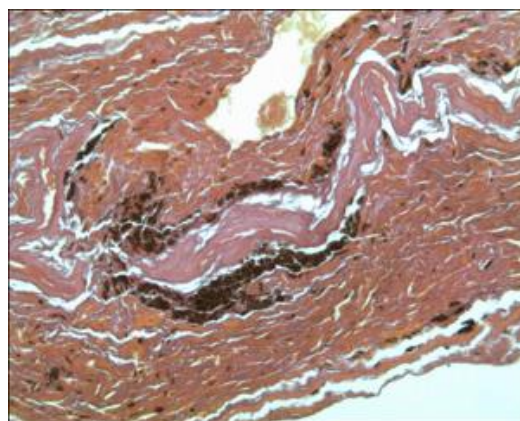
All tissue elements in both samples have been stained a shade of pink. There has been no nuclear preservation in either sample so the haematoxylin has been unable to stain anything blue.

Giemsa

The samples stained by Giemsa were also disappointing. In its modern usage, Giemsa stains nuclei blue or purple and parasites blue or dark blue (www.bris.ac.uk/vetpath/cpl/giemsa.html). When applied to ancient Egyptian

mummified coprolite and lung samples (Figures 3.4 and 3.5 below), it stained everything either dark blue or black. Due to these dark colours, the sections lacked clarity, and the tissue elements were difficult to discern. In the coprolite sample, the possible parasite ova stained black, which did not allow the visualisation of any internal structure.
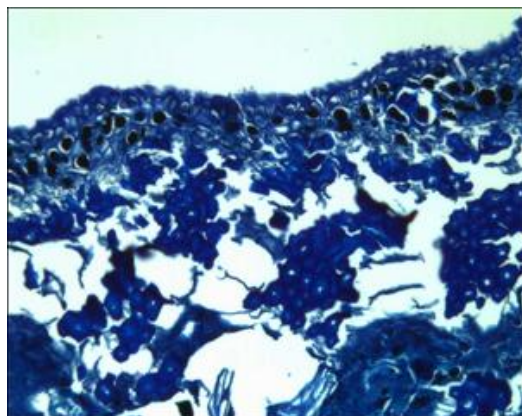
Fig 3.4 – Coprolite sample stained with Giemsa (Mummy A101)
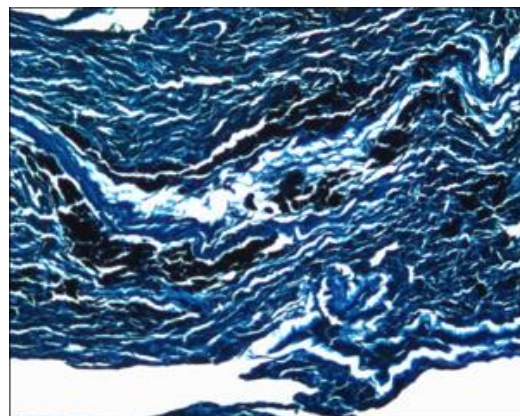
Fig 3.5 – Lung sample stained with Giemsa (Mummy A101)

In the lung sample, the bronchioles, which are quite easy to determine using other stains such as toluidine blue and MSB, are indistinct. Again, due to the dark colouring of the stain, the presence of anthracotic pigment is also difficult to see clearly.

Miller's Elastic Stain
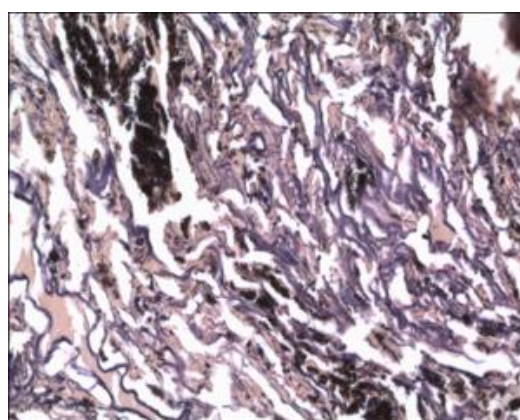
Fig 3.6 – Lung sample stained with Miller's elastic stain (Mummy A126)

While Miller's was very effective in staining the well-preserved elastic fibres either purple or black, the trichrome stain, MSB, was also able to do this. It was decided not to stain the Kellis tissues with Miller's elastic stain as it did not reveal any further information about the samples that One Step MSB and Toluidine blue could. It would be more useful if focussing purely on the preservation and/or function of the tissue.

One Step MSB

The first of the two stains applied to all samples in this project is that of One Step MSB. Trichrome stains, of which MSB is one, are usually part of the panel used by palaeohistologists when examining ancient tissue; the staining reactions of which are designed to separate the various tissues (including connective tissues) by displaying different colours for individual elements.
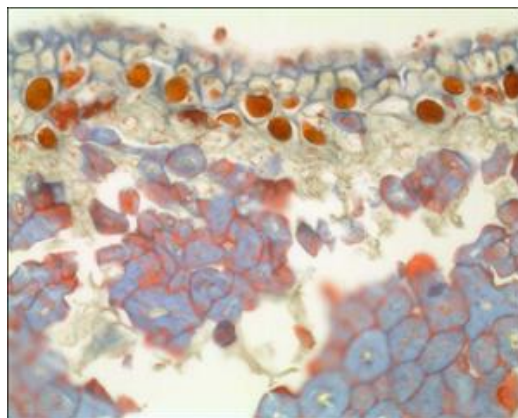
Fig 3.7 – Coprolite sample stained with MSB (Mummy A101)	*Fig 3.8 – Coprolite sample stained with MSB (Mummy A101)*
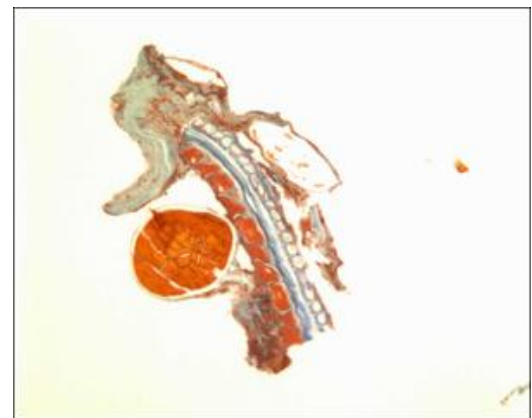
One step MSB was particularly effective when applied to coprolite samples, as can be seen in Figures 3.7 and 3.8 above. Figure 3.7 demonstrates the remains of undigested plant material. The starch cells are coloured a vivid blue and the different layers of the seed coat are well defined.

Figure 3.8 shows a section of coprolite sample under high magnification (x20). The layers of an outer wall of a cereal seed are easily recognised. Also clearly seen abutting the seed wall is an ovular entity which displays the internal structure similar to the ovum of the human intestinal parasite, *Ascaris lumbricoides* (giant roundworm).

The lung sample stained with MSB displays very clearly the colour differentiation MSB gives for various tissue elements.
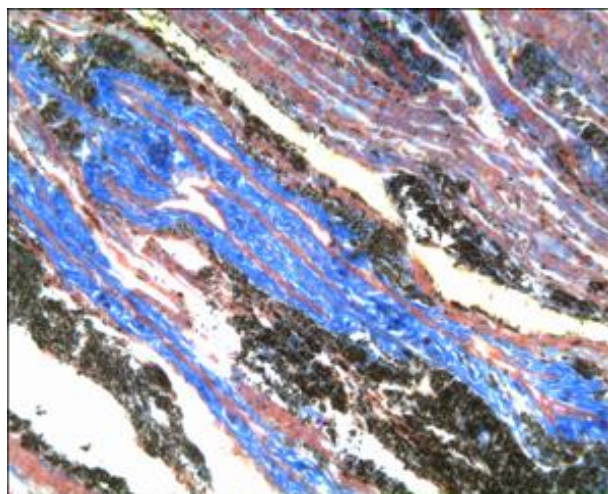
Fig 3.9 – Lung sample stained with MSB
(Mummy A126)

Toluidine Blue

Along with MSB, toluidine blue proved to be the most effective stained applied to the Dakhleh mummy samples. Toluidine blue is a general architecture stain and dyes all elements of the tissue various shades of blue. Despite this lack of distinct colour differentiation, toluidine blue proved to be extremely effectual, especially when used in conjunction with the trichrome stain, MSB.
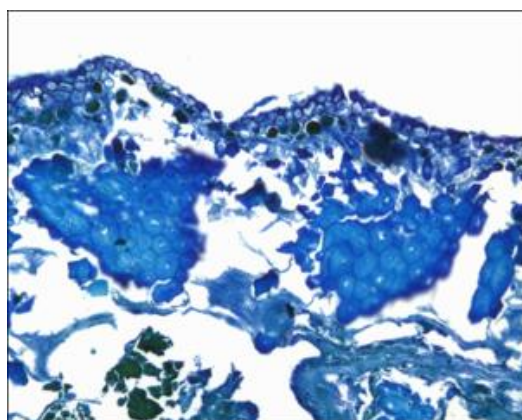
Fig 3.10 – Coprolite sample stained with toluidine blue
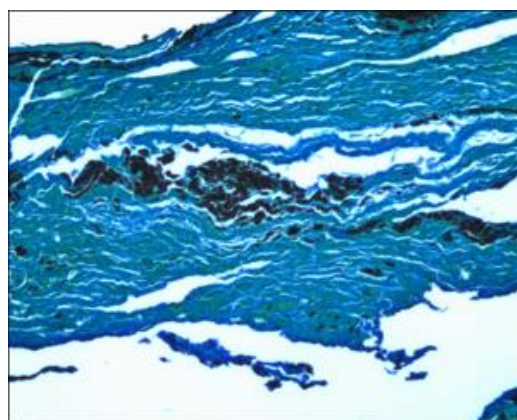
Fig 3.11 – Lung sample stained with toluidine blue

Figure 3.10 shows a coprolite sample stained with toluidine blue; the starch cells are visible, coloured in a bright, almost fluorescent, blue, while other components of the coprolite are stained different shades. In the bottom left-hand corner of the section, some elements have stained a greenish blue; these are most probably parasite ova, which will be discussed further in Chapter 4.10).

Some of the preservation problems the palaeopathologist is faced with when examining ancient tissues are the result of the invasion of the tissues by bacteria and/or fungi, which are often still visible in the sections. Toluidine blue is the best stain to visualise these microorganisms, especially bacteria, which stains a much darker blue than any of the tissue components (Denton 2008; 77).
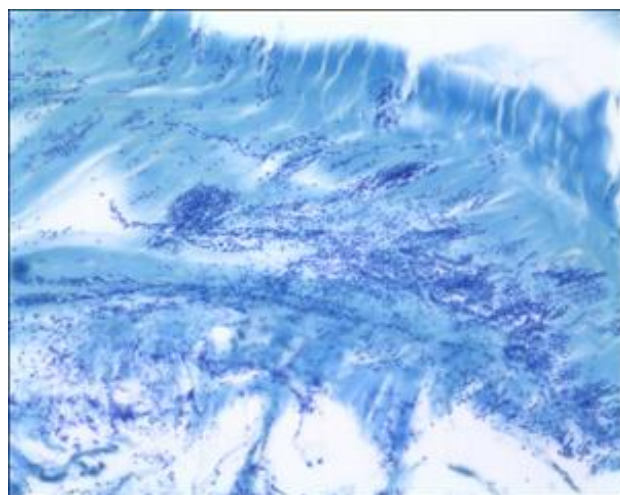
Fig 3.12 – Ligament sample showing bacteria	<u>Stain – Toluidine Blue</u> <u>Magnification – x20</u> Intercostal Ligament samples from Mummy A8 showing the invasion of a large number of bacteria, which are coloured dark blue.
Fig 3.13 – Coprolite sample – purple areas at top of section are metachromatic	<u>Stain – Toluidine Blue</u> <u>Magnification – x40</u> Coprolite sample from Kulab Narti
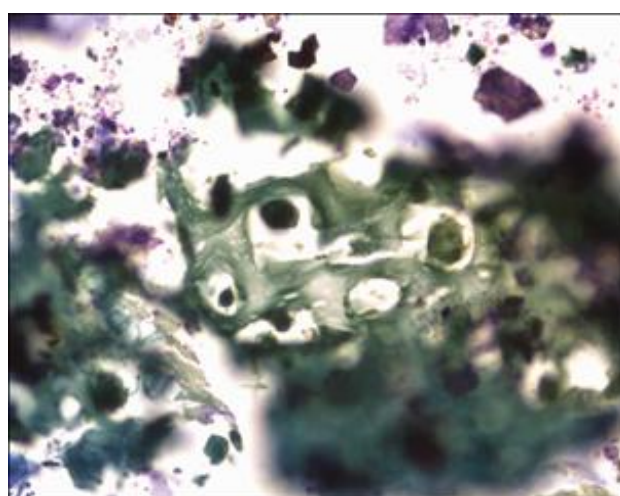
Toluidine blue also colours mast cell granules reddish purple in a process called metachromasia. In ancient Egyptian material, this effect can also be caused by sand or silica particles within the sample, which have the same physical properties as the mast cells (Denton 2008; 77).

Toluidine blue has not been traditionally included in the panel of stains used by other palaeopathologists; Haematoxylin and Eosin more commonly being incorporated to carry out a similar function. However, if samples have been embedded in epoxy or acrylic resins, toluidine blue is the first stain called on for both modern and ancient material. Other stains, such as MSB, if applied to resin sections, stain not only the tissue but the resin as well, making identification of individual elements impossible. Other staining methods are unable to penetrate the resin or are also stains of the embedding resin. Toluidine blue has the advantage of both infiltrating the resin and only differentially staining the tissue within the section (Stevens & Lowe 1997; 7).

Stain – Toluidine Blue
Magnification – x20
Resin Section

A sample of bone from a juvenile crocodile, an ancient Egyptian votive mummy. Provenance unknown. The chondrocytes of the growth plate are beautifully demonstrated.

Fig 3.14
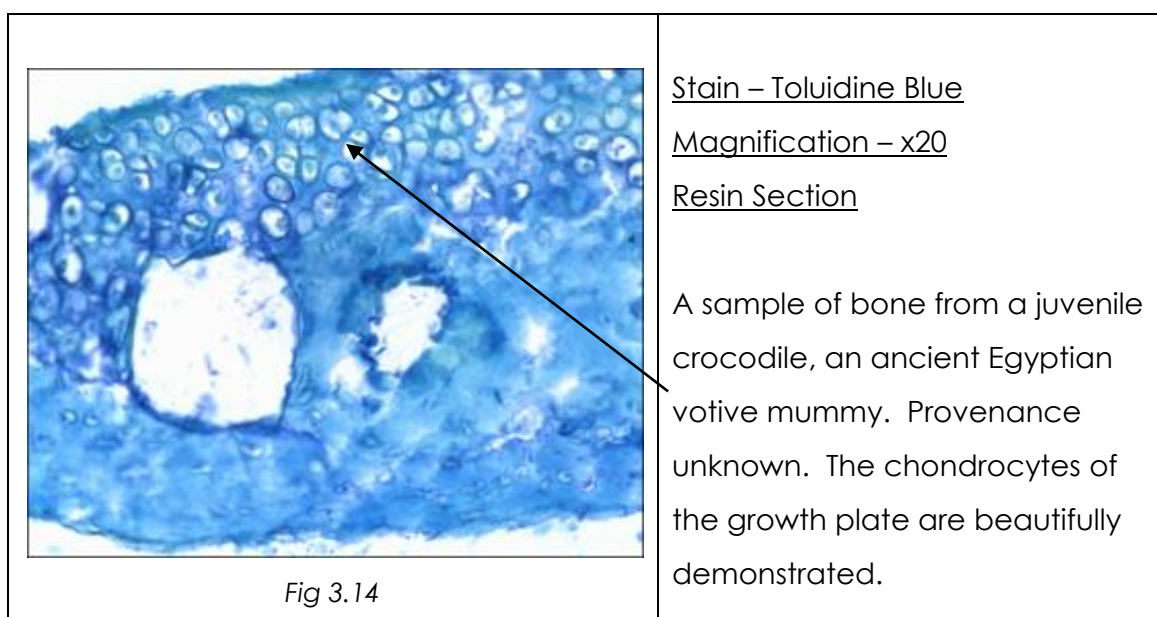
Lewin (1967) successfully used toluidine blue to stain the resin-embedded skin and muscle samples from an ancient Egyptian mummy dated to approximately 600 BCE.

Toluidine blue also had the advantage of acting like a fixative on very fragile material if used prior to embedding.

For this project, toluidine blue was used on samples embedded in resin and paraffin wax.

3.1.2 – Staining Discussion

Since Ruffer's development of effective rehydration, fixation and embedding techniques, a variety of stains and dyes have been utilised for the study of mummified material. While there are thousands of stains employed in modern histology, many of them serve similar functions (Denton 2008; 75). A panel of stains for the study of ancient material aims to reveal specific features of the tissues. In general, the connective tissue stains are the most common because connective tissues are the most commonly preserved in ancient tissues as well as foreign elements such as parasites, bacteria or pigments, where they also are preserved. Epithelial tissue is often missing due to autolysis and/or putrefaction (Zimmerman 2004; 51). Stains are utilised to demonstrate tissue elements such as:

- general tissue architecture
- elastin
- connective tissue
- glycoprotein
- collagen
- reticulin
- cell nuclei
- fungi
- bacteria
- parasites.

As mentioned above, for this project, a panel of five stains was established in order to evaluate the most useful in the study of the Kellis mummies. From these five stains, it was determined that a combination of toluidine blue and One Step MSB would provide all the necessary information required.

3.2 - PRESERVATION ASSESSMENTS

The preservation level of mummified bodies based on gross anatomical examination compared to histological analysis of the same can be extremely varied. Giving an overall soft tissue or bone preservation score, as has been attempted in the autopsy reports of the 49 Kellis 1 mummies, cannot give an accurate reading of either. Within a single mummy, the soft tissue preservation of different organs could range from extremely well preserved to completely degraded (see Table 3, Chapter 3). Examples of this include Mummy A5, the liver of which was in a state of very good preservation (mainly due to its diseased state); however, the heart sample from this Mummy was highly degraded and only just identifiable due to the presence of cardiac veins.

The preservation of mummified remains is affected by five factors:

- autolysis
- putrefaction
- insect attack
- oxidation
- mode of mummification.

Two processes dominate the decay of human remains. These are:

1) Autolysis – a destructive process of post-mortem self-destruction by intrinsic enzymes at a cellular level. Cells become detached and their contents break down. While it operates without the participation of bacteria, the partial destruction of the cellular structures considerably enable further bacterially-driven putrefactive alteration. It is not visible at a macroscopic level however can be recorded histologically (Janaway et al 2009; 316).

2) Putrefaction – the destructive activity that involves the reduction and liquefaction of tissue. It is a microbiologically-dominated process. Putrefaction is mostly due to the action of bacteria and enzymes already present within the body tissues (Janaway et al 2009; 316).

Human decomposition begins as soon as four minutes after death (Fiedler & Graw 2003; 292). After the heart ceases to function and the flow of blood around the body has halted, the corpse goes through the 'classic triad' of changes – livor (post-mortem hypostasis), rigor mortis and cooling (algor mortis)

(Janaway et al 2009; 314). These stages can be differentiated functionally; however, it is not possible to attach an exact timescale to them (Fiedler & Graw 2003; 292). The rate at which the changes occur are mainly related to the environmental conditions, especially temperature, microbial diversity and load (Janaway et al 2009; 314).

The mode of mummification for the examined Kellis 1 mummies has already been discussed in Chapter 2.1. The other factors, and their causes, such as bacteria and fungi, are discussed below.

3.2.1 – Post-Mortem Hypostasis (Livor)

The first stage of human decomposition happens very quickly after death.

Due to gravity, blood drains to the lower parts of the body, causing the characteristic discolouration of these areas. As the blood is depleted of oxygen, the colour changes from bright red to deep purple. This can be seen from one to two hours after death and is fully developed after approximately six hours and is fully fixed around the twelve-hour mark (Janaway 2009; 314).

3.2.2 – Rigor Mortis

There are three stages within rigor mortis:

1) the body becomes flaccid but contractile
2) the body becomes rigid and incapable of contraction
3) the body again relaxes; however can never regain the power of contractility (Janaway 2009; 314).

While the first effect of death is a general relaxation of muscular tone (except in the cases of cadaveric spasm), within a few hours of death, the muscles, starting with the eyelids and jaw, stiffen and contract and the body becomes rigid (Janaway 2009; 314).

This rigidity is caused by the breakdown of adenosine triphosphate (a molecule that 'carries' energy) and the build up of lactic acid to approximately 0.3 percent in the muscles, causing irreversible state of contraction. In temperate climates, this process begins within two to four hours of death and reaches a peak at twelve hours. However, by 24 hours, the rigidity starts to decrease and

the body is again limp within 36 hours due to the action of alkaline liquids produced by putrefaction (Janaway et al 2009; 314).

3.2.3 – Algor Mortis (Cooling)

Due to the loss of living body heat to the external environment, the body will start to cool after death. The rate of cooling is determined by the difference between the environment and the body itself (Janaway et al 2009; 315).

3.2.4 - Microorganisms

Putrefaction results in decomposition of the body and is caused mostly by the action of bacterial enzymes, predominately anaerobic organisms from the bowel (Janaway et al 2009; 316).

After death, microorganisms that are present in the body, especially the gastrointestinal tract, invade the local tissues and then advance throughout the body by the lymphatic and vascular systems (Janaway et al 2009; 316). The reduction potential of tissues decreases very rapidly after death and the growth of aerobic organisms is considerably reduced and anaerobic bacteria become more prevalent (Janaway et al 2009; 316). Only a small number of bacteria of the human gastrointestinal tract are involved in putrefaction during the first days after death, for example *Clostridium* sp., Streptococci and the Enterobacteria (Janaway et al 2009; 316).

Putrefaction begins quickly after death and within seven days marbling of the skin (the skin becomes a green or greenish-red colour) can be seen. Gases are produced during this time, growing to high levels around the tissues being broken down by autolysis and the large bowel (Janaway et al 2009; 316).

These changes to the body cause the remaining indigenous microbiota, especially those of the gastrointestinal tract, to increase their proliferation, which, in turn, hastens the decomposition process (Janaway et al 2009; 317).
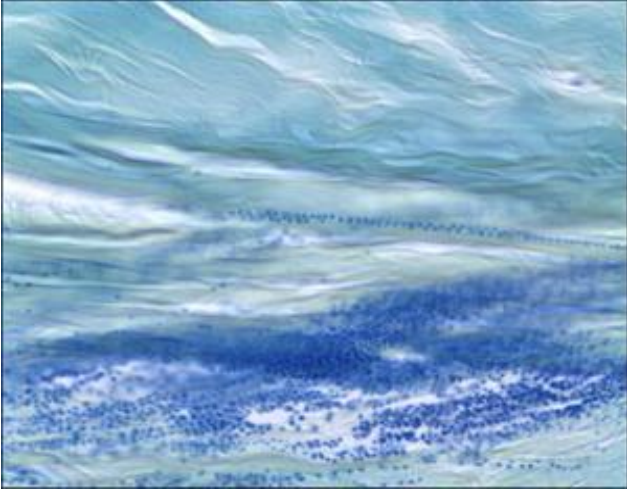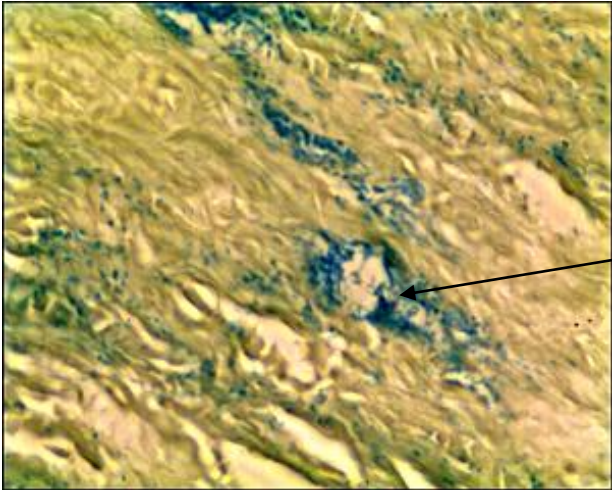
The role of microbiology in human decomposition is significant and ultimately could not proceed without it.

3.2.4.1- Bacteria in the Kellis Mummies

Bacteria are divided into two main groups - Gram-positive and Gram-negative, so-named for the staining technique used to detect them. Although first

described in 1884, the Gram's stain's chemical rationale is still unclear. This is probably due to a number of factors, the most important of these being the increased thickness, the chemical composition and the functional integrity of the cell wall of the Gram-positive bacteria, which stain blue. When these bacteria die, they become Gram-negative, which stain red (Bancroft & Stevens 2003; 293).

For this project, it was deemed unnecessary to determine whether the bacteria present where Gram-positive or –negative and the Gram stain was therefore not used. For the needs of this research, the bacteria were best seen using the toluidine blue stain, which colours the bacteria a darker blue than the other tissue elements (see Figure 3.17 below) (Denton 2008; 77).

Fig 3.15	<u>Stain – Toluidine blue</u> <u>Magnification – x20</u> Ligament sample from Mummy A8 displaying bacteria in dark blue
Fig 3.16	<u>Stain – Toluidine blue</u> <u>Magnification – x40</u> Sample from Mummy A132 displaying bacteria running along but not across the collagen fibres

The samples from the Kellis 1 mummies revealed differing levels of bacterial proliferation; some samples showed no sign of bacterial invasion, while others exhibited evidence of bacterial degradation although the bacteria themselves were no longer visible as they themselves are subject to degradation and some sections displayed large quantities of bacteria within the sample. The cause of these differing results may be due to two factors. Firstly, the time between death and burial in the hot dry sand of the tomb. If the body were not subjected to the desiccating environment of the sand for some time (hours or days) after death, bacteria would be able to invade and proliferate within the body due to the lack of oxygen necessary for aerobic bacteria. Secondly, the type of mummification would have an influence on the bacterial load. Those bodies which had been subjected to the Type Six or Seven mummification pattern (see Chapter 2.1) should least allow bacteria to take hold as the soft, and highly degradable, internal organs would have been removed.

The Figures 3.17 and 3.18 (above) show examples of bacteria found in the Kellis 1 mummies. Figure 3.17 demonstrates a proliferation of bacteria in an intercostal ligament sample from Mummy A8, one of the case study mummies. Mummy A8 was a Type Four Mummification pattern and therefore, the internal organs had not been removed. Figure 3.18 is a comparative sample from Mummy A132, an artificially mummified body of the Type Seven pattern. Both sections exhibit the bacteria travelling up the collagen fibres demonstrating bacteria find it difficult to penetrate collagenous tissue. Therefore, mummification type in Kellis did not appear to have any influence on the presence of bacteria.

3.2.4.2 – Fungi and Egyptian Mummies

Most fungi found on decaying corpses are aerobic, which means that their growth is limited to the exterior surfaces of the body, mainly the skin and only shallow penetration of the tissues takes place. However, fungi can be found growing in body cavities and the intestines (Janaway et al 2009; 323). Fungi can also be found growing in the soil that has been permeated with the decomposition products of the body (Janaway et al 2009; 323).

Fungal bodies within the tissue samples of the Kellis 1 mummies were, like bacteria, not an uncommon finding.

While there are many fungal species that can produce disease in living bodies (such as *Histoplasma* – lung infections and *Sporotrichum* – subdermal lymphatic infections), fungi can also invade deceased bodies and cause tissue degradation and damage at a histological level. As is the case with many mummified tissue samples, it was most often impossible to ascertain whether the fungal bodies found in the Kellis 1 mummies were of modern or ancient origin.

Stain – Toluidine blue
Magnification – x40

Aspergillis sp. fungi within the lung sample from Mummy A102

Fig 3.17
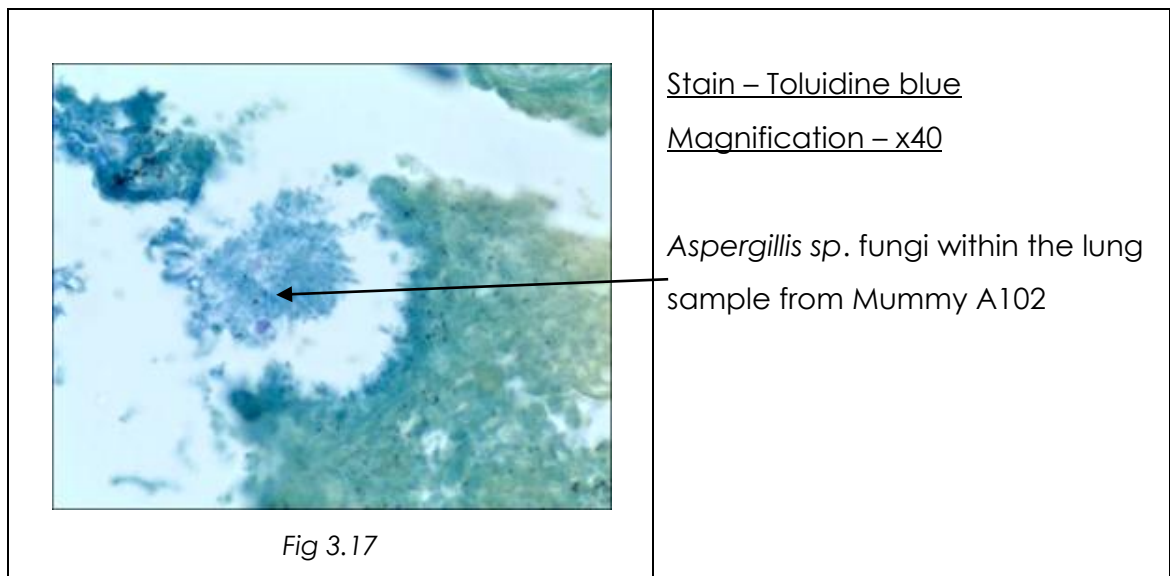
Some fungal species can affect both the living and the dead. *Aspergillus fumigatus* and *Aspergillus niger* can invade the bronchial lining of the lungs of a living person, and after death, can proliferate within the body. Although reported in other mummy studies (Horne et al 1996; 240), only a single example from one of the Kellis 1 mummies examined, exhibited any evidence of an *Aspergillus sp.* presence (see Figure 3.19 above).

Most fungi found on mummified bodies are on the external surfaces, the result of poor storage. While today limiting the humidity of storage areas and exhibition cases controls most fungal infestations, some species can still succeed in these environments. Fungi grow best when moisture is present, so limiting the humidity should therefore halt fungal growth, however, fungi such as *Serpula lacrymans* (dry rot) produces its own water as a metabolic by-product, thus enabling further growth (Denton 2008; 77-78).
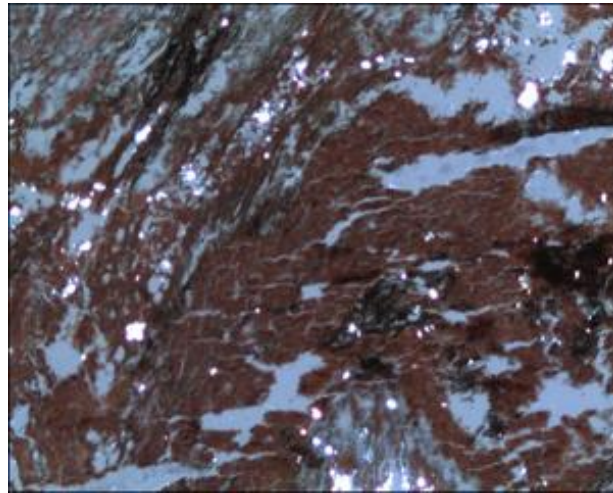
Stain – MSB

Magnification – x5

Semi-polarised Light Microscopy

Lung sample from Mummy A110 displaying crystalline deposits of fungal metabolites (very bright birefringence)

Fig 3.18

Figure 3.20 above shows the birefringent qualities of fungal metabolites. In this image, the fungi is no longer visible, however, the tissue degradation they have caused is clearly demonstrated.

Even the most famous of ancient Egyptians have not been spared the presence of fungal bodies. The mummified body of Ramesses the Great (1279 – 1213 BCE) was found to have 89 different types of fungi on both the external surface of his body and within the remaining soft tissues. This was due to the many years of poor storage after the body was excavated in the nineteenth century (Balout & Roubet 1978; 21). The mummy was successfully subjected to gamma radiation in 1976 in order to kill these fungi (Brier 1994; 198).
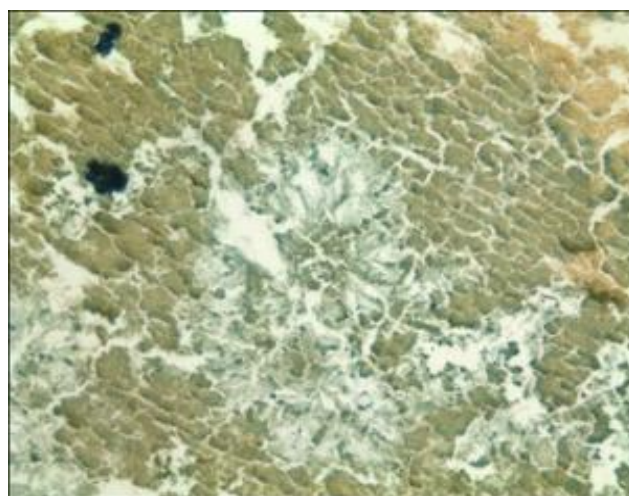
Stain – Toluidine blue

Magnification – x20

Fungal bodies within badly degraded liver sample from Mummy A107

Fig 3.19

3.2.5 – Insects and Egyptian Mummies

Invasion of the body by insects can occur within hours of death. Insects can be used as an important indicator for the calculation of time since death (Janaway et al 2009; 322). This, however, becomes difficult when investigating the Kellis 1 mummies due to a number of elements, including the uncertainty of th3e environmental conditions at the time of death (winter or summer), the amount of looting that had gone on within the cemetery and the consequent damaging of many of the mummies and whether or not the tombs had been originally sealed well enough to not allow insects to enter.

Blowflies (Calliphoridae) can arrive at the body within minutes of exposure (Janaway et al 2009; 322). The female flies use the natural body openings of the head (eyes, nose, ears and mouth) and genitalia for the deposition of eggs, up to 180 at one time (Janaway et al 2009; 322). Fly larvae can penetrate sand and even natron, however, if a body is buried more than half a metre deep, it is usually beyond their reach (Goff 2010; 16). It is possible for eggs to be laid before burial and then they can hatch and the larvae can feed (Janaway et al 2009; 322).

Desiccation of the body will constrain normal putrefactive changes, however, these naturally mummified tissues are still susceptible to insect attack by beetles, such as *Dermestes* sp. or *Necrobia rufipes* (Janaway et al 2009; 323).

Two members of the Demestrid species were found within the subcutaneous tissues and cranial cavities of the Kellis 1 mummies - *Demestes frische* Kugelan and *Demestes leechi* Kalik. However, by far the most numerous beetle found within the Kellis 1 bodies is that of *Necrobia rufipes (*red-legged ham beetle), masses of which were found in areas such as the skin of the thigh and subcutaneous tissue of the ankle as well as within the wrappings (Don Stenhouse, pers. comm.). Both these genus of beetles have previously been found in ancient Egyptian mummified remains, and in fact, the most common insect to be previously discovered in mummies is *D. frischi,* which has been recovered from both animal and human mummies, including from the body of Ramesses the Great (1279 – 1213 BCE) (Hope 1842; 53-55, Hope 1836; 11-13, Alluaud 1998; 32-36, Cockburn et al 1998; 96, Strong 1981; 136-139). *Necrobia rufipes* is also common find within ancient Egyptian mummies, again being

found on the body of Ramesses the Great as well as in the Manchester Museum mummy 1770 (Alluaud 1908; 33-36, Curry 1979; 111).

Fig 3.20 – Dermestes frischi beetle
(www.ento.csiro.au)

Fig 3.21 – Necrobia rufipes beetle
(www.ento.csiro.au)

In 1825, Mr J Atkinson of Leeds wrote to the Linnaean Society to report that when he examined an undated mummy from Thebes, he found 'thousands of larvae, which have been prevented from arriving at their perfect state by the process of embalming being finished'. These larvae belonged to the beetles *Necrobia sp.* and *Dermestes sp.* (Atkinson 1825; 586). This pattern was also apparent in the case of the mummy PUM IV. Both the mummy and the wrappings had eggs, larvae and adult insect remains (including *D. frischi*), suggesting that at some point, the embalmers had poured hot liquid resin in and over the body, which killed and embalmed the insects immediately (Cockburn et al 1998; 79).

While it can be difficult to ascertain when insects enter ancient remains, it would appear, from the type of insects found and the area of the body in which they were discovered, that the insects from the Kellis 1 mummies arrived during the early stage after death (Calliphoridae) and the stage when the soft tissue was present but desiccating, or desiccated (*D. leechi, D. frische and N. rufipes*). The fact that large quantities of larvae were found within the subcutaneous tissues mirrors the findings of Atkinson (1825; 586) and Cockburn et al (1998; 79) and it may be that the completion of mummification, artificial or spontaneous, halted their development. Only two of the Kellis 1 bodies examined (A13 and A112) had skin defects caused by insect attack, although others that were not the subjects of this project displayed similar findings.

Chapter 3.3 discusses the preservation levels of the sample types from the Kellis 1 Mummies.

3.3 – PRESERVATION ASSESSMENT OF KELLIS 1 SAMPLES

3.3. 1 - Breast Tissue

The process of desiccation can cause the breasts of mummies to collapse to the point they can no longer be recognised; this is especially true if the body has been wrapped tightly in bandages, as many of the Kellis 1 mummies had. The reason for this collapse is that post-mortem hydrolysis releases free fatty acids from the breast's neutral fat, which then seep away, leaving the breast flattened (Aufderheide 2003; 521).

If a woman was lactating at the time of death, the increased water content can result in skin loss over the breast area (Aufderheide 2003; 318). An effect of natron is the shrinking of the female breast leaving neither form nor structure distinguishable (Sigmund & Minas 2001; 1858).

Within the Kellis 1 cache, breasts were recognisable in eight of the 49 mummies, including in two adult males, at the time of autopsy. For this project, only one of the ten case studies had breast tissue available for analysis (Mummy A4). This, and one of the comparative samples (Mummy A106) were examined and found to contain only the thick connective tissue of the chest wall; no breast tissue remained.
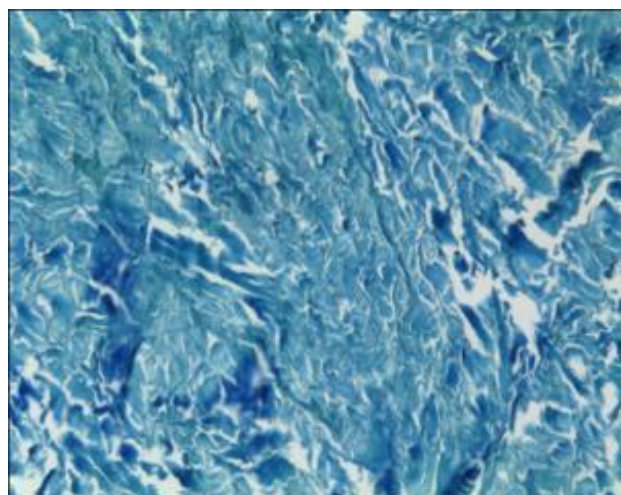
Stain – Toluidine Blue
Magnification – x10

Sample labelled 'Breast' from Mummy A4, is actually connective tissue from the chest wall

Fig 3.22

Connective tissues are often the only elements remaining in the ancient body after the processes of autolysis and putrefaction (Denton 2008; 76). These

tissues consist of cells (for example fibroblasts and mast cells), fibres and intercellular material. Fortunately for the palaeopathologist, these tissues are distributed throughout the body and have many functions including support, packing, defence and repair (Kiernan 1981; 92). The individual constituents vary, depending on the function of the tissue, which assists in the identification of ancient tissues. Different types of connective tissue include adipose tissue, areolar connective tissue, blood, lymph, cartilage and bone (Bancroft & Stevens 1996; 120-122).

3.3.2 - Gastrointestinal Tract and Contents

In desiccated body, the stomach will usually retreat under the rib cage or bowel loops making it difficult to identify unless the oesophago-gastric junction is present (Aufderheide 2003; 320). However, the loops of the bowel and colon are so numerous and large (up to five metres) that often at least some parts remain (Reinhard 1998; 373). Within the Kellis 1 cache, only Mummy A108 had a remaining identifiable stomach, while nine of the 49 mummies had loops of colon, fourteen those of ileum, with eight bodies having both colon and ileum preserved. Approximately half of the Kellis 1 mummies with preserved colons contained coprolite material (Aufderheide et al 2003; 139).

Fig 3.23 – Coprolite material in situ is easily identifiable (Aufderheide 2003; 354)

Of the ten case study mummies, three bowel and three colon samples were available for histological examination, however the preservation levels of these rendered disappointing results, with only the thick collagenous colon or bowel walls identifiable (see Figure 3.24 below).
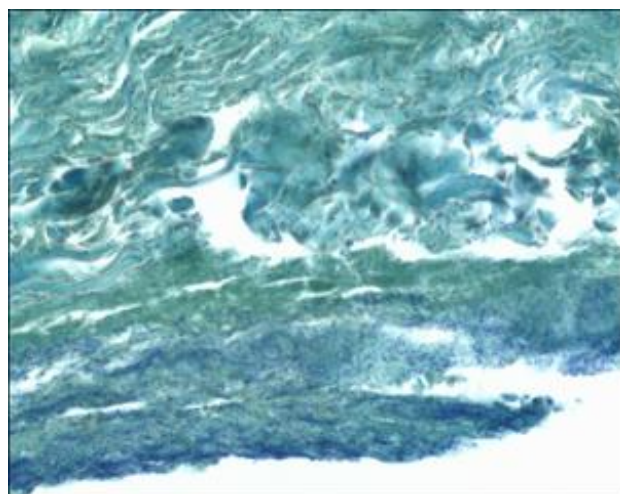
	Stain – Toluidine blue Magnification – x20 Bowel sample from Mummy A9, with little identifiable detail preserved
Fig 3.24	

Two coprolite samples were examined (Mummies A101 and A106), both of which displayed excellent levels of preservation (see Figures 3.25 and 3.26 below).

 Fig 3.25	<u>Stain – Toluidine blue</u> <u>Magnification – x5</u> Bowel sample, including intestinal contents (part of a seed), from Mummy A106
 Fig 3.26	<u>Stain – MSB</u> <u>Magnification – x10</u> Plant remains, from Mummy A106 Bowel wall

When present, the colon can be identified quite easily; however the rigidity of the desiccated structures makes dissection at the hepatic flexure (the right angle bend of the colon on the right hand side of the body, close to the liver) difficult.

While the gastro-intestinal tract occupies the most space within the abdominal cavity, the microscopic structure, and any pathology thereof is very much under-represented in the palaeopathological literature (Aufderheide 2003;

454). As the samples from the Kellis 1 mummies demonstrate, this under-representation can be mainly blamed on the lack of preservation. The intestinal lesions consist mostly of mucosal epithelium, which rarely survives post-mortem processes (Aufderheide 2003; 454). The elements of the intestinal walls survive better as they are made up of elastic and collagenous material.

The mummified intestine is thin, transparent and friable; peri-mortem compression and post-excavation handling can damage the fragile tissue so much that detailed examination is impossible. The bacterial content of the intestine also adds to the post-mortem loss of identifiable tissue components (Reinhard 1998; 373).

Some studies examining the structure of the intestine have, however, been successful. In Shaw's investigation (1938; 122) of the canopic material from the Eighteenth Dynasty singer, Har-mose, he identified peritoneal, subserous, muscular and submocous elements in the bowel sections. Ruffer (1909; 1005) was able to discern the submucous tissue and the glands of the intestines of two Twenty-First Dynasty mummies.

| *Fig 3.27* | <u>Stain – Toluidine blue</u> <u>Magnification – x5</u> Bowel sample, including contents, from Mummy A9 Seed coat |
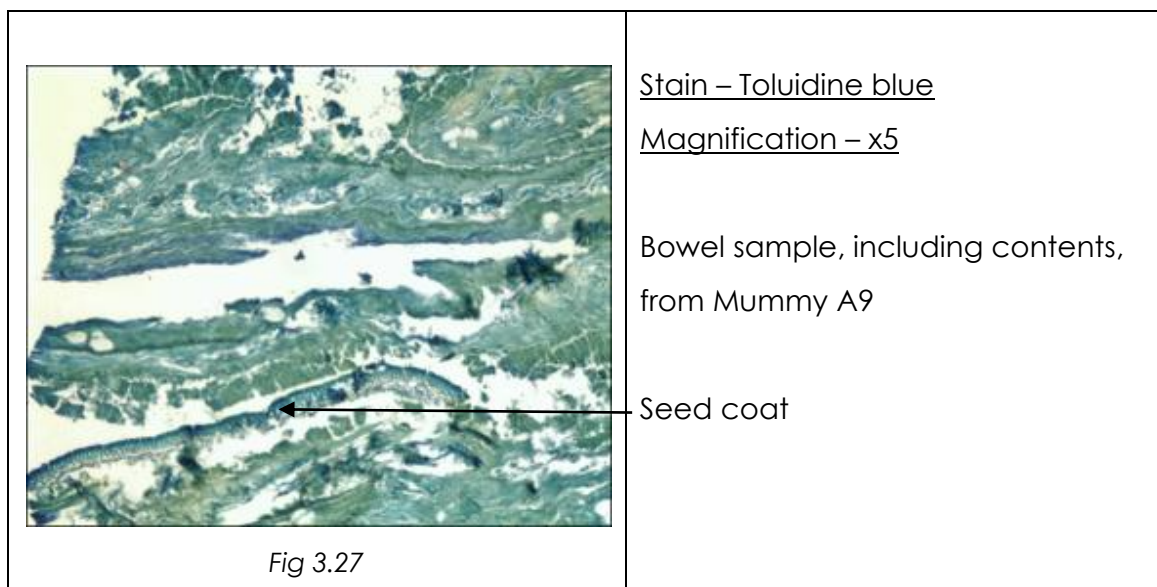
While few studies have been able to generate any useful or valid intestinal sections, the contents of the gastro-intestinal tract (coprolites) are remarkably well preserved and make a fascinating subject for study (Reinhard 1998; 372-377). The lower rectum is usually devoid of faeces in both living and dead

bodies, and coprolites are most often discovered in the cecum, which in desiccated bodies often lies in the lower pelvis (Aufderheide 2003; 454). The histological examination of coprolite material can provide details on diet, as well as being extremely useful when investigating parasitic infections suffered by the ancient Egyptians.

3.3.3 - Heart

The ancient Egyptians believed the heart to be the centre of human understanding (Andrews 1994; 76). While the brain was believed to be unimportant, the heart was the source of all wisdom, memory and emotions. It continued to play a vital role in the Afterlife, ensuring that the deceased could pass through the Underworld safely (the weighing of the heart ceremony) and enjoy eternity with the God Osiris, Lord of the Underworld. It was imperative then for the heart to remain in the body after death, even if the deceased was to be eviscerated. If it was accidently removed, the heart was sown back in place (Dawson 1927; 43).

Despite this, the heart is often missing from mummies, not simply because of any carelessness on the part of the ancient Egyptian embalmers (although this is most likely a factor) but also due to the structure and function of the heart itself. Even when the other thoracic organs are preserved, the heart has often been reduced to nothing more than a black stain (Aufderheide 2003; 319).

Of the 49 mummies examined form the Kellis 1 cemetery, only six bodies had hearts preserved. Even within some of the bodies that had undergone the most careful of embalming methods (see Types Six and Seven in Chapter 2.1), the heart could often not be recognised. In the ten mummies that were investigated for this project, only two had heart samples available; both of which were extremely degraded.

As stated above, this lack of preservation can be explained by the structure of the heart. The myocardium (the middle and thickest layer of the heart wall) is rich in proteolytic enzyme content and very slow to desiccate. It is, therefore, far more likely to dissolve after death than organs such as lungs. Some elements of the heart, including the valves, arteries and veins, are made up of elastic or fibrous tissue, which are relatively resistant to decay, and therefore any ante-mortem pathologies within these structures are more able to be identified (Kerr 2000; 131, Aufderheide 2003; 351).

Figure 3.28 below demonstrates this contrast in preservation levels with a cardiac vein being clearly visible - stained in blue - while the surrounding tissue is extremely degraded and no definition of components can be identified.

	Stain – MSB
	Magnification – x2.5
	Heart sample from Mummy A5
Fig 3.28	
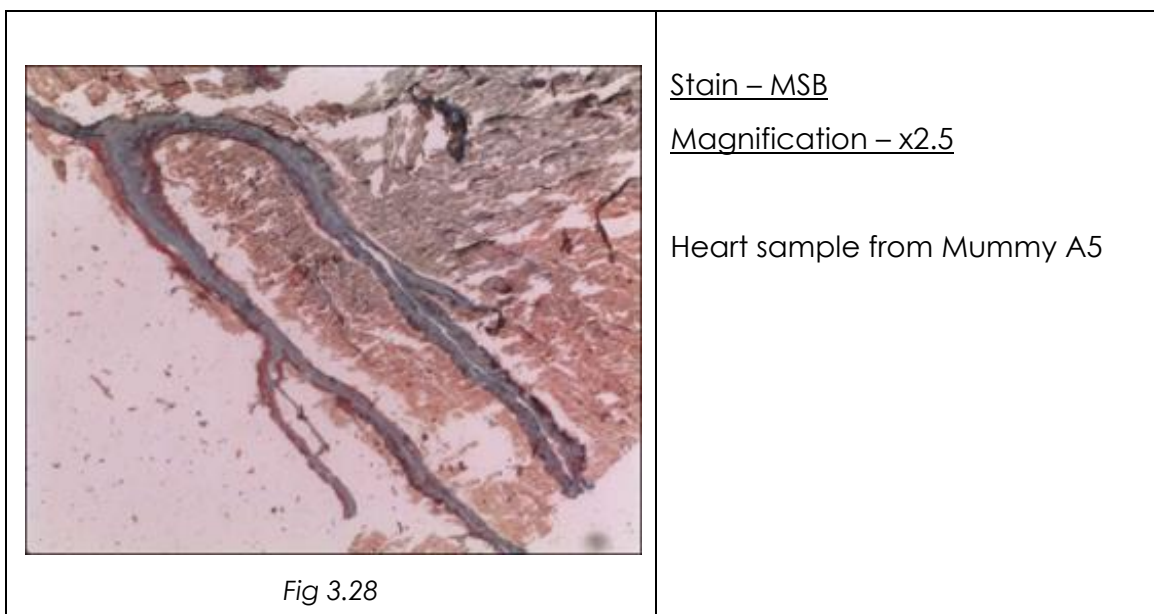
The autopsy report for Mummy A108, which contained the other heart sample examined as part of this project, states that although the heart was in place, it contained 'no internal structure except for a few fibrous cords' (Aufderheide 1998; 6). Pathologies from this heart sample will be discussed in details in Chapter 4.17.

In previous studies, the heart is reported as present in the mummified body; however the tissue proved to be so badly degraded that histological and microscopic examination has not been possible (Reyman & Peck 1998; 111). However, studies concentrating on the aorta and similar structures of the vascular system have been able to identify a number of pathologies, especially the presence of calcification.

Two such reports concern the Royal mummies of the Nineteenth Dynasty (1295 – 1186 BCE). In 1912, the anatomist Grafton Elliot Smith reported on tortuous calcareous temporal arteries in the mummy of Ramesses the Great (1279 – 1213 BCE). Ramesses' son, the Pharaoh Merenptah, was also not immune to vascular disease; in 1909, Samuel George Shattock (the Pathological Curator of the Museum of the Royal College of Surgeons) using frozen sections of Merenptah's aorta was able to identify long parallel wavy lamellae of elastic tissue with inorganic calcium in the inter-lamella substance (Sandison 1962; 77). Both Ramesses and Merenptah were, even in today's estimate, elderly when they died (Ramesses was possibly as old as 97) and it is probable that calcification was simply a complication of old age.

171

While the heart was supposedly never deliberately removed, some vascular tissue remains have been found in visceral packages and canopic material. The study by A F B Shaw (1938; 122-3) of the Eighteenth Dynasty singer, Harmose's canopic material, described the appearance of the superior mesenteric arteries as displaying fibro-elastic thickening. The Manchester Museum Mummy Project also found heart tissue within the canopic jars of the Twelfth Dynasty mummy of Nekht-Ankh. Despite the material being a hard and brittle mass, histological preparation was able to render the tissues viable for microscopic examination. Found attached to the lung, part of the wall of Nekht Ankh's heart displayed fibrous tissue obliterating the pericardial and pleural cavities. It was clear that there was inflammation in both the lungs and the heart, probably associated with a bout of pneumonia (Tapp 1979; 99).

While much of the heart is usually degraded in ancient Egyptian mummies, arteries and veins tend to be relatively well preserved and can be histologically examined without great difficulty (Sandison 1962; 80). Previous studies, including those involving experimentally mummified tissue (Zimmerman 1972; 273), have proven that histological analyses of vascular tissues is worthwhile and can add much to the knowledge of the life, and even death, of the ancient Egyptians.

Fig 3.29 – Normal heart from the
Mummy Nakht (Millet et al 2003; 97)

3.3.4 - Liver

The state of preservation of samples of ancient mummified liver varies greatly. As it is such a large organ, weighing up to 1500g in life, it is usually the most obvious of surviving viscera. In the Kellis 1 cache, fifteen of the 49 mummies had an identifiable remaining liver, albeit reduced to approximately five to ten percent of its original weight. Two of these mummies (Mummies A3 and A122) had, according to Aufderheide et al (2003; 150) been eviscerated through an incision on the left hand side of the abdomen. This type of evisceration included the removal of the intestines, stomach, lungs and liver, all of which were then embalmed and wrapped, and either placed back into the body cavities or into canopic equipment that would accompany the deceased into the burial place (Dawson 1927; 43). At the time of the Kellis 1 burials (the early Roman Period, 30 BCE – 250 CE) it is believed that embalmers made less effort with the preservation of the body itself, focussing instead on the external appearance of the mummy (Ikram & Dodson 1998; 129). The remaining livers in the two eviscerated Kellis 1 mummies suggest this may be the case for them.

When it is preserved in its correct anatomical place, the liver is found in the right upper abdominal quadrant. However, post-mortem displacement is not uncommon and it can be found in the pelvis or thoracic cavity, or even as an isolated mass external to the body (Aufderheide 2003; 355).

Of the ten mummies used as case studies for this project, nine had liver samples available for histological examination. However, the results were disappointing due to the extreme state of degradation the samples were in. Most samples dissolved at the time of rehydration, and some that survived this process, turned to dust when sectioned.

This degradation is not surprising given that 90 percent of the liver's volume is composed of epithelial cells that are extremely susceptible to autolysis by bacteria and lysosomal enzymes such as lipase, which digests lipids, amylase, which digests amylose and starch, protease, which digests proteins and nuclease, which digests nucleic acid (Aufderheide 2003; 320).

In desiccated bodies, any remaining liver tissue is black, hard and brittle; shrinkage obscures the normal living liver's gross morphology. Zimmerman (1972; 272) experimentally mummified a number of soft tissues and discovered

that the liver 'fared poorly'. Degradation by gas-forming bacteria caused compression of the intervening parenchyma and a loss of cell outlines. By utilising a trichrome stain (Masson's), he could identify portal areas due to their relatively large quantity of fibrous tissue. However, bile ducts and blood vessels could not be distinguished, due to the loss of epithelium (Zimmerman 1972; 272).

Mirroring Zimmerman's findings and those of this project were the results of the histological analysis of the liver from the Eighteenth Dynasty singer Har-mose, which was found, for the most part, to have been reduced to 'granular debris', which had in consequence collapsed the fibrous framework producing the appearance simulating cirrhosis (Shaw 1938; 121).

The histological findings from the multidisciplinary study of the Twentieth Dynasty weaver, Nakht, revealed his liver to be preserved as cords of indistinct hepatic parenchyma intersected by interlacing bands of fibrous tissue. As some of the portal areas contained *Schistosoma sp.* ova, it is highly likely that these parasites caused Nakht's cirrhosis (Millet et al 1998; 99).

The liver of the Kellis 1 Mummy A5 demonstrated similar results to that of Nakht, the features and implications of which will be discussed in Chapter 4.7. This liver was the only one from the Kellis 1 cache that could be studied in any detail and this was due to the greater than normal amount of fibrous tissue allowing the otherwise severely degraded sample to hold together (see Figure 3.30 below).
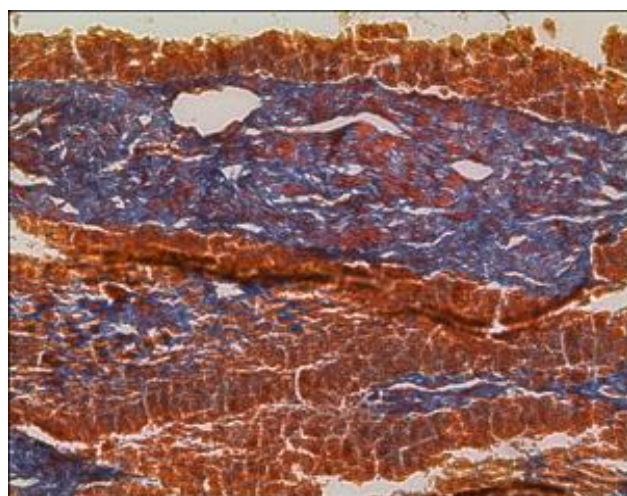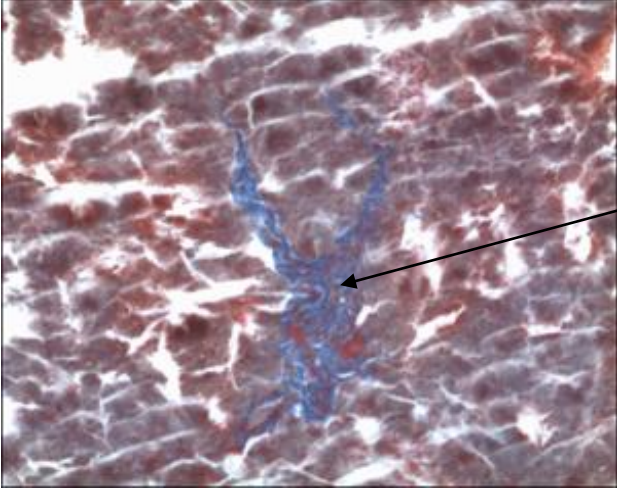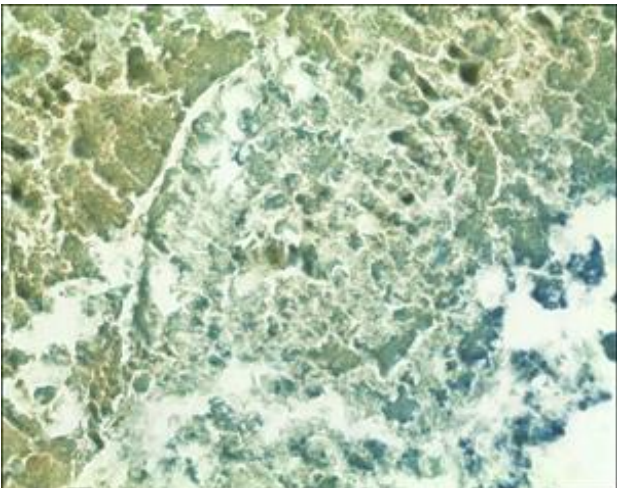
Stain – MSB
Magnification – x5

Liver sample from Mummy A5, the only liver viable for histological analysis from the Kellis 1 cache due to the large amount of fibrosis

Fig 3.30

Histological preparations of mummified liver samples are rarely successful, making microscopic visualisation virtually impossible (Zimmerman 1972; 272). However, when it is viable, it often suggests a diseased state, such as cirrhosis. How and why diseases like this occurred in the ancient Egypt can add an interesting dimension to the study of the living conditions of ancient societies.

 Fig 3.31	<u>Stain – MSB</u> <u>Magnification – x20</u> Degraded liver sample from Mummy A7 showing areas of fibrosis
 Fig 3.32	<u>Stain – Toluidine blue</u> <u>Magnification – x20</u> Degraded liver sample from Mummy A107

3.3.5 - Lungs

Much of the space in expanded living lungs is taken up by capillaries suspended by air, with only a thin covering of epithelial cells. After death, the lungs collapse, especially when the body is placed in a supine position, as they were in the Kellis 1 cache (see Chapter 2.1). As is the case with most ancient soft tissue, the epithelium (bronchial and alveolar) is lost and what remains is a mass of collapsed tissue consisting of mainly fibrous membranes (Aufderheide 2003; 321).

In the Kellis 1 cache, thirteen of the 49 mummies had the lungs remaining, including Mummy A3, who had been eviscerated via an abdominal incision. While A3's stomach, liver and intestines were absent, as expected, some lung tissue was left. This was due either to carelessness on the part of the ancient Egyptian embalmer or because part of the lung had adhered to the inside of the chest wall, making it difficult for the embalmers to remove through the relatively small incision.

When bodies have been desiccated quickly, like those spontaneously mummified in the hot dry sands of Kellis, the lungs are preserved as one to two millimetre thin black or brown membranes (Aufderheide 2003; 351).

The alveolar structure within the lungs is often well preserved, although little cellular detail remains. Collapsed air sacs and bronchioles are clearly visible, especially when using a trichrome stain such as MSB (see Fig. 3.9).

Like liver samples, lung tissue from canopic equipment and visceral packages can be analysed successfully. An example of such comes from one of the canopic jars from Manchester Museum's Twelfth Dynasty mummy Nekht-ankh. Despite appearing to be extremely degraded, the lung sample enabled diagnoses of both pleurisy and sand pneumoconiosis (Tapp 1979; 97). Both of these conditions would have made breathing extremely difficult or Nekht-ankh. Walker et al (1986) examined six lung samples from ancient Egyptian mummies of varying dates. They noted that the lungs of a mummy dated to 200 to 300 BCE had a cellular infiltrate suggestive of pneumonia, which in turn would imply respiratory compromise for this person during life (Walker et al 1986; 48).
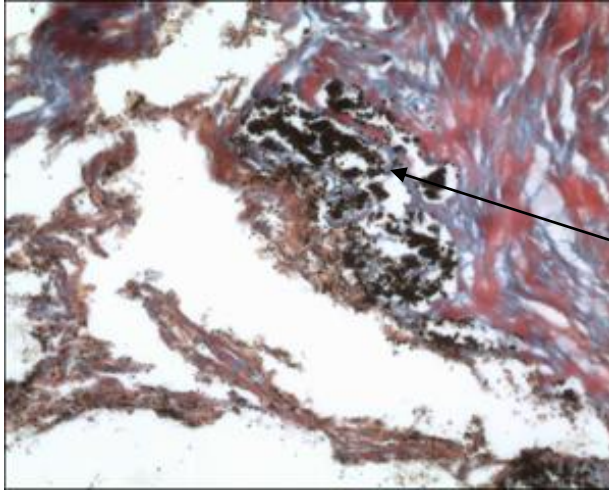
Fig 3.33

Stain – MSB

Magnification – x20

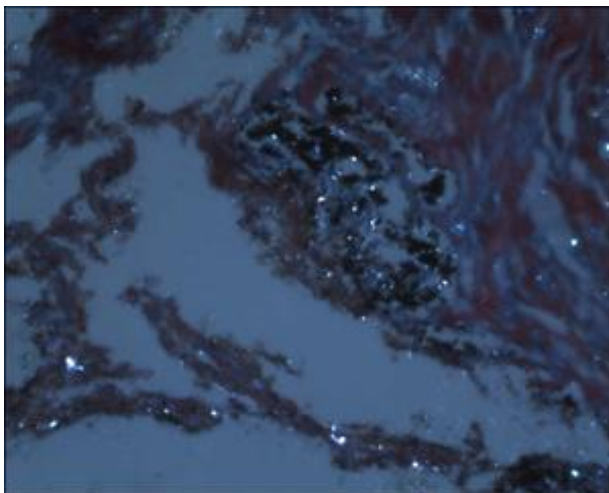Badly preserved lung sample from Mummy A107 showing evidence of carbon-type particles

Fig 3.34

Stain – MSB

Magnification – x20

Same image as Figure 3.6.1, using polarised light microscopy, the silica-type particles are birefringent
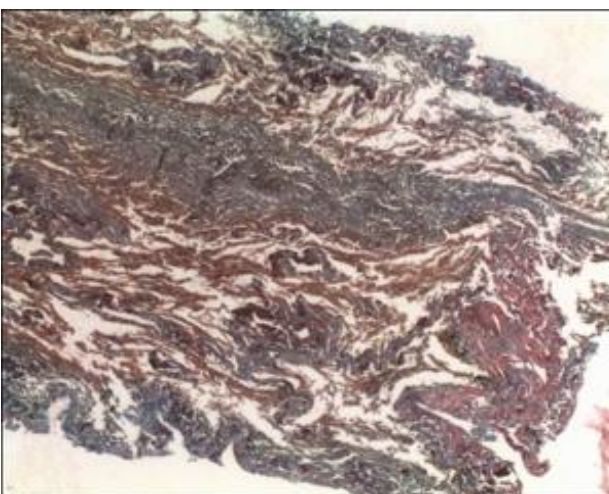
Fig 3.35

Stain – MSB

Magnification – x2.5

Lung sample from Mummy A107 at low magnification – areas of anthracosis are visible as dark areas within the tissue
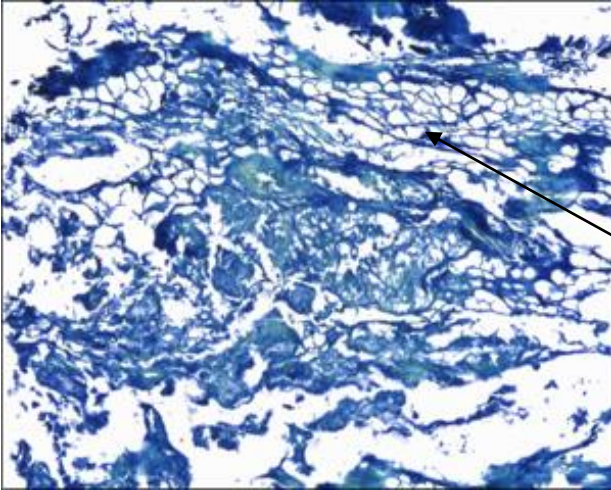
Particles such as silica, carbon and/or similar, have been discovered in the lungs of many ancient Egyptian mummies (Walker et al 1986; 47, Reyman et al 1976; 511, Zimmerman 1977; 34, Shaw 1938; 118, Cockburn 1998; 79, Millet et al 1998; 99). All adult mummies examined from the Kellis 1 cache showed evidence of both carbon- and silica-type particles, which were clearly visible using light and polarised light microscopy respectively, even if the surrounding lung tissue was extremely degraded (see Figures 3.33 to 3.35 above).

The histological examination of ancient lung tissue has proven to be extremely valuable. The revelation of conditions such as pleurisy, sand pneumoconiosis and pneumonia has helped inform scholars on the diseases, both common and rare, with which the ancient Egyptians were afflicted. Even when the samples appear too degraded to be viable, demonstration of particles such as silica and carbon is possible.

3.3.6 – Skeletal Muscle

Little work has been done relating to the preservation of mummified skeletal muscle. When he experimentally mummified various samples of soft tissue, Zimmerman (1972; 272) found that skeletal muscle fibres became marginally swollen by the processes of desiccation and rehydration. The sections displayed the retention of cross-striations, a finding that was first recorded by Ruffer (1909; 1005).

Fig 3.36

Stain – Toluidine blue

Magnification – x5

A poorly preserved sample of skeletal muscle from Mummy A1. Structure is hard to determine, although some adipose cells are visible

Fig 3.37

Stain – MSB

Magnification – x 20

Well preserved skeletal muscle showing spaces between fibres, facia between muscle bundles and slight colour change within fibres demonstrating fast and slow muscle types and striations (Mummy A108)

Within the ten case study mummies from Kellis 1, eight had samples of skeletal muscle available for histological examination. The results of these examinations varied from very poor, where it was impossible to identify the tissue as muscle

(identification was made by the dissectors at the time of autopsy) to the preservation being so good that even fast and slow muscle fibres could be identified.

3.3.7 - Skin

The skin forms the interface between the human body and the local external environment, which makes it susceptible to the effects of thermal changes and toxic agents. In addition to this, the skin of artificially mummified bodies has usually been subjected to harsh chemical treatment while spontaneously mummified bodies are often simply wrapped and interred in tombs, leaving the invasion of bacteria and fungi unchecked (Aufderheide 2003; 497). However, in spite of this vulnerability, mummified tissue has been widely studied and with much success. Of the 49 mummies from the Kellis 1 cache, only four did not have skin preserved.

Moisture from internal tissues must travel through the skin during the process of dehydration. By the time the moisture reaches the skin's surface, it is filled with endogenous proteases from the now-destroyed tissues it has passed through. This process means that the skin is the last organ to dry. When bodies have been mummified using natron, the epidermis becomes attached to the encrusted natron and many of the skin's outer layers would be removed at the time when the natron is peeled off the body by the ancient embalmers.
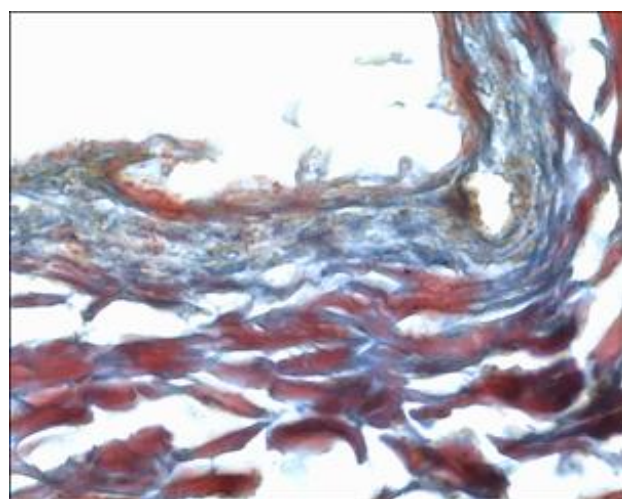
Stain – MSB
Magnification – x40

Skin sample from the artificially mummified body of Mummy A110 showing the epidermis in the process of sloughing off.

Fig 3.38

Spontaneously mummified bodies, either simply wrapped or unwrapped and placed into the tomb with no attempt at dehydration using natron are also often lacking the skin's epidermal layer. Sand or bandages becomes adhered to the skin and, as with the removal of natron, the outer layers are removed or
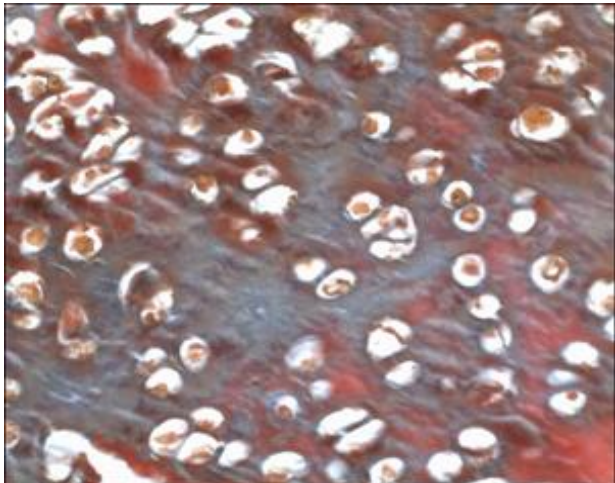
destroyed when the sand or bandages are removed, either through the activity of looters in antiquity or by modern archaeologists or dissectors.

Tissues, such as scalp, ears, fingers and toes, which contain minimal quantities of underlying soft tissue, more commonly have the epidermis present due to the much quicker dehydration time needed (Aufderheide 2003; 498).

 Fig 3.39	<u>Stain – Toluidine blue</u> <u>Magnification – x10</u> Well preserved skin and cartilage sample from Mummy A111
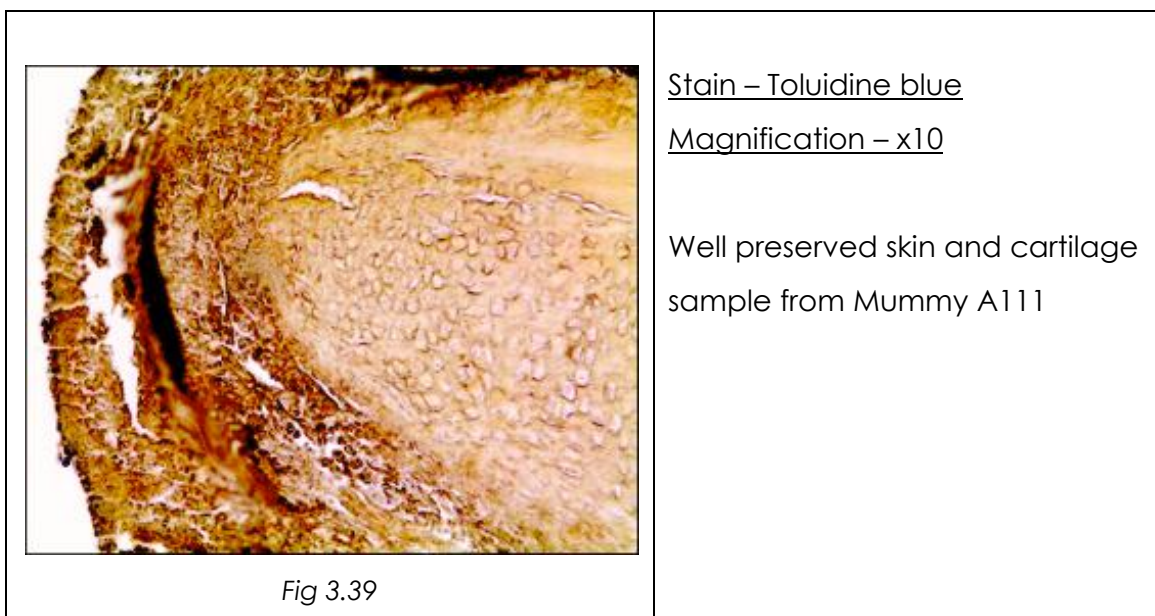
The application of resin, an attempt by the Egyptians to improve preservation of the body, has been confirmed at the Predynastic site of Hierakonpolis, but becomes common from the Twelfth Dynasty onwards (Ikram & Dodson 1998; 109). For the modern palaeopathologist, this ancient innovation was a failure as the resinated skin displays a coagulation necrosis, 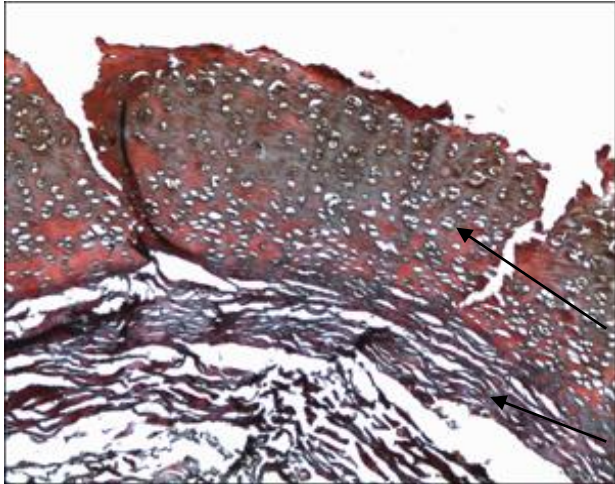the like of thermal burns (Zimmerman 1977; 35). The Kellis 1 mummies, however, do not follow this pattern; according to the autopsy reports, many of the bodies have been coated with a resinous substance, however the only skin defects found come from insect activity and man-made incisions (autopsy reports 1993 – 1998). This suggests the possibility that the resin was applied to the bodies well after desiccation. A reason for this could be that the bodies, after burial, had been looted in an attempt to find valuable objects, such as amulets. The damaged bodies had then been reconstructed using bandaging and resin to hold them firmly together. Whatever the reason may be the application of resin appears to have had no effect on the preservation of the skin.

Ancient Egyptian mummified skin was one of the first tissue samples to be successfully microscopically analysed (see Chapter 3.1) and since that time, many studies on the good preservation of ancient skin (Lewin 1967; 417, Mekota & Vermehren 2002; 9-10, Rabino-Massa & Chiarelli 1972; 261, Ruffer 1909; 1005, Sandison 1963; 417, Zimmerman 1977; 34).

Fig 3.40	<u>Stain – MSB</u> <u>Magnification – x5</u> Skin layers visible from skin (ear) sample from Mummy A110 Cartilage Dermis
Fig 3.41	<u>Stain – MSB</u> <u>Magnification – x20</u> Central cartilage sample showing preservation of chondrocytes with nuclei from Mummy A110

Chapel et al (1981) undertook a histological examination of a number of skin samples from five mummies, ranging in date from 1200 BCE to the start of the Current Era. The results determined that most skin samples retain 'surprising histological architectural detail' including some cell nuclei preserved in papillary bodies. Collagen bundles were clearly visible as were elastic fibres. Several sweat ducts remained in underlying dermis, and although sweat glands

could not be identified, several hair follicles were present (Chapel et al 1981; 29).

The skin samples from the Kellis 1 mummies displayed good results in terms of tissue component preservation. A characteristic example of this can be seen in the sections from Mummy A110, which had the layers of the skin easily identifiable and cell nuclei well preserved (see Figures 3.40 and 3.41 above).

While ancient skin samples are vulnerable to the external environment and at the time of death, mummification and burial, they are able to retain a preservation level that proves useful to palaeopathologists. Dermatological findings of other studies include smallpox, obesity (displayed by exaggerated folds of skin), dermatofibroma and tattoos (Aufderheide 2003; 498, Zimmerman 1977; 34). All of which add to our knowledge of ancient societies and their people.

3.3.8 - Bone

The breakdown of bone in the soil or ground is termed diagenesis. Diagenetic studies concentrate on the processes that change the nature of bone during burial, how these processes are environmentally determined and the ways in which specific types of embodied information can be altered or recovered (Hedges 2002; 319).

Many changes can happen to bone during burial. These include:

- the uptake of cations (positively charged ions) and circulating organics
- exchange of some ions
- breakdown and leaching of collagen
- microbial attack
- alteration and leaching of the mineral matrix
- infilling with mineral deposits (Hedges 2002; 320).

In this project, all bone samples were decalcified so examination of the mineral matrix was not possible. However, the collagen content of the ancient bone was of interest.

Much of the weight loss and increase in porosity (approximately twenty and 50 percent respectively) in bone can be attributed to collagen loss and the major cause of collagen loss is due to microbial attack (Hedges 2002; 319).

The Kellis 1 bone samples were, in general, in good histological condition, that is macroscopic anatomy and microscopic structures were visible (see Table 3.1). The reason for this could be the fine-grained dry sand retarding the activity of aerobic bacteria (Janaway et al 2009; 322).

Skeletal tissue can be a valuable biological indicator for assessing the lifestyle of ancient societies, including providing information on diet; fortunately for the palaeopathologist, the histological structure of ancient Egyptian bone often remains well preserved.

As early as 1849, John Thomas Queckett, founder of the Royal Microscopical Society, observed the gross histological details of animal fossils. He recorded that despite fossilisation, canals and lacunae were still demonstrable (Stout 1978; 601). In 1878, Dr Chr. Aeby had undertaken an extensive histological

analysis of bone from fossil genera. From this analysis, he was able to demonstrate the characteristic birefringence that is seen in fresh bone, is still visible in bone of considerable antiquity (Aeby 1878; 371-381). Since these early studies, advances in technology have added to the understanding of how the histologic structure of bone is preserved. These studies have shown that the length of time bone has been dead appears to have little effect on preservation.

While much of the structure of ancient bone remains, components such as osteoid (the precursor to bone laid down as part of remodelling) cannot often be estimated as it is removed as part of the bacterial and fungal putrefaction process. When osteoid is lost, certain diagnoses are no longer possible, for example, rickets and osteomalacia. The elements that can be observed in decalcified bone include osteoporosis by simply measuring the bone volume against an age- and sex-matched normal control (Denton 2008; 81).
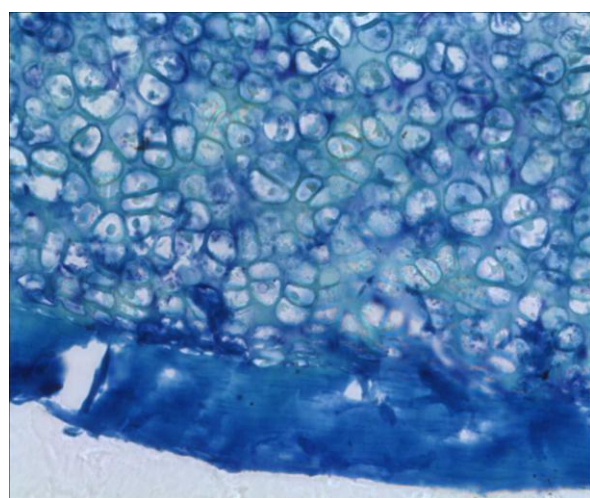
 Fig 3.42	<u>Stain – Toluidine blue</u> <u>Magnification – x20</u> Bone sample from a votive crocodile mummy (provenance unknown) displaying clearly cartilage becoming bone (ossification)
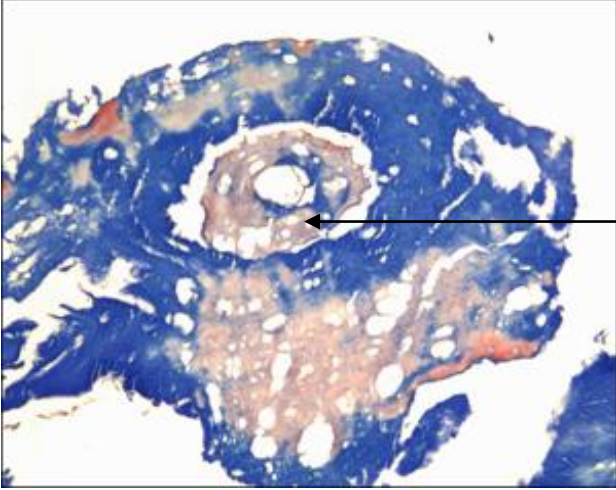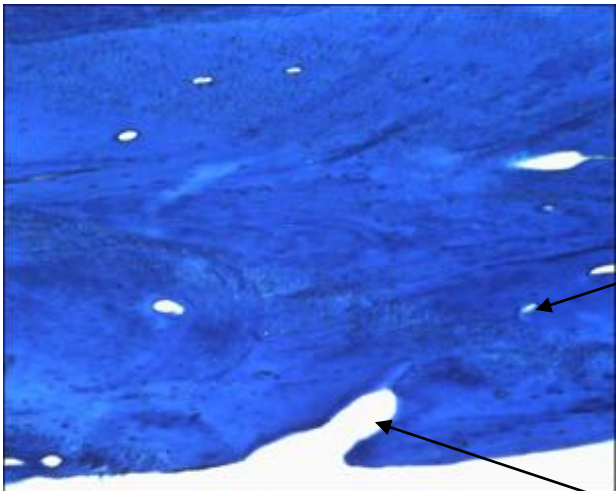
For this project, only samples of bone that had been decalcified were histologically examined. These samples displayed a variety of preservation levels, from very good to extremely poor, however they usually exhibited some of the histomorphology was intact in at least some areas (see Figure 3.43 below).

Figure 3.43 below shows a bone sample from Mummy A107 that although degraded has kept its structure to some extent.

 Fig 3.43	Stain – MSB Magnification – x10 Poorly preserved bone sample from Mummy A107 still able to visualise Haversian system
 Fig 3.44	Stain – Toluidine blue Magnification – x5 A beautifully preserved bone sample from Mummy A1 showing no signs of putrefaction – canaliculi and osteocytes with nuclei are still visible Volkmann's canal

There are many holes in the section caused by the putrefaction process. The bacteria have penetrated by moving up the osteocyte lacuni. Toluidine blue doesn't generally stain collagen, which is the main component of bone; however it stains elements associated with collagen such as proteogylcons (bone proteins). This sample had undergone putrefaction; enzymes have been produced that degrade collagen (collagenase), protein (protease) and the proetogycons. Where the section has been stained pink, large holes can be seen due to the absence of these protoegylcons, in the areas where the section has stained blue, the holes are smaller and the proteogylcons are more likely to be present. This sample displayed no birefringence under polarised light because the collagen was so degraded. Although the tissue is much

degraded, it has retained its macro-structure and even some of its micro-structure – in other words, when it is under the microscope, it is still obviously bone.

Figure 3.44 above shows a beautifully preserved bone sample from Mummy A1. There are no holes caused by putrefaction and the canaliculi are clearly visible, both longitudinally and tangentially. A Volkmann's canal, through which the blood vessels would go, can be seen at the bottom of the slide. The visible Haversian systems (while holes in section) identify this as cortical bone.

Figure 3.45 below shows a line of fungi stained red eating away at the surface of the bone. In the biological eroding process, very few things will cross collagen, however, this fungi has intimate contact with it. Underneath the fungal line, the section is pale, indicating it is being dissolved.

Stain – MSB

Magnification – x20

Bone sample from Mummy A107 showing fungi (red line) digesting the surface

Fig 3.45
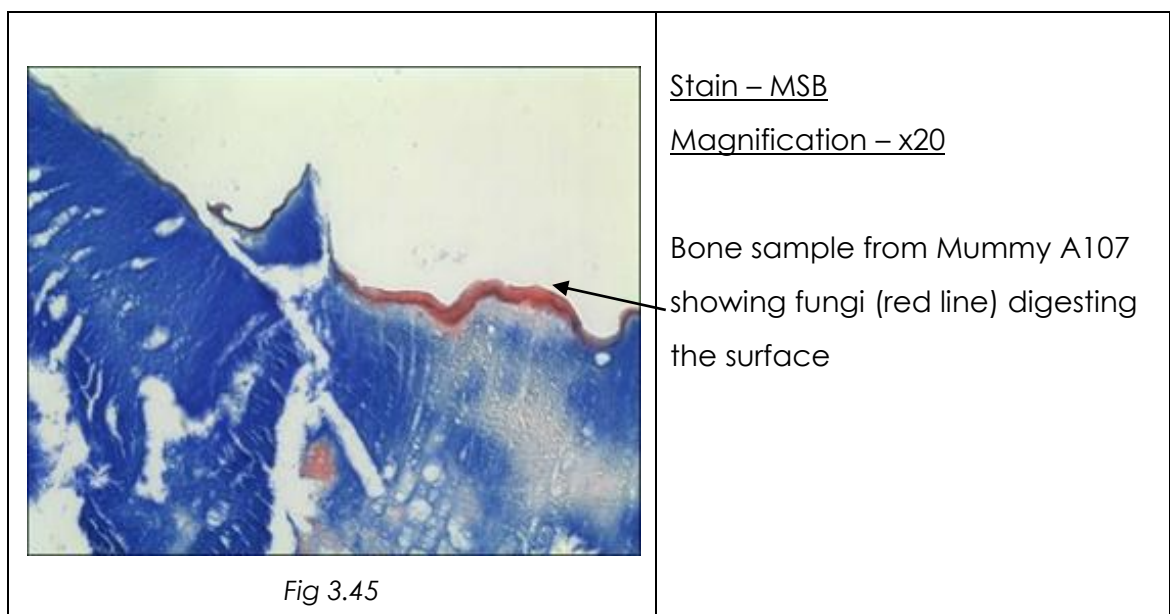
In Figures 3.46 and 3.47 below, crystals can be seen within the bone section. These crystals form when fungi produce organic acids such as oxalic acid as part of their metabolic processes, this is especially likely when the fungus *serpula lacrymans* is present (Denton 2008; 77). The oxalic acid begins to decalcify bone without producing soluble calcium salts but instead producing insoluble crystals of calcium oxalate.

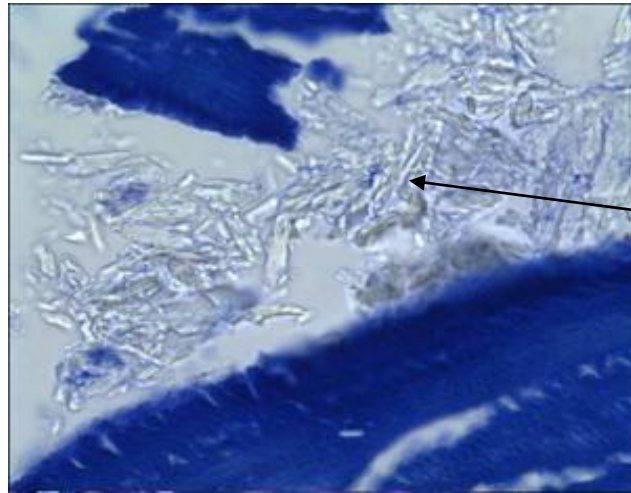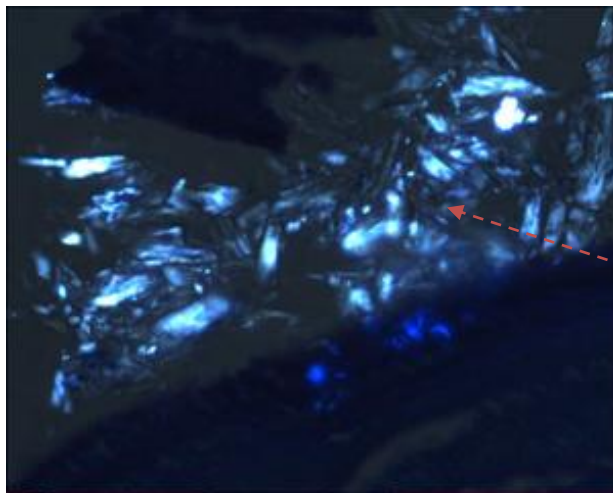|	
 Fig 3.46	<u>Stain – Toluidine blue</u> <u>Magnification – x 40</u> Bone sample, with crystals of calcium oxalate, from Mummy A14
 Fig 3.47	<u>Stain – Toluidine blue</u> <u>Magnification – x40</u> <u>Polarised Light Microscopy</u> Bone sample, with birefringent crystals of calcium oxalate, from Mummy A14

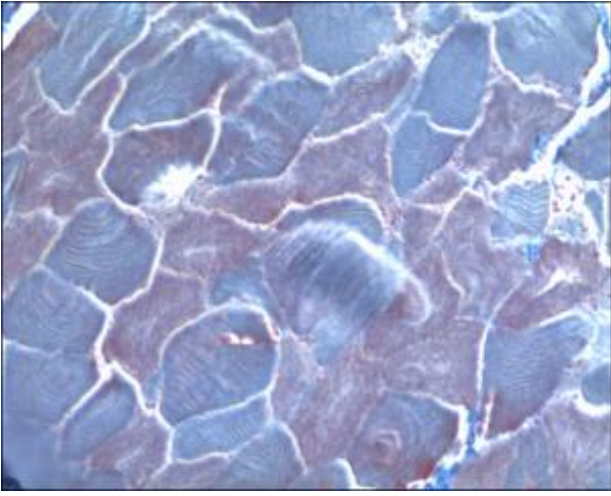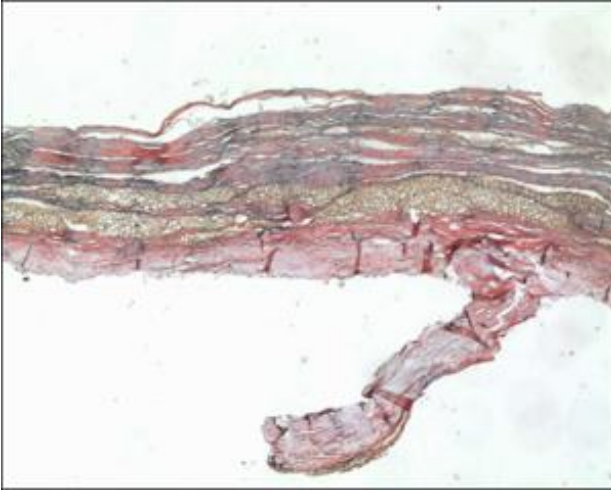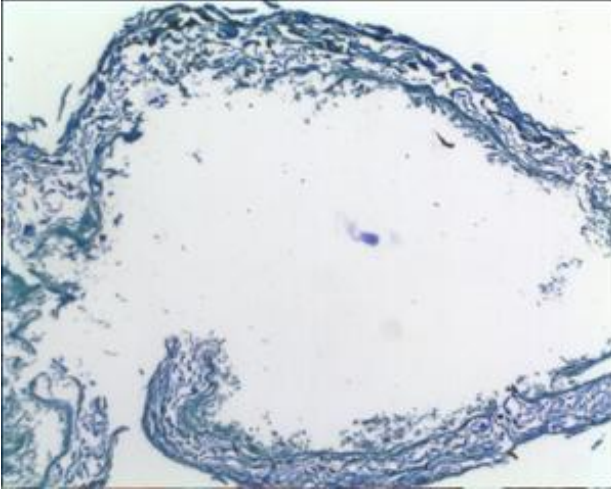### 3.3.9 – Summary of the Preservation Assessment for the Kellis 1 Mummies

According to Aufderheide (2003; 335), an estimate of soft tissue preservation of an ancient body is desirable. He created a system resulting in numerical values without the need for instrumental measures. He also applied this system to asses bone preservation. Aufderheide's system assigns points out of 25 to the major soft tissue and skeletal areas of the body (head, chest, abdomen, both arms and legs). These points are then added together to achieve a mark out of 100, this is converted to a percentage. Aufderheide states that these quantitative estimates convey more information than terms such as 'poorly preserved' or 'well preserved' with minimal time and effort needed to obtain the data, as well as producing a great amount of, and more reproducible information (Aufderheide 2003; 335).
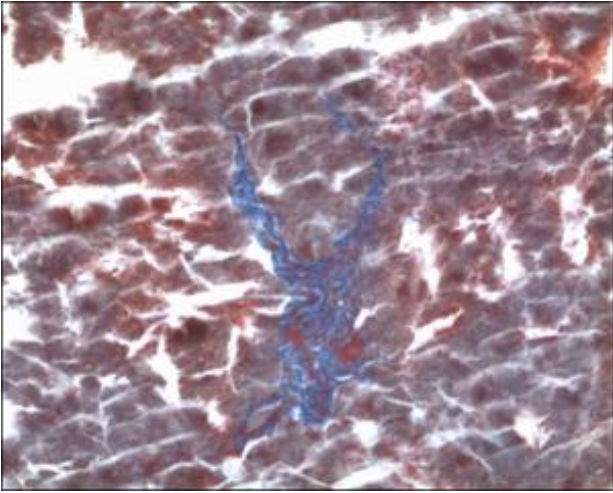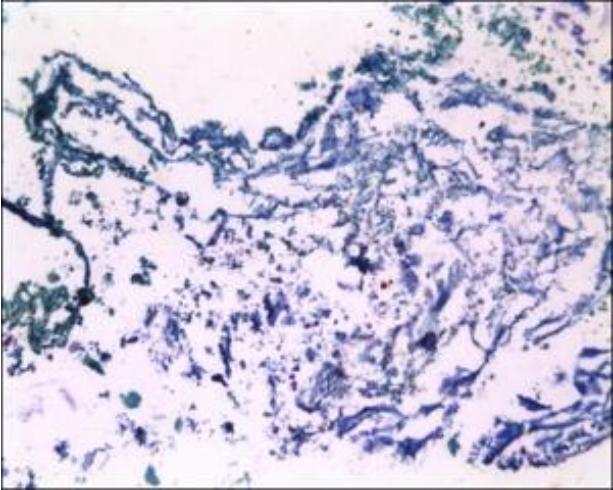
Such general estimates have, however, proved to be less than helpful, and even misleading, when applied to the same tissue examined by histological techniques. In many of the examined Kellis 1 mummies, the various types of soft tissue demonstrated a great difference of preservation. For example, the skin of an individual mummy could be very poorly preserved, while the muscle or other organs remained in a good state of preservation. Some mummies examined had been given soft tissue and/or bone preservation scores of 100 percent at the time of autopsy, however, when examined histologically were unidentifiable due to degradation.
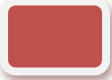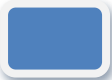
Other than the soft tissue preservation score given by Aufderheide, Cartmell and Zlonis given at the time of autopsy of the Kellis 1 mummies (see autopsy reports), it would appear that no other histological study has attempted to compare mummified samples in a uniform way as has been undertaken in this research.

Table 3.1 below presents a summary of the preservation findings of the ten Kellis 1 case studies, as well as their original preservation scores given at autopsy. The key to this table is on pages 171-172.

Fig 3.48-3.52 - Key to Table 3.1

 Fig 3.48	<u>Very Good</u> Macroscopic anatomy and microscopic structures are visible, pathologies, if present, are diagnosable, comparable to modern tissue (muscle)
 Fig 3.49	<u>Good</u> Macroscopic anatomy and microscopic structures visible, identification possible (thyroid)
 3.50	<u>Fair</u> Structure is obvious but can be made but little other information is available (dura)

\n*Fig 3.51*	<u>Poor</u> Some resistant structure remaining, for example, connective tissue, allowing for tentative identification based on autopsy labelling of sample (liver)
\n*Fig 3.52*	<u>Very Poor</u> Unidentifiable – no macroscopic anatomy or microscopic structure remaining (intestinal contents)

 No Sample Available

 Autopsy Scores

Case Studies	Breast Tissue	Bowel/ Colon	Heart	Liver	Lung	Skin	Muscle	Soft Tissue Autopsy Preserv. Score %	Bone	Bone Autopsy Preserv. Score %
Mummy A1				Fair		Fair	Good	96	Very Good	96
Mummy A4	Poor			Fair	Good	Very Good	Poor	56	Sample not bone	100
Mummy A5			Fair	Very Good		Good	Fair	96	Fair	96
Mummy A8		Very Good		Good		Good		32	Poor	60
Mummy A13		Fair		Fair	Poor	Good	Poor	99	Good	100
Mummy A101		Very Good (coprolite)		Sample not liver		Good	Very Good	96	Fair	100
Mummy A102		Fair		Fair	Very Good	Very Good		72	Fair	99
Mummy A108		Fair	Very Good	Very Poor	Fair		Very Good	90	Sample not bone	90
Mummy A126				Very Poor	Fair	Sample not skin	Very Poor	52	Very Good	66
Mummy A129		Poor		Poor		Poor	Very Poor	100	Good	100

Table 3.1 – Table of the Preservation Assessments of the Ten Case Studies from Kellis 1

3.4 – CAVEATS FOR THE USE OF HISTOLOGY ON ANCIENT MATERIAL

3.4.1 – Tissue Identification

When examining mummified tissue, a not uncommon problem can be that of tissue identification. There are three main circumstances where this can be an issue:

1)   The mummified sample can be too degraded by post-mortem activity for any structures to have survived, making identification impossible.
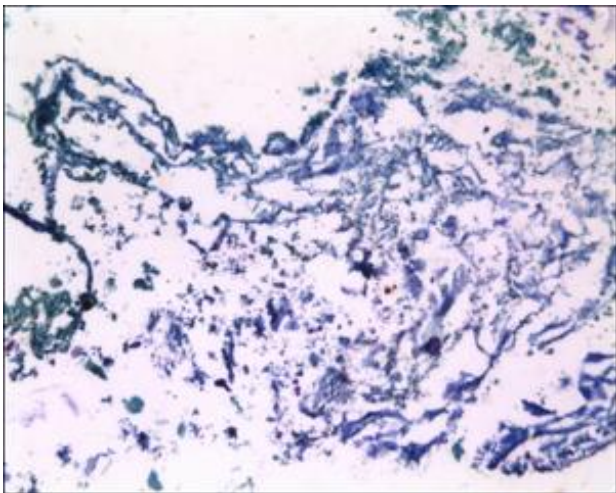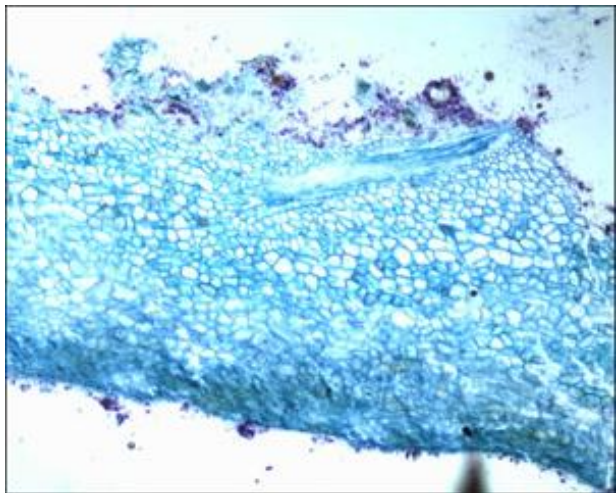
 Fig 3.53	<u>Stain – Toluidine Blue</u> <u>Magnification – x10</u> Intestinal contents from the visceral packages of Asru – no structures are visible to allow identification
 Fig 3.54	<u>Stain – Toluidine Blue</u> <u>Magnification – x5</u> <u>Resin Section</u> Structures remain allowing identification of plant material, therefore sample is intestinal contents

Figure 3.53 above is a sample of the intestinal contents collected from the visceral packages of the Late Period (747-332 BCE) mummy Asru (Manchester

Museum). No macroscopic anatomy or microscopic structure is recognisable. When the sample was processed, it disintegrated giving it the fragmented appearance. However, a sample of Asru's intestinal contents was also processed using plastic resin (LR White) and this allowed the sample to retain some elements, allowing for an identification of bowel contents to be confirmed (see Figure 3.54 above). Unfortunately, some samples were so degraded that even when processed them using plastic resin, could any anatomy be identified.

2)   Samples may have some resilient structures remaining, such as connective tissue; however, these structures are not diagnostic, meaning that the sample is in a fair state of preservation, still unable to be identified.

Stain – MSB
Magnification – x5

Collagen

Empty fat cells

Unidentifiable section

Fig 3.55
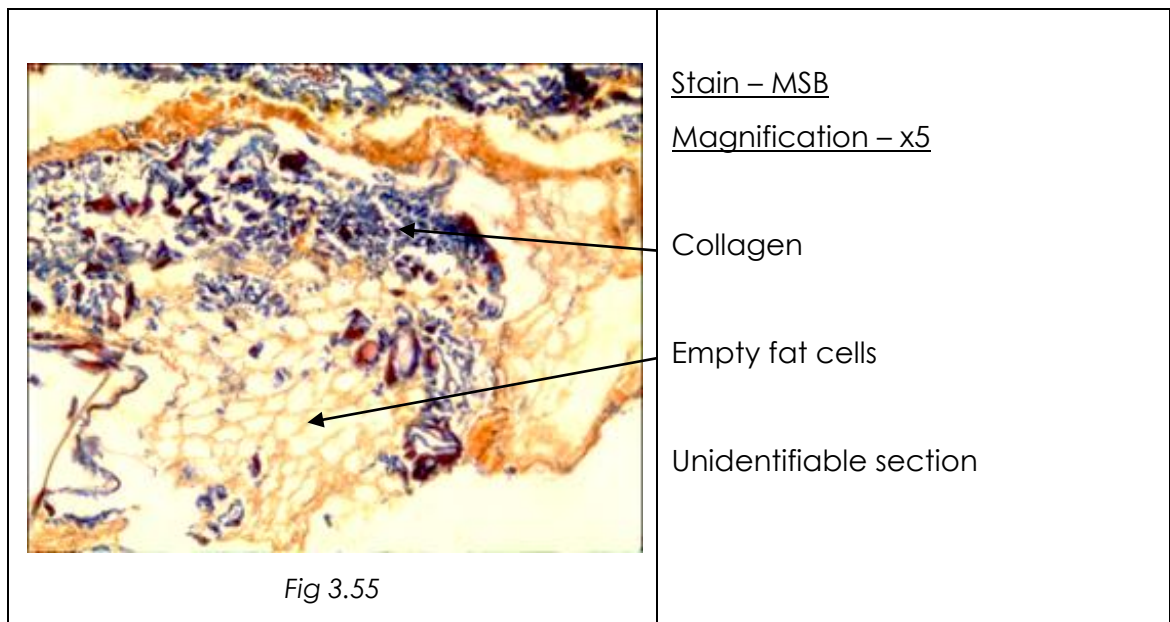
3)   Samples are misidentified at the time of dissection. This is an understandable occurrence, as the processes of desiccation, mummification and the passage of time, leaves mummy tissue brown/black, hard and brittle and almost homogenous in appearance.

Fig 3.56 – Samples of mummified tissue

Figure 3.56 above shows three samples of mummified tissue from the Kellis 1 mummies, the type with which a histologist would be presented. Although their appearance is similar, they are (from right to left) 1) breast tissue, 2) muscle and 3) skin.

The Kellis 1 mummy samples were identified at autopsy by the dissectors and there are some cases where this identification has been wrong, confirming that visual identification at the time of gross anatomical examination or autopsy is often not accurate. Confirmation of tissue type is important if any further, more sensitive techniques, such as ancient DNA or stable light isotope analysis, are to take place. Histology offers this confirmation.
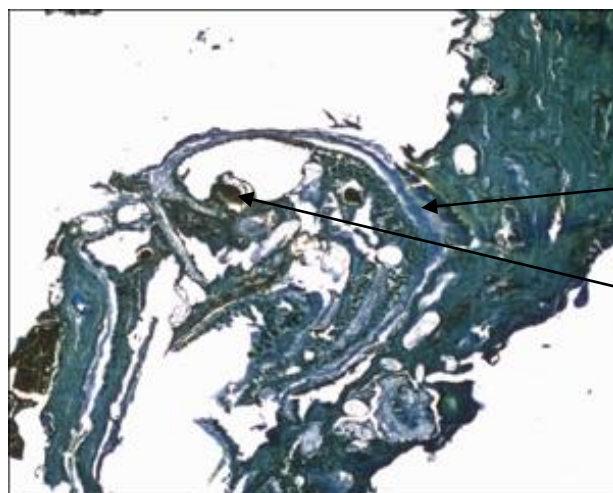
Stain – Toluidine Blue

Magnification – x2.5

Seed coat

Possible parasite ovum

Fig 3.57 – Labelled liver, proved to be coprolite

Fig 3.58 – Labelled liver, proved to be coprolite
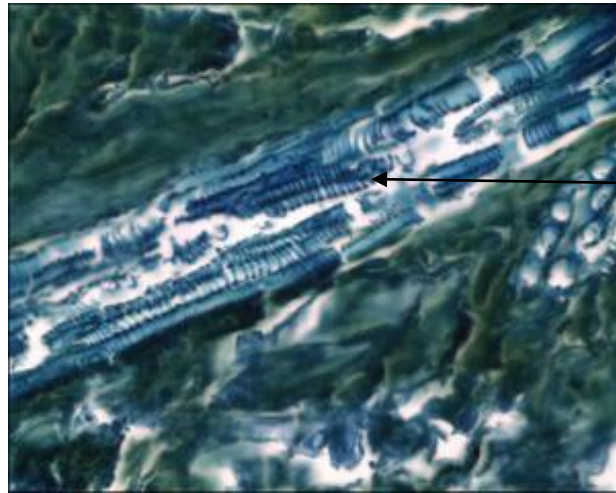
Stain – Toluidine Blue

Magnification – x20

Sieve tubes of a plant

Fig 3.59 – Labelled lung, probably thyroid
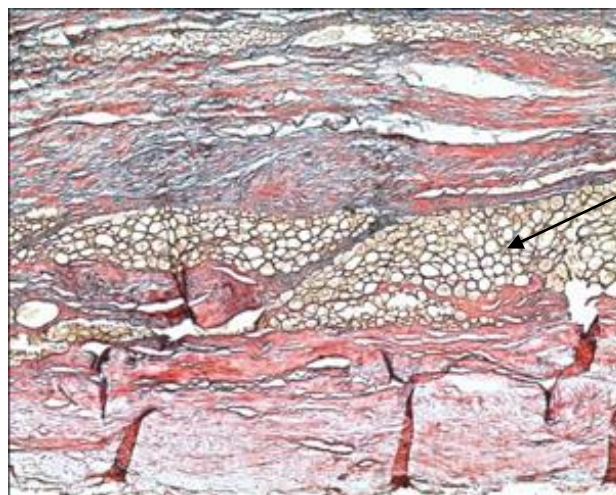
Stain – MSB

Magnification – x5

Thyroid colloid

Fig 3.60 – Labelled lung, probably thyroid
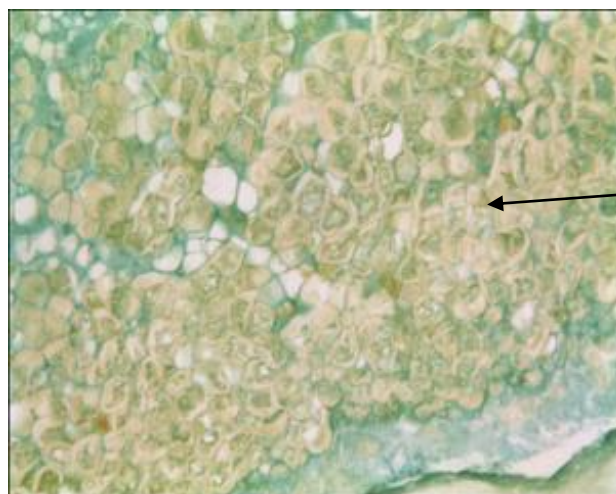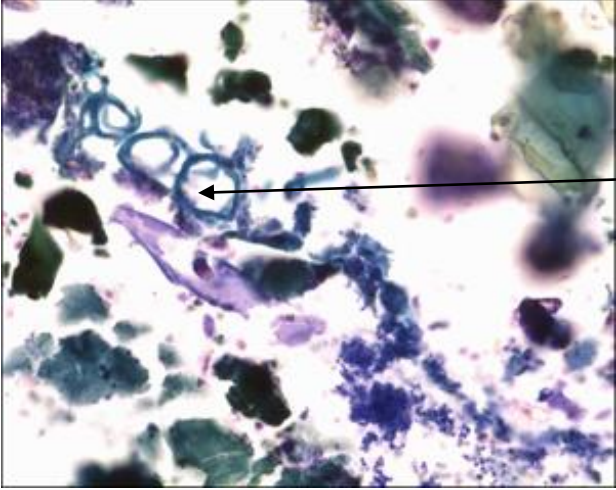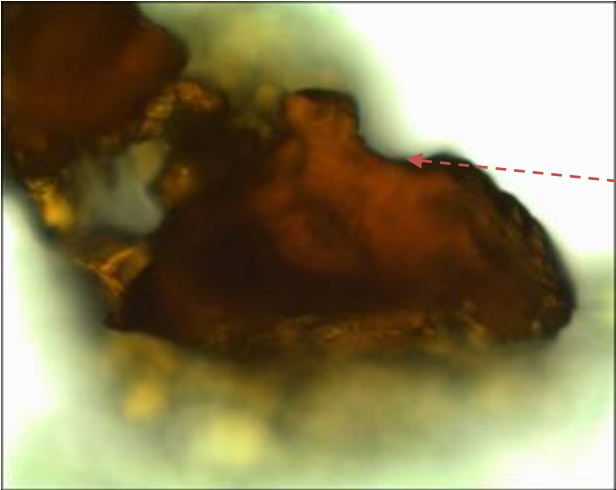
Stain – Toluidine Blue

Magnification – x10

Thyroid colloid

Fig 3.61 - *labelled lung, proved to be coprolite (Kulab Narti S85)*

Stain – Toluidine Blue

Magnification – x10

Sieve tubes of a plant leaf or stem

Fig 3.62 – *Labelled coprolite, proved to be resin*

Stain – MSB (did not stain)

Magnification – x20

Concoidal fracture, characteristic of resin

3.4.2 – Histological Technique Problems

3.4.2.1 – Rehydration and Fixation

The first of the processes necessary for the histological examination of mummified tissue is the combination of rehydration and fixation (see Chapter 2.2). Most ancient samples respond well to this and an increase in size can be seen as the tissues absorb the rehydration and fixation solution.

One of the problems that can occur during this stage is the uneven absorption of the solution in samples of cartilage, causing the section to fold (see Figure 3.62 below). However, as cartilage is connective tissue, and therefore one of the more resilient structures, the basic macro anatomy and micro-elements remain intact and identification of the tissue is usually not difficult.

Stain – Toluidine Blue

Magnification – 2.5

Folds in the cartilage

Fig 3.63 – skin/cartilage sample from Mummy A13
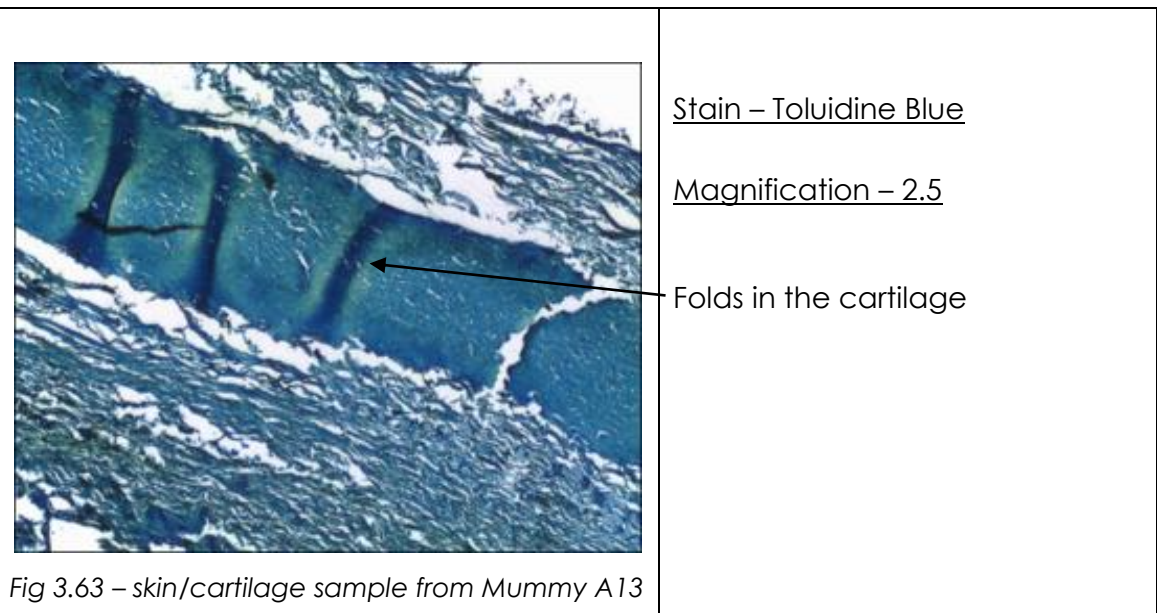
Figs 3.64 – An example of sample that has not taken up the solution

Figs 3.65 – An example of sample that has taken up the solution

Samples that are too solid or tightly packed might not allow the rehydration and fixation solution to infiltrate. This can also occur if the sample turns out to be inorganic. Figure 3.64 above is a sample from York that had been labelled 'conglomerate' and thought to contain coprolite material. However, after many days immersed in the solution, with no evidence of absorption taking place (note the lack of colour change within the liquid), the sample is probably inorganic, such as a metal or stone of some sort. Figure 3.65 above is a sample of liver (Mummy A126). The tissue has rehydrated well and the liquid displays a distinct colour change due to the putrefactive breakdown of proteins.

3.4.2.2 – Decalcification

For this project, it was decided that all bone samples would be decalcified. The samples appeared to be extremely brittle, and it was hoped that decalcification would provide the most successful results. If the bones had not been decalcified, it is likely they would have been impossible to section. The decalcifying solution chosen was ethylenediamine tetra-acetic acid (EDTA) (see Chapter 2.3.2). EDTA is a chelating agent, which means is it a much slower process and a lot more gentle on the degraded bone samples than an acid.

Once sectioned and stained, some of the Kellis 1 bone samples demonstrated that they had been well decalcified and the preservation levels were extremely good, both in term of macro anatomy and micro structures (see Figure 3.66 below).

Stain – Toluidine Blue
Magnification – x5

Extremely well-preserved bone sample

Osteocyte

Volkmann's canal

3.66 – Bone sample from Mummy A1
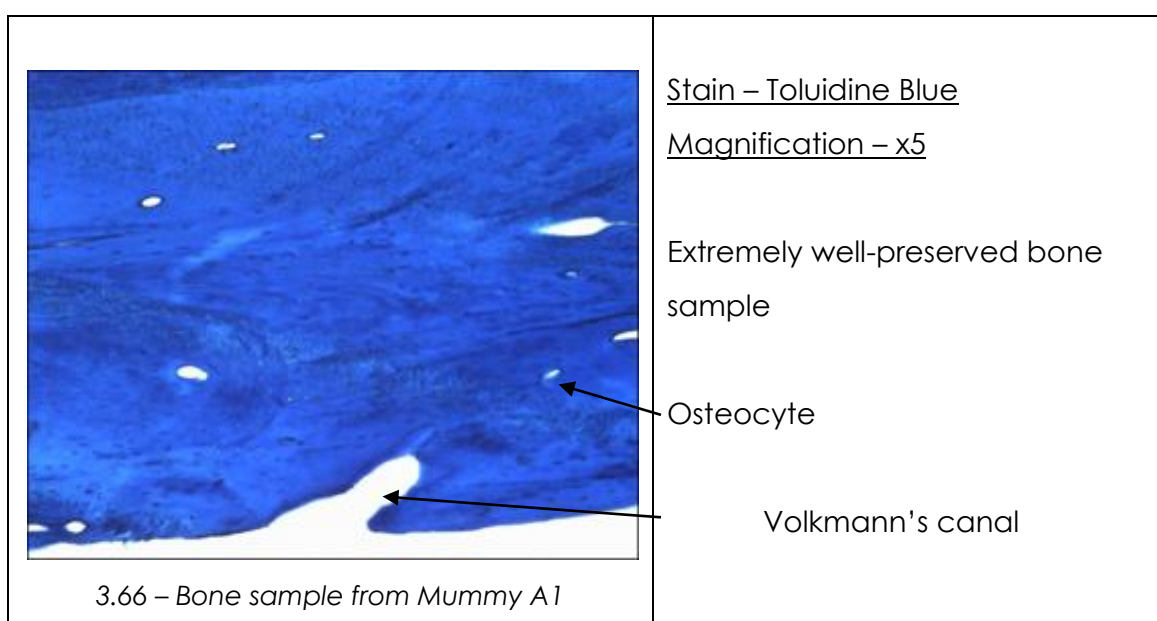
Some samples did not decalcify well (see Figure 3.67 below), the cause of which was either the sample not being left for a long enough time period in the decalcifying agent, or, the sample being initially too degraded for the EDTA to have been able to work.

	Stain – MSB
	Magnification – x2.5
	Decalcification (blue)
	Lack of decalcification (pink)
Fig 3.67 – Bone sample from Mummy A107	
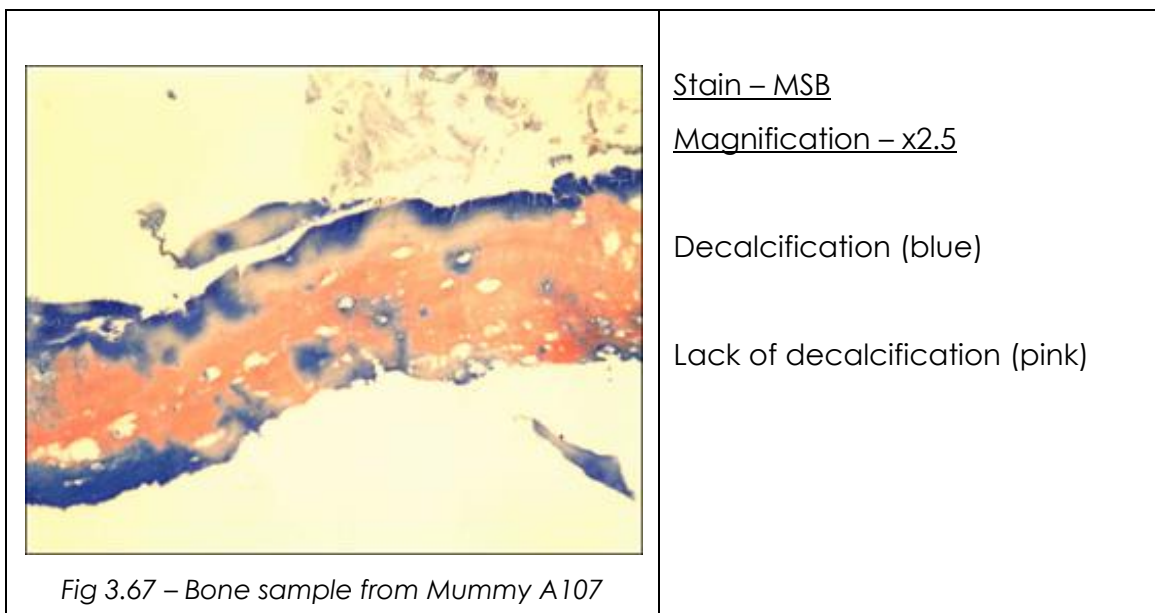
3.4.2.3. – Embedding

The Kellis 1 samples were embedded mostly in blocks of paraffin wax, although a small number that did not yield good results, were also embedded in LR White, a plastic resin.

	Stain – Toluidine Blue
	Magnification – x5
	Resin Section
	Bone sample too degraded for resin to be of use
Fig 3.68 – Bone sample from Mummy A101	
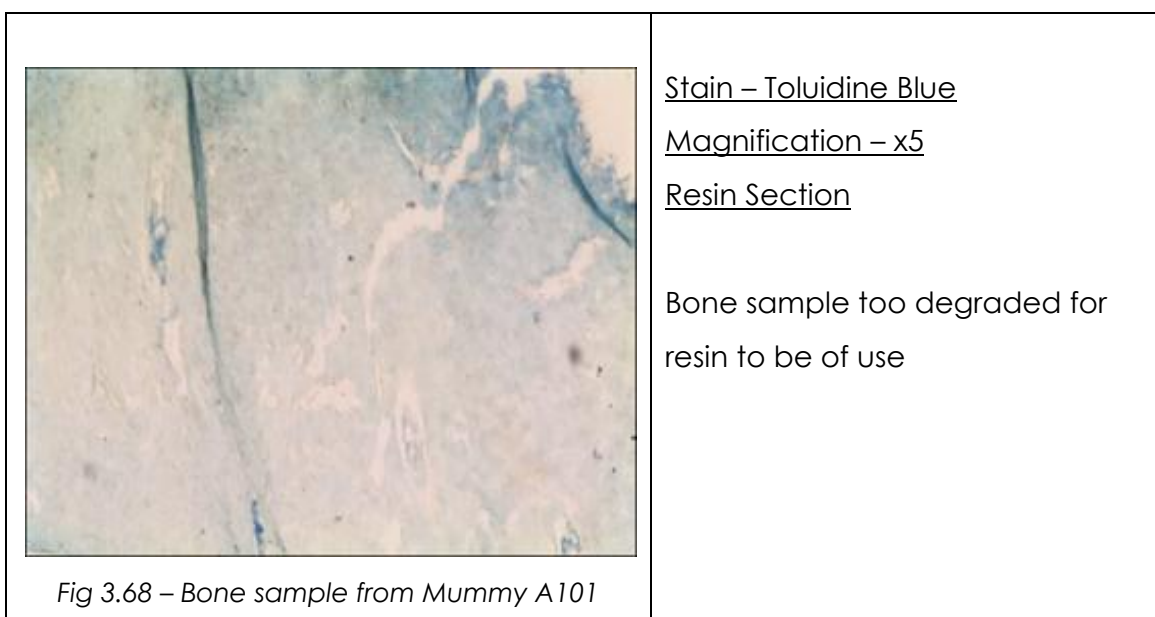
For these samples, it was hoped that the resin would provide a stronger structure, in which the samples would hold together and not disintegrate. This presumption held true for only a few samples, for example, the sample of intestinal contents from the mummy Asru (see Chapter 3.4.1) and a heart sample from Mummy A108, although the paraffin wax-embedded sections of this sample also yielded informative results. Unfortunately, most of the resin-embedded sections were not successful due to their very poor state of preservation (see Figure 3.68 above). In these cases, no other techniques could be used – the sample was simply too degraded to be of histologic value.

3.4.2.4 – Blocking Out

Blocking out, which involves placing the processed tissue sample into a metal cassette of paraffin wax, then freezing it in order to solidify the wax, ready for sectioning, is not s difficult process. However, one issue that can arise is getting the orientation of the tissue wrong at this point. Some samples, especially skin, if oriented transversally, only yield a minimal amount of information (see Figure 3.69 below).

Stain – MSB

Magnification – x10

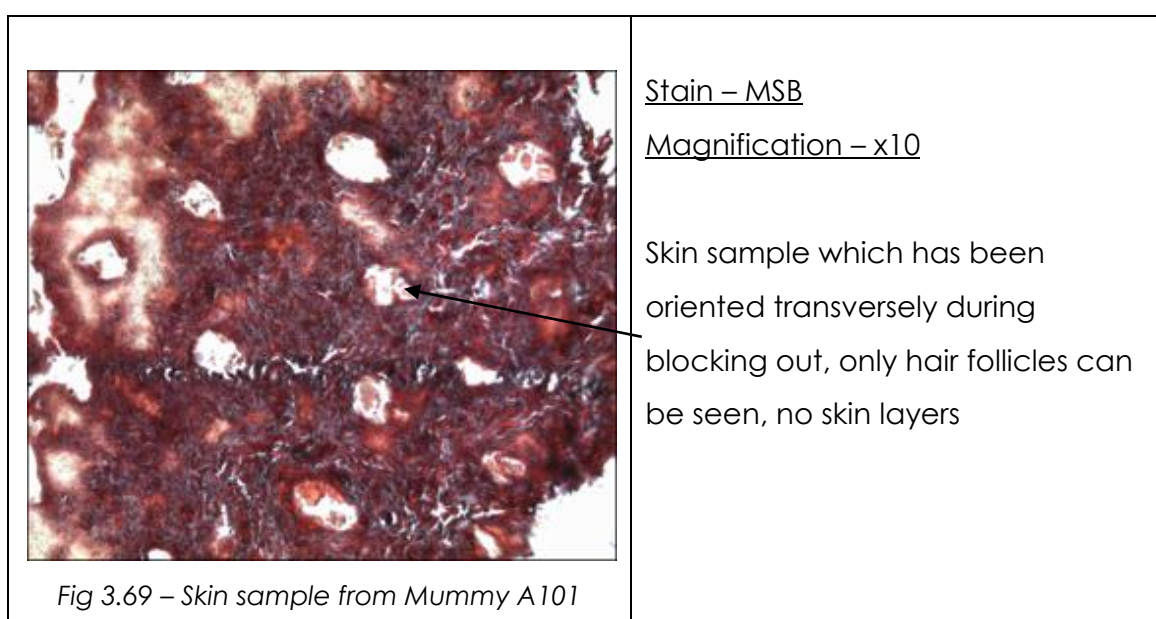Skin sample which has been oriented transversely during blocking out, only hair follicles can be seen, no skin layers

Fig 3.69 – Skin sample from Mummy A101

3.4.2.5 – Sectioning

Sectioning was one of the most problematic parts of the process. While most samples sectioned well or at least well enough to enable staining and examination under a microscope, some samples turned to powder as soon as the microtome blade touched them (see Figure 3.70 below). This is due to not

rehydrating – the sample is either too degraded or too dense to absorb the rehydration and fixation solution. The resulting section is left with a hole in the wax where the sample should be, and therefore, there is nothing to stain.

Fig 3.70 – The paraffin wax block of the liver sample from mummy A126, a fine dust can be seen on the blade where the sample has disintegrated as soon as the blade touched the sample

3.4.2.6 – Staining

While the staining of sections proved to be mostly very successful, occasionally problems could occur. These were:

1) The section was so degraded that the stain could not successfully bind to any components, leaving it 'colourless' (see Figure 3.71 below).

 Fig 3.71 – Liver sample from Mummy A111	Stain – Toluidine Blue Magnification – x5 Resin Section Despite being stained with toluidine blue, the tissue elements have not taken to the dye at all

This could sometimes be remedied using Differential Interference Contrast Microscopy (see Chapter 2.2.9.2).

2) Some sections were over-stained; this was especially true of the Giemsa stain, where the protocol for fresh tissue was used (see Figure 3.72 below). Ancient samples appear to take up the Giemsa stain more readily than their fresh counterparts.
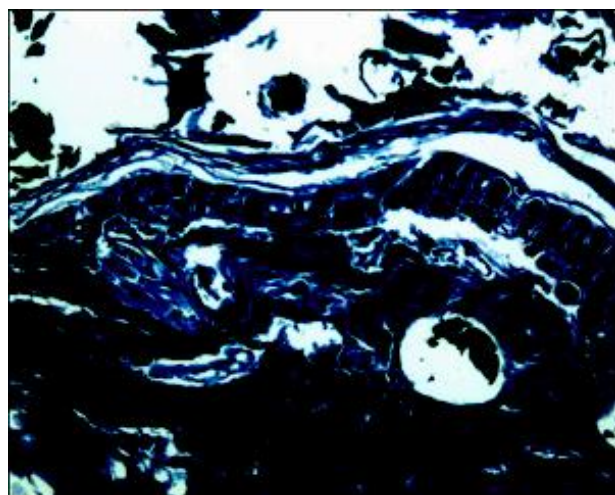
Fig 3.72 – Coprolite sample from Mummy A101	<u>Stain – Giemsa</u> <u>Magnification – x10</u> This section had been over stained with Giemsa so that it is extremely difficult to identify any micro anatomy

Something that must be taken into account when using trichrome stains, such as MSB, is the possible post-mortem change in pore size, due to oxidation, environmental conditions or even the type of mummification employed. This change can result in a reversal of colours from that seen in modern tissues. For example, in Figure 3.73 below, the collagen, which is normally stained blue has been coloured a vivid red.
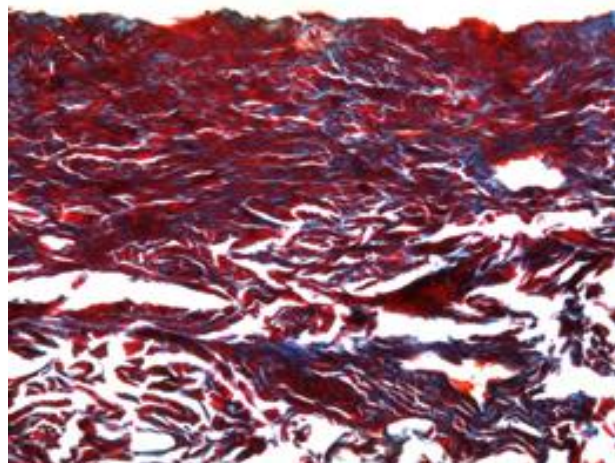
Fig 3.73 – Skin sample from Mummy A1	<u>Stain – MSB</u> <u>Magnification – x10</u> Thick collagenous layer that should be stained blue but is a vivid red

3.4.2.7 – Mounting

Although rare, samples sometimes that appeared to have successfully been rehydrated and fixed, processed, embedded, sectioned and stained, dispersed at the time the section came into contact with the mounting medium (Xam) (see Figure 3.74). Despite this, it is usually possible to identify some elements when the sample is examined under a microscope. Figure 3.75 displays the microscope image of Figure 3.74; despite the disintegrated coprolite section, plant material can still be identified.

Fig 3.74 – Coprolite sample from Peru

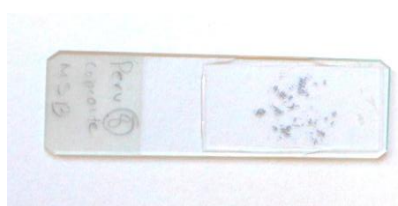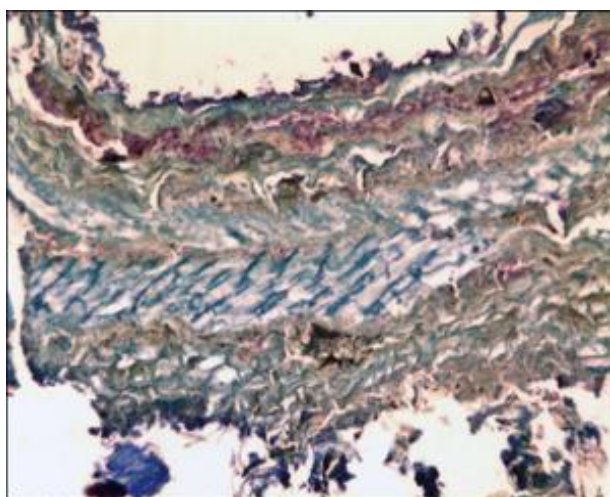|	
 Fig 3.75 – Microscope image of disintegrated Coprolite sample from Peru	Stain – MSB Magnification – x10 Some type of plant material

3.5 - Conclusion

While some bone and soft tissues undergo anatomical changes (mainly due to autolysis and putrefaction) that render them unidentifiable, many tissues remain viable for histological examination.

Histology enables positive identification of samples and demonstrates a good means of assessment of preservation of samples, which can assist when deciding on further techniques to be employed such as aDNA, as well as sometimes assisting with an understanding of the mummification method used. One of the main advantages offered by histology is the recognition of morphological changes in the tissues caused by disease that no other scientific technique is able to identify (Aufderheide 2003; 372-3).

3.5.1 – Case Study - Bone Sample from Mummy A15

Mummy A15 was an unusual mummy in that it was composed of four different bodies (see Chapter 2.1.14). The sample examined in this project was from the femur of a seven-year old child.
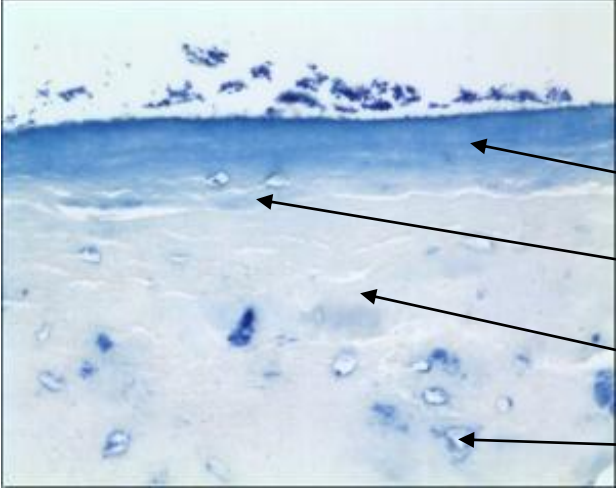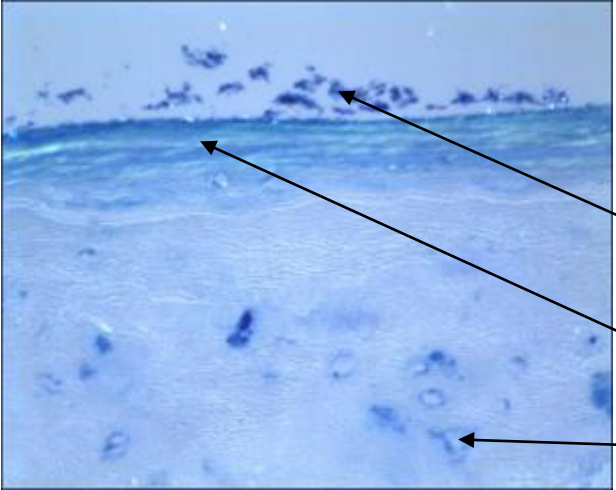
The sample was decalcified and embedded in wax as it was originally thought it could provide a good comparison for bone samples decalcified and embedded in LR White resin. However, the tiny sample of femur from Mummy A15 had its own story to tell.

At first observation, the sample appears extremely degraded, with many areas of the section not taking up the stain, due to bad or incomplete decalcification (see Chapter 3.5.2.2). On closer examination, the stained and unstained areas have more to do with the different composition of bone being visualised. The pale, unstained areas are woven bone, or rapidly laid down repair bone and the darker, stained areas represent normal, lamella bone.

The overall view of the femur sample when examined using light microscopy (see Figure 3.76 beow) immediately suggests that there are two types of bone present. In the lower part of the image, the sample is paler, as though it has not taken up the toluidine blue stain. However, when inspected more closely, the visible osteocytes are distributed irregularly; some areas displaying clusters, while other areas are devoid of osteocytes completely. This disorganisation of the osteocytes is suggestive of bone that has been rapidly laid down. The

reason for the pale colour is most likely due to fewer proteogylcans being present at the time of this bone's formation. The dark area above this, on the other hand, appears to be normal healthy bone.

The junction between the dark and pale areas of the sample (seen as a thin white line) has scalloped edges, evidence of the process of osteoclasis. It is unusual for such a large area to undergo osteoclasis at the same time.

Fig 3.76

Stain – Toluidine Blue

Magnification – x20

New normally laid lamella bone

Junction between the two types of bone

Rapidly laid bone

Osteocytes

Fig 3.77

Stain – Toluidine Blue

Magnification – x20

Semi-polarised Microscopy

Debris – not related to the bone

Lamellae (visualised in lines)

Osteocytes

When the sample is viewed using semi-polarised light microscopy (see Figure 3.77 above) the idea of types of bone is validated. The dark area at the top of the sample displays the lines, or plates, of lamellae. The dark blue lines are the collagenous lamellae that have been down running in one direction, the

brighter, white lines are the lamellae that have been laid down running a different direction. This confirms that this bone has been formed, as normal, healthy bone should be.

It is impossible to ascertain which direction the collagen (lamellae) is oriented within the pale area of the sample. This part displays characteristics of the rapid laying down of emergency repair bone.

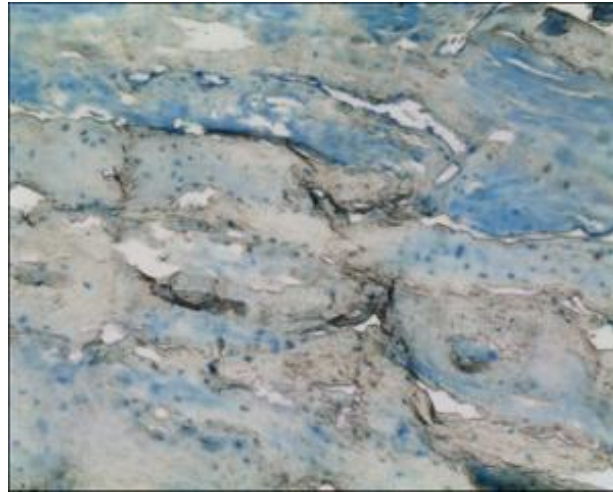Stain – Toluidine Blue
Magnification – x5

New normal bone (blue)

Older rapidly laid bone (white)

Fig 3.78

Figure 3.79 demonstrates a mixture of old (pink) and new (blue) bone. A mixture such as this is a feature of the occurrence of a fracture; one that the process of healing was fairly complete at the time of death.
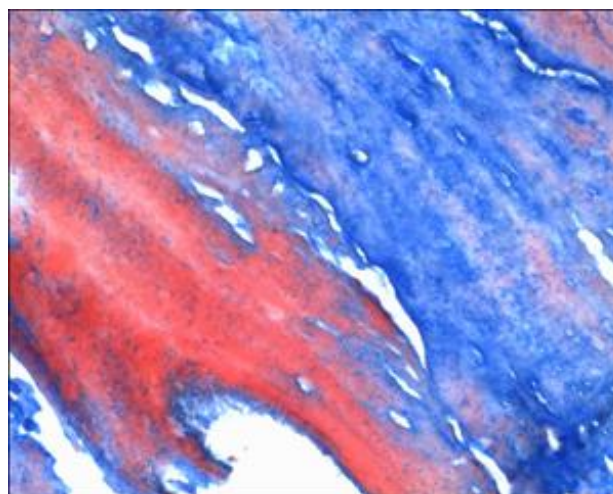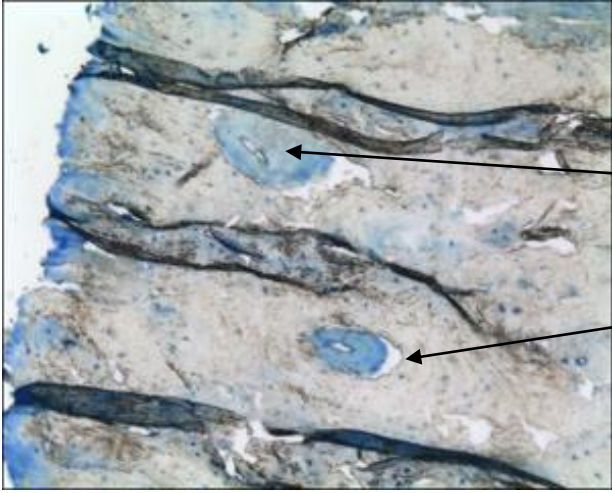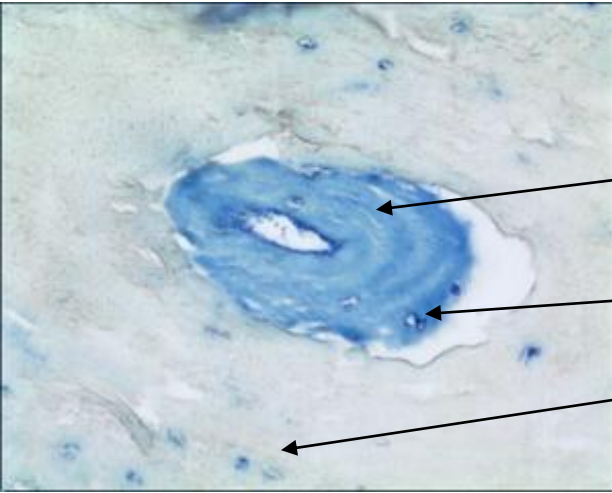
Stain – MSB
Magnification – x20

New bone (blue)

Old bone (red)

Fig 3.79

Figure 3.79 above is the sample stained with MSB. The difference between old (red) and new (blue) is very obvious is this image.

 Fig 3.80	<u>Stain – Toluidine Blue</u> <u>Magnification – x5</u> Haversian system Scalloped edge due to tunnelling resorption
 Fig 3.81	<u>Stain – Toluidine Blue</u> <u>Magnification – x20</u> Haversian system Osteoblast Osteocyte

Figures 3.80 and 3.81 show well-preserved Haversian systems. The edging of the pale area is scalloped, which is evidence of tunnelling resorption. The darker blue area is the new, healthy bone. Within this area are osteoblasts, which make new bone, as well as osteocytes, which still have recognisable related canaliculi.

The images relating to the femur sample of the reconstructed Mummy A15 confirm that its owner went through a long period of being nutritionally deficient. Sometime before death, however, the situation improved for this individual and their health returned, at least in a nutritional sense. The

nutritional deficiency suffered by the owner of A15's femur can be caused by demands made of the skeleton, such as during the times of pregnancy and lactation. At this time, the foetus, or child respectively had a great need for calcium, most of which comes from the maternal skeleton (see Figure 3.82 below).
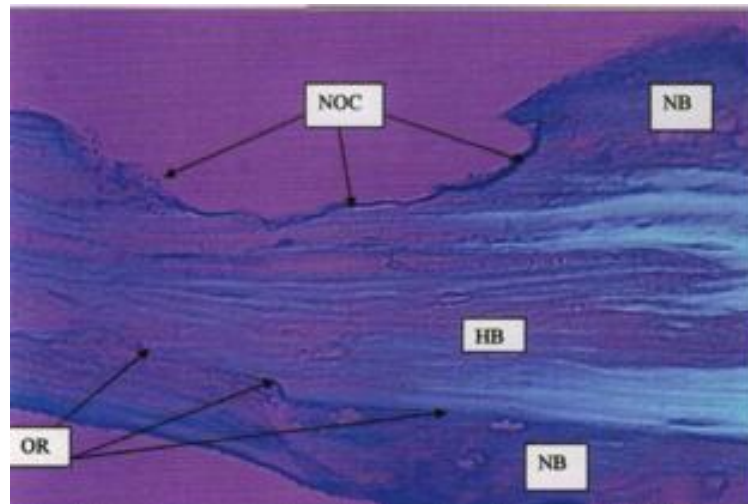
Fig 3.82 – Bone sample from Nubian female
HB – Healthy bone, OR – Old resorption line, NB – New Bone, NOC – Osteoclasis

This sample demonstrates a pattern of severe bone removal by osteoclastic resorption, leaving a scalloped surface, similar to that on the sample from A15. This was followed by a healing phase, ... Unlike A15, this pattern was rep......... on died. This type of pattern sugge......... d the child, quickly becoming pregn......... nts, compounded by a poor diet, ... 2008; plate VIII).
Famine, or .... extreme poverty can .... also be causes of .... malnutrition; neither of which were unknown in ancient Egypt (see Figure 3.83 below). Malnutrition can also be the result of deriving too much of one's diet from a single source, such as maize or wheat.
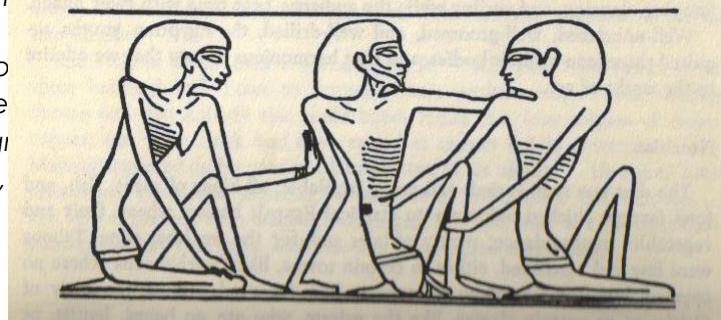
Fig 3.83 – One of at least three reliefs that represent famine in ancient Egypt. This one is found on the Unas causeway in Giza from approximately 2600 BCE (Ghalioungui 1973; 154)

Today, malnutrition in young children contributes significantly to the global burden of disease, and is the cause of 53 percent of childhood deaths (Caulfield et al 2004; 195). Any child with an inadequate dietary intake is susceptible to diseases such as diarrhoea, pneumonia, measles and malaria. In turn, disease suppresses appetite and inhibits the absorption of nutrients in food and competes for a child's energy (Smith & Haddad 2000; 5). Certain stages of life are more demanding of the human body such as the aforementioned pregnancy and lactation, and adolescence, where during a growth spurt, the daily deposit of calcium can be twice that of normal deposition (45 percent of the skeletal mass is added during adolescence) (Smith & Haddad 2000; 5).

The owner of A15's femur, at seven-years of age, was most obviously too young to be suffering malnutrition relating to pregnancy, lactation and adolescence. That said, it must be acknowledged that a child suffering from malnutrition, or related diseases, may demonstrate a smaller bone structure than a healthy child at the same age. Therefore, it is possible that the owner of A15's femur may have been older than recorded.

One of the most likely causes of malnutrition for this individual is more likely to be a severe infectious disease inhibiting the intake of the necessary nutrients needed for normal bone growth. The child recovered from this serious disease and began to eat normally, demonstrated by the newer layer of normal healthy bone in the sample.

While the cause may remain vague, histology has confirmed that this child at some point in their lives suffered from stress and became nutritionally deficient. This was followed by a period of recovery (Figure 3.76). Information of this detail could only be achieved using histology; it is below the resolving power of even the most advanced radiography and computer tomography methods and microscopy alone could not have differentiated between the bone types. Only by the combination of staining and polarised light microscopy can such a description of a time in a child's life be possible. From here, other techniques can be employed to further this story but without histology, there would never have been a place to start.

CHAPTER FOUR - CASE STUDIES

4.1 – INTRODUCTION

Fig 4.1 – Mummies in the tombs in the Kellis 1 Cemetery (photograph courtesy of the Dakhleh Oasis Project)

The excavations of the Kellis 1 or Western Cemetery have thus far been contained to 21 tombs; however, the cemetery is far more extensive with its limits yet to be defined. These 21 tombs were clearly used for successive burials, with the only exception being tomb 10, in which bodies had been laid systematically on the chamber floor, strongly suggestive that the burials were contemporaneous. None of the bodies in the Kellis 1 Cemetery had been placed in coffins, although some were associated with cartonnage head and foot coverings (Birrell 1999; 33).

Fig 4.2 – Cartonnage head covering from Kellis 1 (photograph courtesy of Dakhleh Oasis Project)

The 49   mummies

from the Kellis 1 cemetery have been the subjects of much previous study (Aufderheide et al 2003, Birrell 1999, Dupras 1999, Aufderheide et al 1999, Cook 1992). While this means that a great deal is known about this population, the main hypothesis for this project is that histological analysis of such mummies is a valid and valuable exercise that will add even further useful data that could not be obtained using any other scientific technique.
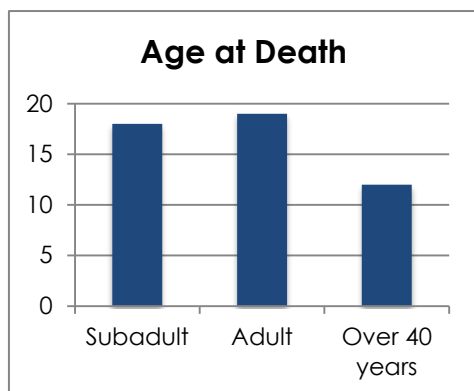
Fig 4.3 – Breakdown of Age at Death of the 49 Kellis 1 Mummies. Sub-adult refers to individual less than twelve years at time of death
N = 49
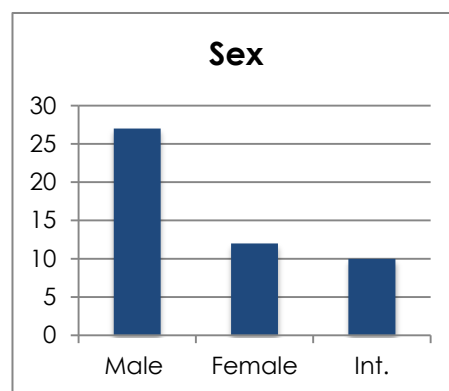
Fig 4.4 – Breakdown of Sex of the 49 Kellis 1 Mummies. Int. = Indeterminate
N = 49

4.1.1 - Mummification

This project focuses on ten individual mummies from the Kellis 1 cemetery. The mummies vary in terms of mummification methods, sex and age at death. When histologically examined, they also differed greatly in the level of preservation.

Initial examinations of the bodies revealed that some of them had desiccated in the hot dry sand of the tombs, while others had been eviscerated and embalmed in a method indicative of the most extensive procedures of the Nile Valley. Many of the mummies had been simply painted with resin onto the skin's surface; others had resin applied to both the external surface and poured into the internal body cavities (Aufderheide et al 2003; 139).

The 49 mummies have been labelled by Aufderheide et al (2003; 140) as either spontaneously or artificially mummified.

*Fig 4.5 - Breakdown of the Mummification Methods in the Kellis 1
Cemetery. Int. = Indeterminate
N = 49*

Spontaneously, or naturally, mummified bodies are those for which no human effort has been employed to achieve soft tissue preservation. Artificial, or anthropogenically, mummified bodies have been subjected to deliberate human acts to retain soft tissue after death (Aufderheide et al 2003; 142). In Kellis, the spontaneously mummified bodies were achieved by the arid climat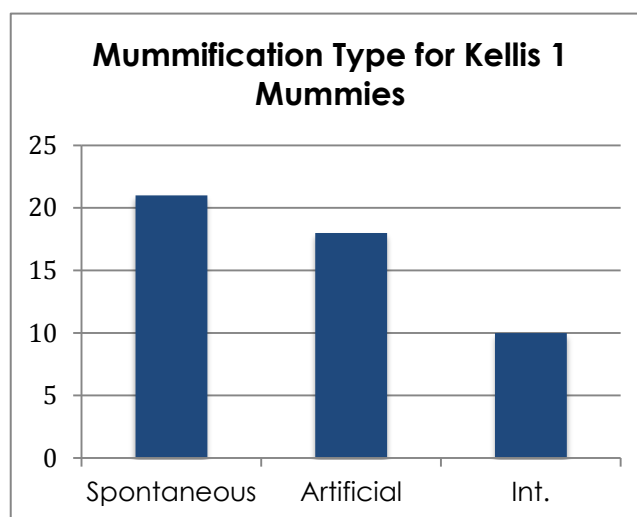e and hot summer temperatures; as well, most of the bodies showed signs of having been wrapped at the time of burial and the wicking action of wrappings acted to conduct moisture away from the bodies (Aufderheide et al 2003; 142).

While Aufderheide et al (2003; 139) have categorised 21 of the Kellis 1 bodies as being spontaneously mummified, it should be noted that all but two of the 49 had undergone transnasal craniotomy for the purposes of brain removal. The ancient Egyptians considered the brain to be of no use, they believed the heart carried out the functions that we now know to be those of brain. As the brain is one of the first organs to undergo post-mortem autolysis, the removal of it would appear to be a sensible measure in the quest to delay decomposition (Gaafar et al 1999; 257).

As stated above, many of the spontaneously mummified bodies had a coating of resin painted onto the skin's surface. It is possible that this resin was intended simply to assist the wrapping process (as an adhesive) and therefore not used for any preservative means. However, one of the labelled spontaneously mummified bodies (Mummy A9) also had resin poured into the internal body

cavities. The stomach and lungs of this body were absent. As the large majority of the Kellis 1 mummies had, Mummy A9 had been excerebrated. Resin, known in ancient Egypt for it preservation and anti-bacterial properties, had been applied to the external and internal areas of the body. Also, two of the four visceral organs traditionally removed as part of the artificial mummification procedure, were absent. In this case, despite Aufderheide et al's conclusions, it is hard to confirm that no human effort had been employed in order to preserve this body.

Questions can also be raised concerning some of the bodies categorised as artificial mummies by Aufderheide et al (2003; 139). Mummies A107, A110, A126 and A129 demonstrated no evidence of an evisceration incision. The lack of such an incision in the left side of the abdomen cannot be used as definitive proof against artificial mummification as the visceral organs could also be removed via a perianal incision through the anus (four mummies had evidence of this – A3, A123, A124 and A133). However, mummies A107, A110 and A126 and A129 have no incisions in either area. Mummy A110 has an atypical entry wound located in the back; if this was method of removal it was inefficient as the embalmers left behind the lungs and part of the intestines. Mummies A107, A126 and A129 displayed no evidence of any incision wounds, and, also had visceral organs remaining:

- A107 – liver, intestines
- A126 – liver, lungs, intestines
- A129 – liver, intestines.

It is difficult to accept with certainty that these four mummies had been artificially mummified.

It is anticipated that once the ten case study mummies have been histologically examined, more information regarding the mummification and preservation of these bodies will become available.

Fig 4.6 – Figure of Anubis caring for the elaborately mummified body – Tomb of Senedjem (19th Dynasty) (http://images.nationalgeographic.com/wpf/media-live/photos/000/247/cache/anubis-mural_24753_600x450.jpg)

4.1.2 - Brain Removal

As stated above, all but two of the 49 Kellis 1 mummies had the brain removed. Brain removal (excerebration), suggested as a means of slowing decomposition, is evidenced in the Middle Kingdom (2055-1650 BCE), and became a common element of the embalming process during the New Kingdom (1550-1069 BCE) (Strouhal 1986; 142). However, as the brain is encapsulated within the cranium, and even in a state of extreme decay, would not influence the decomposition of other organs, its removal as part of the mummification process is an unnecessary step; the putrefied brain would not even create an unpleasant smell as the visceral organs would. The removal of the brain (excerebration) when no other attempt is made at preservation (and for all but two of the 49 Kellis 1 mummies to have undergone this treatment) is curious. In the Roman Period, when less care was purported to have been taken with the preparation of the body, the practice of brain removal remained popular, the exact reason for which remains unknown.

The normal procedure involved forcing a hooked instrument through one nostril (usually the left), through the ethmoid bone into the cranial cavity. A certain degree of force was needed for this, and often, if the embalmers were not careful, both sides of the nasal passage were damaged (Dawson 1927; 42).

In a study of Pharaonic and Roman Period mummies, Gaafar et al (1999; 119) discovered that the nasal openings in the skulls of Pharaonic mummies was usually clean cut, of about one to two centimetres in diameter. In Roman

mummies, the opening was more central, much larger and involved both posterior ethmoid regions (Gaafar et al 1999; 119).
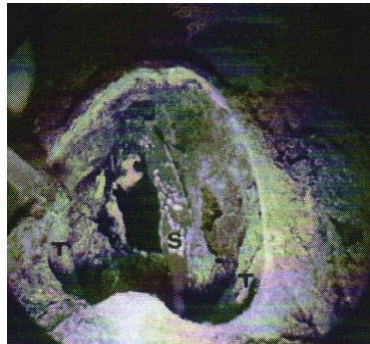
Fig 4.7 – Nasal endoscopic view of a Pharaonic Period Mummy showing hole in right posterior ethmoid region (Gaafar et al 1999; 119)
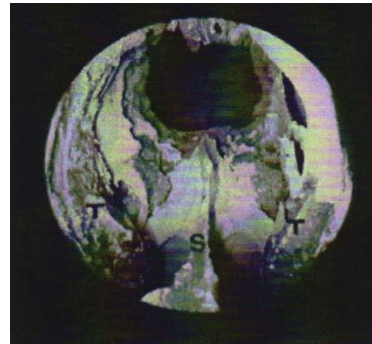
Fig 4.8 – Nasal endoscopic view of a Roman Mummy showing a large central hole communicating the nasal and cranial cavities (Gaafar et al 1999; 119)

In 49 percent of the Kellis 1 mummies, both sides of the nasal passage have been destroyed during the removal of the brain. Despite this process, in some mummies, brain material (mainly dura) remained in the cranial cavity.
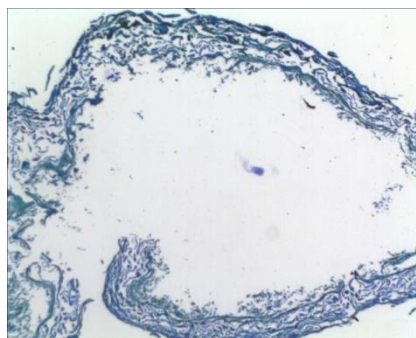
Fig 4.9 – Dura remaining in the cranial cavity after excerebration (Mummy A110)

4.1.3 – Pathologies of the Ten Case Studies

One of the main reasons for the selection of the ten case studies mummies was their lack, of near lack, of ante-mortem pathologies. Nor was there any cause of death recorded from the initial gross anatomical examinations.

Gross anatomical examination and/or imaging techniques (including radiography and computed tomography) are very good at demonstrating pathologies such as fractures, Harris growth arrest lines, tuberculosis (ten percent of tuberculosis cases result in skeletal changes), osteoporosis and

osteoarthritis. Many diseases, such as septicaemia, would not be visible on skeletal remains. Histological examination of soft tissue and bone samples can provide information on pathologies that are not visible using other techniques, including anthracosis, silicosis and pneumonia (although septicaemia would remain elusive).

Mummy Identification	Post-Mortem Pathologies	Ante-Mortem Pathologies
A1	Left transnasal craniotomy	45 ° clockwise rotation of left mandibular canine 2 dental caries
A4	Left transnasal craniotomy	Loss of 1 tooth Dental caries on 1 tooth
A5	Transnasal craniotomy (both sides	n/a
A8	Transnasal craniotomy (both sides)	Loss of 2nd left mandibular premolar tooth
A13	Transnasal craniotomy (both sides)	Osteophytosis Osteoporosis Compression of lumbar vertebrae Loss of 18 teeth Dental caries on 2 teeth
A101	Transnasal craniotomy (both sides) Fracture of the T7 vertebrae	Dental caries on 2 teeth
A102	Transnasal craniotomy (both sides)	Fistula from a dental abscess Dental caries
A108	Transnasal craniotomy (both sides)	n/a
A 126	Possible transnasal craniotomy	n/a
A129	Right transnasal craniotomy	n/a

Table 4.1 – Summary of Post- and Ante-mortem Pathologies of the Ten Case Study Mummies

4.1.3.1 – Dental Pathology

As is made clear by Table 4.1 above, the most common ante-mortem pathology suffered by the ten individuals used in this project as case studies is dental disease (six of the ten mummies have some form of dental pathology). Teeth survive very well in archaeological contexts and most of the mummies that have been examined demonstrate some form of dental disease. This type of pathology was certainly did not respect the class system of ancient Egypt. Some of the most well-known pharaohs, who ruled in the golden ages of ancient Egypt, had the most appalling dental health at the time of their death, including Ramesses the Great, his son and successor Merenptah (Nineteenth Dynasty) and Amenhotep III (Eighteenth Dynasty)(Filer 1995; 94).

Fig 4.10 – Ramesses the Great – shown as forever healthy and youthful (photo courtesy of the British Museum)

Fig 4.11 – X-ray of Ramesses the Great showing severe periodontal disease (Harris et al 1980; 328)
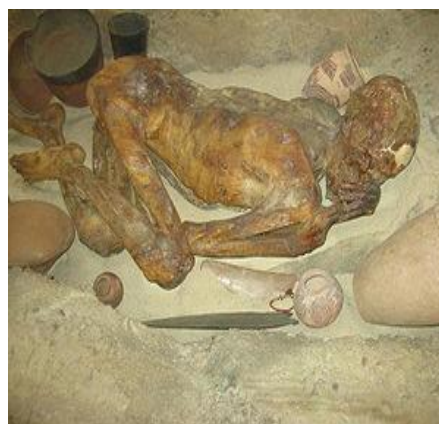
Fig 4.12 - The Predynastic body of "Ginger" had notably less dental disease than some of Egypt's greatest Pharaohs (photograph courtesy of the British Museum)

219

The ancient Egyptian diet, while appearing to be very healthy (fruit, vegetables, cereals and variety of meat), had a devastating effect on the teeth. It is believed that one of the main reasons for widespread dental disease is the presence of abrasive particles in the food, including one of the staples of the ancient Egyptian diet – bread. Whether grit made its way into the bread by deliberate means, added to the grain to assist grinding, or accidentally during any of the stages of bread production, its abrasive quality caused attrition.

Fig 4.13 – Breadmaking from the Tomb of Ti, Dynasty 5 (Donovan & McCorquodale 2004: plate 13.1)

Fig 4.14 – Bakery dated to Second Intermediate Period – Kharga Oasis (www.ancientfoods.wordpress.com)

Attrition, not itself a pathological condition, however, if severe, can lead to other serious problems. These problems can be categorised into two main forms:

1) Periodontal disease (involving bone structures, including abscess)
2) Dental caries.

Both of these conditions can be evidenced on the bodies of the ten case studies (see Table 4.1).

While dental caries occurred in throughout the history of ancient Egypt, they were less frequent during the Pharaonic Period than in later times, reaching their highest levels during the Roman period when refined carbohydrates, such as sugar, were introduced to the diet (Harris et al 1998; 61).

Caries are caused by the build up of dental plaque, a consequence of a heavy carbohydrate diet. Oral bacteria, creating an acidic salivary pH, invade the plaque. This, in turn, causes decalcification of the tooth enamel and the breakdown of the mineral matrix, resulting in cavity formation. The presence of cavities allows for further bacteria invasion. The site of this bacterial attack on

the tooth varied at different time periods, due to changes in diet. In the Predynastic Period, the majority of caries appear in the roots of the teeth, however, in later periods, interstitial caries (between the teeth) are more common, as they are today (Miller 2008; 57). Dental caries are the most common ante-mortem pathology of the Roman Period mummies examined for this project.

If the tooth decay continues into the dentine, it will then progress very quickly into the pulp chamber, where it may affect the nerves of the root, which in turn can spread into the bony socket causing a dental abscess (Miller 2008; 58).
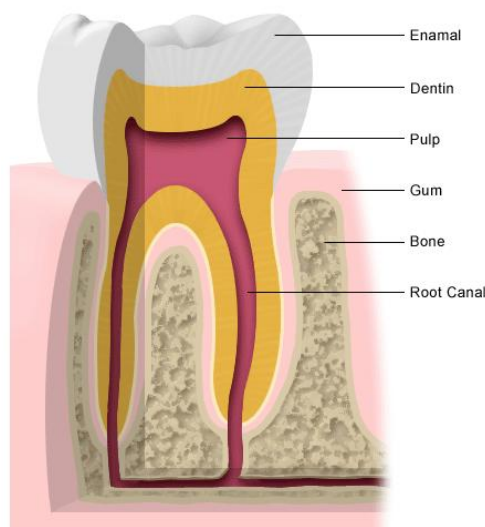
Fig 4.15 – Anatomy of a tooth
(www.lpch.org/media/images/conditions/ei_0420.gif)

None of the six case study mummies displaying evidence for oral pathology show any signs of having undergone any form of dental treatment. Despite Herodotus stating that Egypt boasted doctors specialising in diseases of the teeth (Bk 2; 85), as well as the title of 'dentist' (ibh.y) being attested as early as the Third Dynasty, physical evidence of organised dental treatment during the Pharaonic Period is lacking – in the 1960s, F F Leek examined over 3000 ancient Egyptian skulls and found no evidence of any active human interference with the course of dental disease (Leek 1967; 57).

Fig 4.16 – Panel of Hesy-Re, a Third Dynasty official, commonly regarded as the first dentist, despite the lack of physical evidence for dental treatment until the Ptolemaic Period (Leek 1967; plate x)

The Ebers Medical Papyrus has a number of remedies concerning treatment of the teeth. They are all external applications and none appear to be for carious cavities, but mainly directed at stabilising loose teeth or some disorder regarding the gums (there was no distinct word for 'gum', they were referred to either as teeth 'ibh.w' or as flesh h'.w). As the Ebers is dated no later than the New Kingdom, the lack of remedies for caries can possibly explained by the fact that at this time, they were not the main dental issue. However, periodontal disease, which would result in loose teeth, would have been common, as has been evidenced in farmer and pharaoh alike throughout Egyptian history (Leek 1967; 53).

The only other notable ante-mortem pathologies come from Mummy A13, a 55+ year old male and are all related to degenerative diseases of the vertebrae. As these are only displayed in one of the ten case study mummies, it will be discussed in the section concerning Mummy A13.

Histologically speaking, not all of the ten case study mummies were of interest. As would be expected in a modern population sample, noteworthy

pathologies were only detected in a minority of these bodies. Some mummies, such as A101, displayed quite extreme degradation in all soft tissue and/or bone samples examined and due to this no pathologies could be identified, even if present. Some mummies, for example A1, display a good level of preservation for most samples examined and no pathologies can be identified. This could mean that no pathologies were present, or they were present in areas of the body not examined as part of this project.
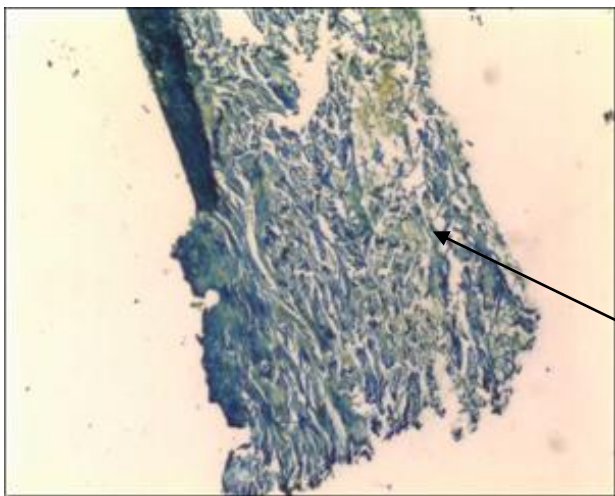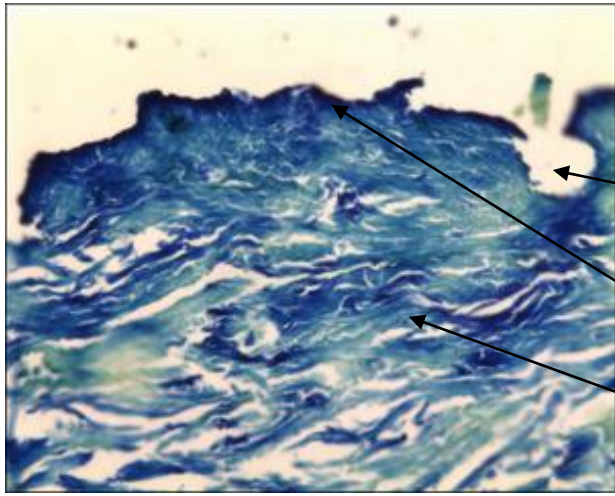
The mummies that are lacking detailed histological interest have other noteworthy features recorded at the time of autopsy or excavation. For example, Mummy A1 demonstrated good preservation of most samples with no histologically significant details; however Mummy A1 had been circumcised, as had three other of the case study bodies (Aufderheide 1993a; 7). It is this feature that will be discussed in its wider context in ancient Egyptian history, rather than just the scant histologic findings. By amassing the data, both archaeological and histological, from all ten case studies, not only will more information be available on the individual mummies, but it should also be possible to go some way in furthering the position of the Kellis 1 mummies in their historical context within the history of Egypt.

4.2 - RESULTS – MUMMY A1

4.2.1 – Skin (Ear)

Although the skin sample appears not to be in a particularly good state of preservation, a number of elements are recognisable. The epidermis is still visible as are the fat cells, with the remains of adipocere. In one area of the deep dermis, red blood cells are preserved.

No pathologies could be identified.

 Fig 4.17	<u>Stain – Toluidine Blue</u> <u>Magnification – x2.5</u> Overview of skin sample Fat cells with remaining adipocere
 Fig 4.18	<u>Stain – Toluidine Blue</u> <u>Magnification – x10</u> Hair follicle Epidermis Dermis

Fig 4.19

Stain – MSB

Magnification – x10

Z-stack

Red blood cells
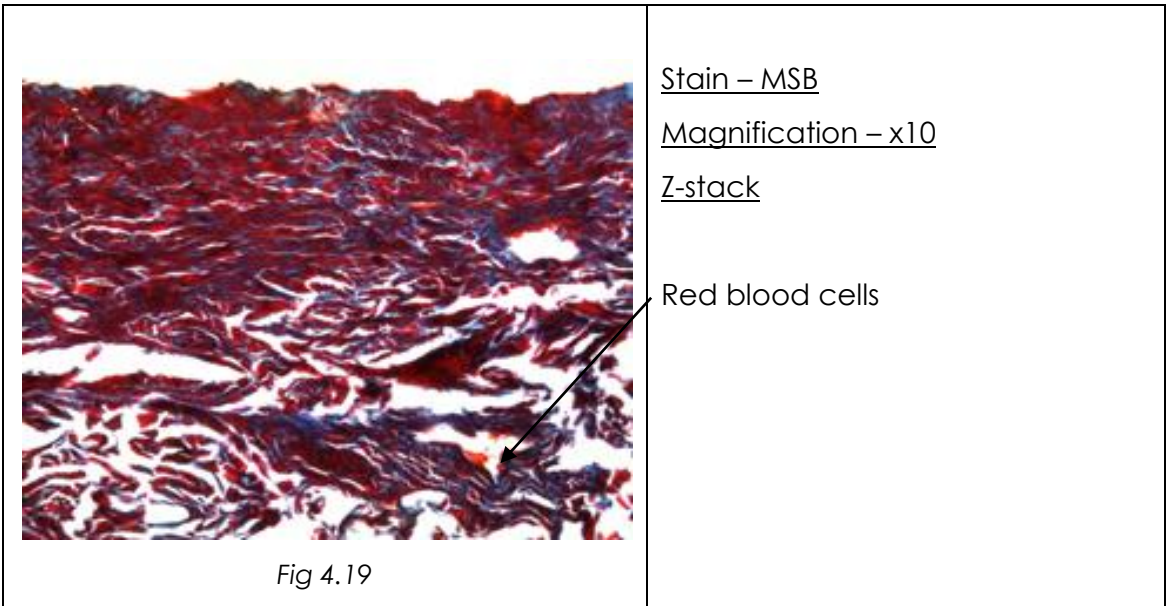
4.2.2 - Liver

The liver sample from Mummy A1 was in a fair state of preservation when compared to many other liver samples. While many areas had degraded, some elements remained and could be identified.

There was no evidence of fibrosis or any other pathologies.
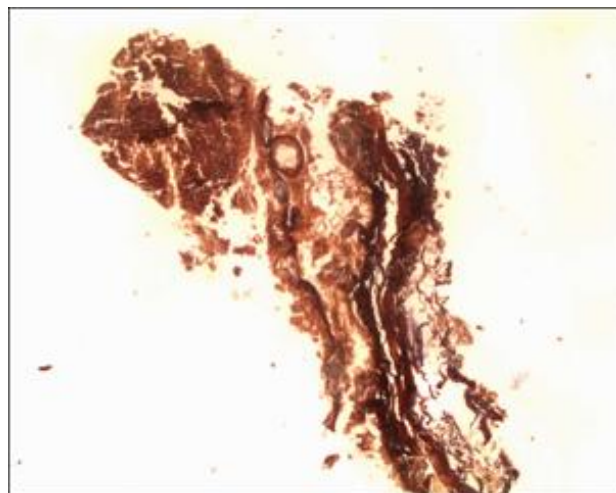
 Fig 4.20	<u>Stain – MSB</u> <u>Magnification – x1.6</u> Overview of liver sample
 Fig 4.21	<u>Stain – MSB</u> <u>Magnification – x5</u> Vessel, probably artery
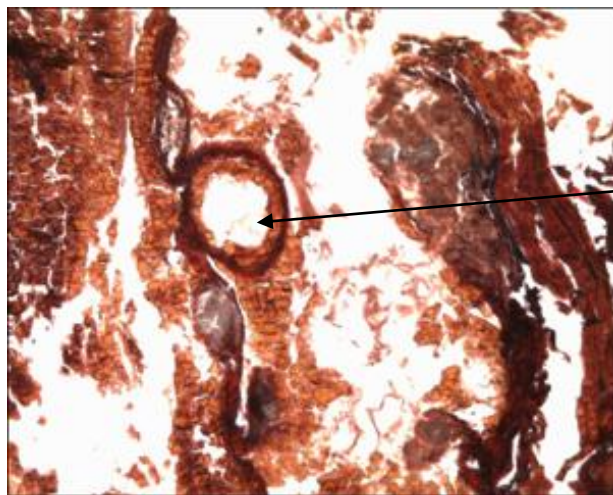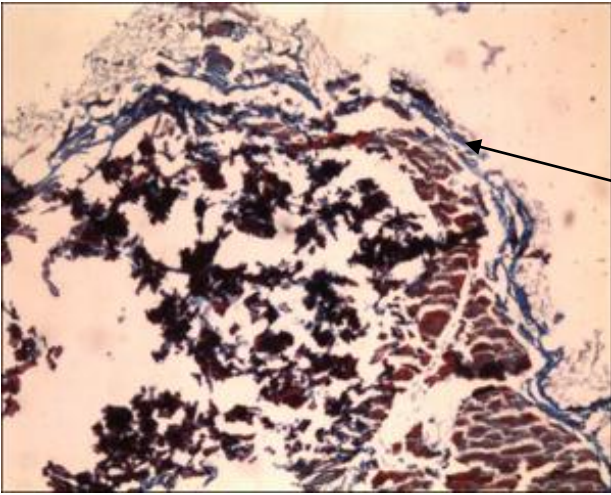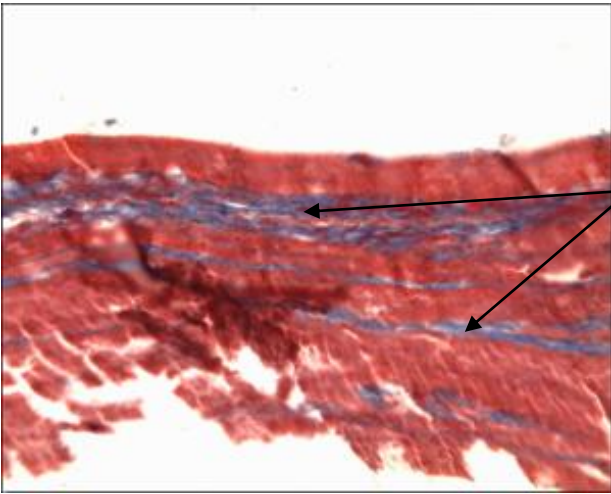
4.2.3 - Muscle

The muscle sample from Mummy A1 is not well preserved. Many muscle samples examined were of similar quality because tissues such as brain, liver and muscle are, during life, very metabolically active. This means, that after death, these organs degrade very quickly as they contain little connective tissue (resilient to post-mortem change), consisting mainly of proteins (highly susceptible to autolysis) (Zimmerman 1972; 275).

A small number of collagen fibres are still recognisable as blue lines in the sections stained with MSB. The fatty layer surrounding the muscle tissue is clearly identifiable, although the cells are empty of any adipocere.

No pathologies could be identified.

 Fig 4.22	Stain – MSB Magnification – x5 Collagen fibres
 Fig 4.23	Stain – MSB Magnification – x10 Well preserved collagen fibres
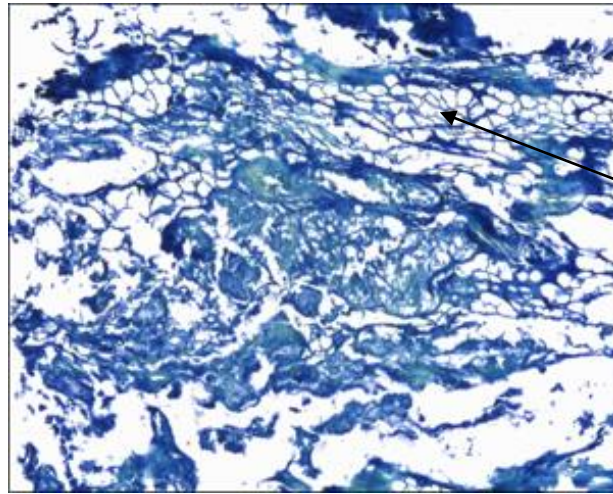
Fig 4.24

Stain – Toluidine Blue

Magnification – x5

Adipose layer composed of fat calls
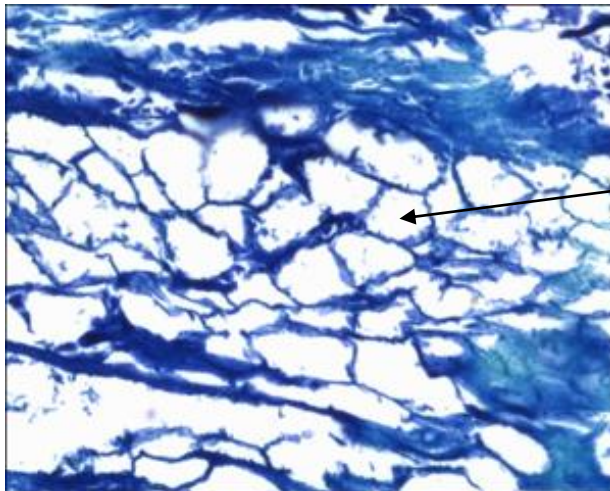
Fig 4.25

Stain – Toluidine Blue

Magnification – x20

Empty fat cells
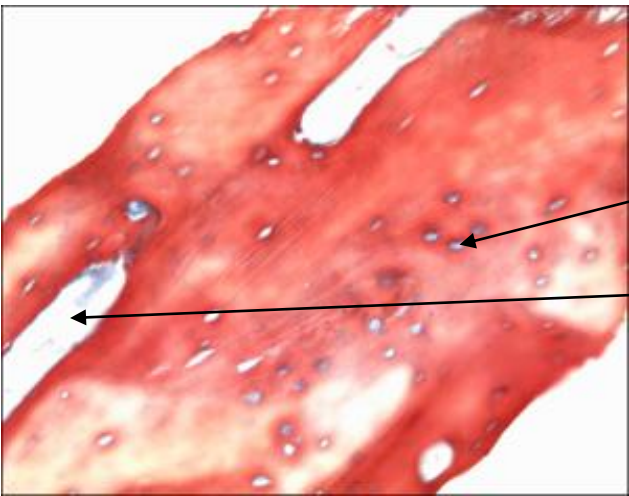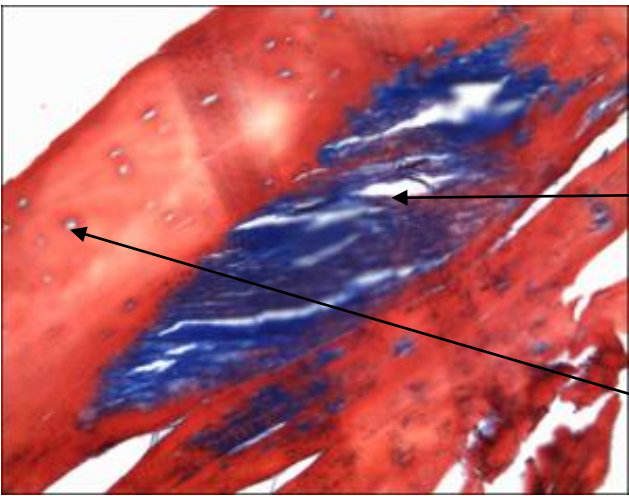
4.2.4 - Bone (Femur)

The femur sample from Mummy A1 is well preserved, although it has not been completely decalcified. The blue area in the middle of the sample shows that the sample was not left in the decalcifying solution, in this case ethylenediamine tetra-acetic acid (EDTA), for a long enough period.

Osteocytes are still clearly visible; however, no nuclei can be recognised. A Volkmann's canal is also identifiable.

The femur appears to be healthy and normal, and no pathologies could be identified.

Fig 4.26	Stain – MSB Magnification – x10 Osteocyte Volkmann's canal
Fig 4.27	Stain – MSB Magnification – x10 Area which has not been decalcified during histological processing Osteocyte

4.2.5 - Bone (Rib)
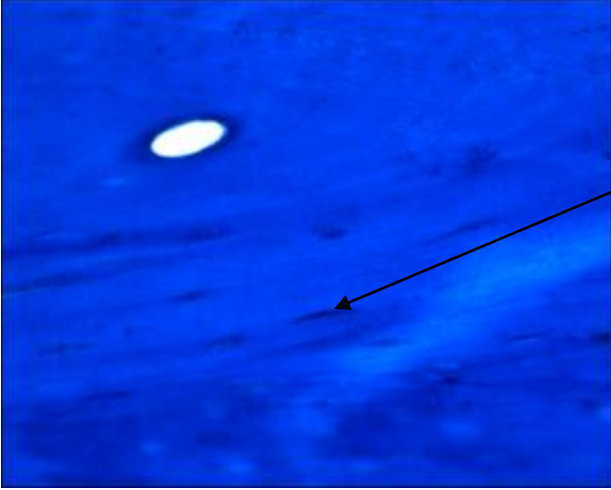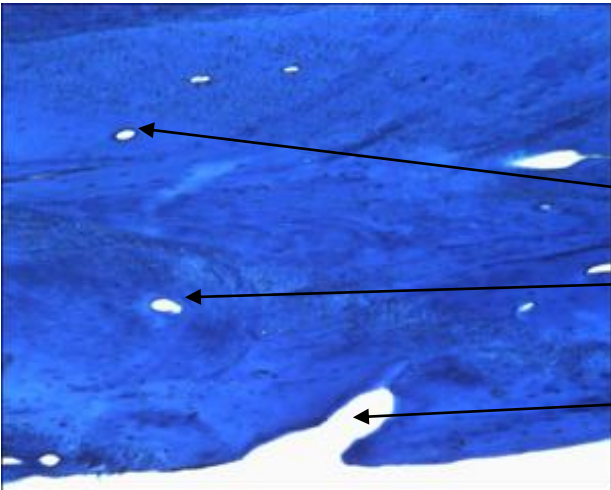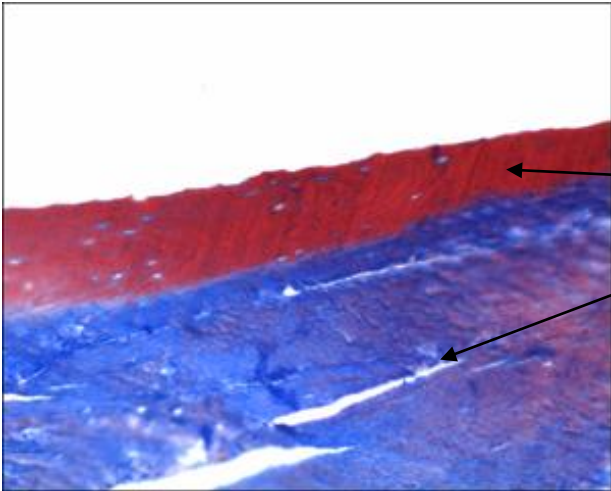
The rib sample from Mummy A1, although slightly over-stained, is extremely well preserved, mirroring what would be seen in fresh tissue. Tissue elements, both macroscopic and microscopic, are clearly visible, including osteocytes with their associated canaliculi, Volkmann's canal, and Haversian systems. The canaliculi can be seen transversely and longitudinally. Some nuclei remain within the osteocytes. A substantial bone packet can be recognised, displaying a normal rate of bone turnover.

Haversian systems or canals are a series of tubes, which surround blood vessels and nerve cells throughout the bone. Volkmann's canals (also known as perforating holes) are microscopic structures found in compact bone, usually running at obtuse angles to the Haversian systems. They contain anastomosing (connecting) vessels between the Haversian capillaries as well as carrying small arteries throughout the bone.

There is no sign of any ante-mortem pathologies or post-mortem putrefaction.

This is an example of healthy, normal compact rib bone.

	Stain – Toluidine Blue
	Magnification – x10
	Osteocyte
	Haversian system
Fig 4.28	
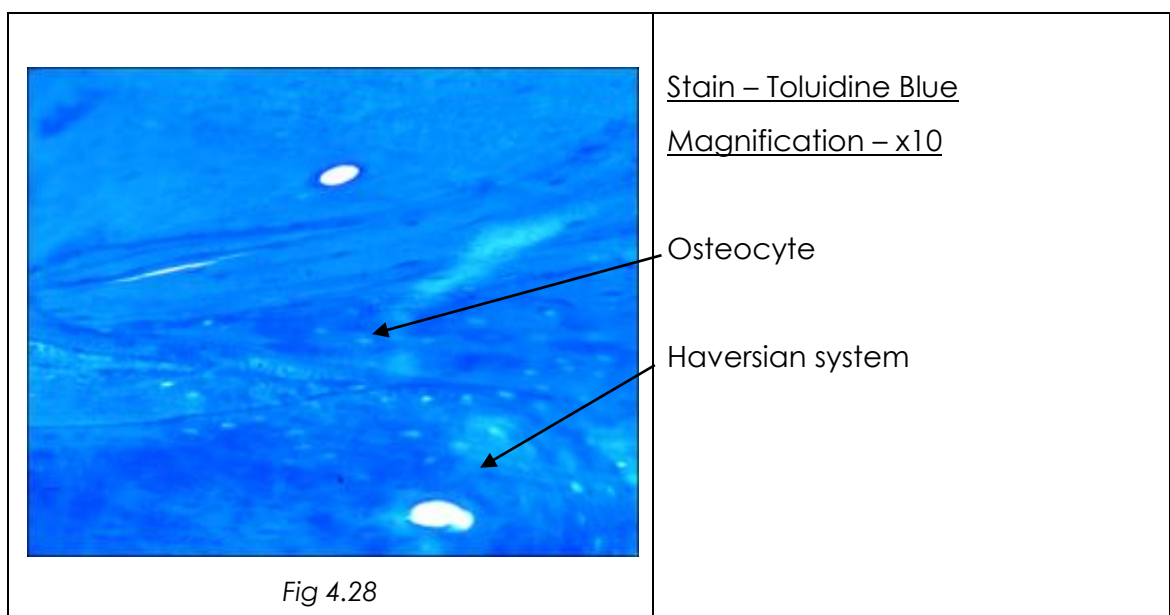
Stain – Toluidine Blue

Magnification – x20

Osteocyte nuclei

Fig 4.29

Stain – Toluidine Blue

Magnification – x5

Osteocyte

Haversian system

Volkmann's Canal

Fig 4.30

Stain – MSB

Magnification – x10

Compact bone

Spongy bone

Fig 4.31

4.3 - TO BE OR NOT TO BE – CIRCUMCISION IN ANCIENT EGYPT – DISCUSSION OF MUMMY A1

Mummy A1 was a male, aged thirteen to seventeen years at the time of death. At the time of gross anatomical examination, no cause of death could be assigned. The only pathologies found were dental caries, affecting two teeth. No pathologies could be found either as a result of the histological examination of skin, liver, muscle and bone (rib and femur). The samples all displayed good to very good states of preservation, which may be due to the mummification type (Type Four – see Chapter 1.2.5), where only a thin layer of resin had been applied to the skin. This would enable the hot, dry sand of the tomb to desiccate the body very quickly and effectively.   The body must have been buried very closely to the time of death, as the epidermal layer is still present and identifiable.

The rib sample displayed evidence that it had not been completely decalcified. This is due to not being left in the decalcifying agent for a long enough period of time, in this case ethylenediamine tetra-acetic acid (EDTA). EDTA is a chelating agent and was chosen because it is much gentler on the bone samples than the acid decalcifiers. However, this means that the samples needed to be left in the solution for a much longer period.

The mummy's sex was identified by the presence of visible external genitalia, including a circumcised penis. By the time Kellis was occupied in the Roman Period, circumcision was an already ancient practice, dating back at least to the Predynastic Era. While it appears to have been less popular as time passed, it is clear from the Kellis mummies (nine of the males were confirmed as circumcised at the time of autopsy) that it was still an important ritual for at least some members of the population.

4.3.1 – Circumcision in Ancient Egypt

Herodotus (Bk 2; 104) wrote that the Egyptians were the first of the ancient peoples to circumcise children. The practice of circumcision was to survive in Egypt for 4000 years, and unlike many practices in the hierarchical society of ancient Egypt, it was not the realm of only the nobility or priesthood (Bailey 1986; 26).

It appears from the scant pictorial evidence that the practice was the realm of priests, not doctors, which could explain the silence of the medical texts on the operation. Although, it should be noted that no text relating to priestly duties makes mentions the practice either.

There is only one possible account of the operation in the Ebers Papyrus, however, it is dependent on a rather suspect translation by B Ebbell:

Remedy for a prepuce which is cut off and blood comes out of it:

Ebbell, in the above translation, ignores the determinative of a tree, and translates the word 'prepuce'. Ebbell is now regarded as an over enthusiastic and uncritical translator and therefore most of his interpretations of the Ebers' remedies should not be taken at face value. A more correct translation by later authors, *Remedy for an acacia thorn if it is extracted and blood comes out of it,* cannot be used as evidence for circumcision in the medical papyri (Ghaliongui 1973; 8).

However despite the lack of textual evidence, that circumcision was carried out on boys in ancient Egypt is in no doubt; indeed it is likely the world's oldest recorded operation (Janssen & Janssen 2005; 76). It is believed that the act of circumcision originated in Egypt and was later adopted by the Israelites and Phoenicians (Meyer 1894; 559). The earliest artistic evidence is in the form of a slate palette, now housed in the British Museum (United Kingdom), the recto of which portrays a lion attacking his enemies. These enemies lay strewn throughout the image; naked and clearly circumcised. It is dated to the Nagada II Era (3500-3200 BCE) (see Figure 4.32 below). Here, it must be remembered that it is the enemies of Egypt (represented by the lion) that are circumcised not the Egyptians themselves (Sasson 1966; 473). This perhaps adds to Sasson's argument (1966; 476) that the concept of circumcision travelled from north to the south and not the other way around. However, from wherever it came, it is clear that circumcision was practiced in Egypt by the Predynastic Period and onto the Old Kingdom, when it was an extremely common, if not mandatory, practice.

Texts, sculptures and mummies from Egypt show that babies did not undergo the operation; not a single boy wearing the sidelock of youth hairstyle is shown circumcised, unlike the Hebrews who, from the time of their first patriarch,

circumcised male children at the age of eight days (Sasson 1966; 474). It is more likely that in ancient Egypt the act was reserved for an initiation into manhood. Mummy A1 was aged between thirteen and seventeen years so well of the age for which this operation would have been performed.

Fig 4.32 – Nagada II slate palette showing Egypt's enemies being slaughtered – all of which have clearly been circumcised (Capart 1905; pl179)

Many textual and artistic artefacts can be used to understand circumcision in ancient Egypt. On a stela from Naga ed-Deir, dated to the First Intermediate Period, a man states 'I was circumcised together with 120 men', suggesting that an entire age group took part in a single ceremony. However, as time proceeds, this becomes scarce and any texts from the Middle Kingdom onwards usually concentrate on a single boy (Janssen & Janssen 2005; 77).
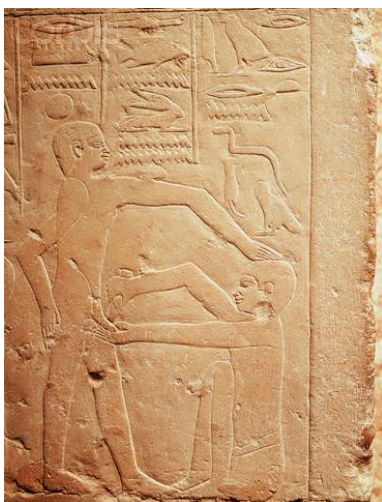
Fig 4.33 – Part of the original circumcision scene from the tomb of Ankhmahor (Donovan & McCorquodale 2004; pl 7.1)
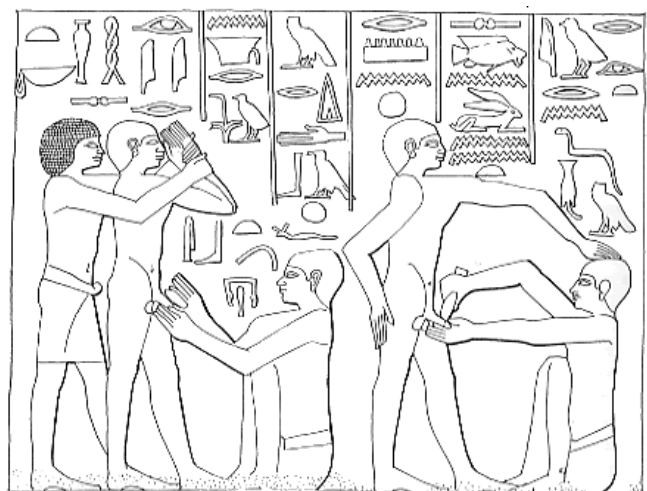
Fig 4.34 – Line drawing of the circumcision scene from the tomb of Ankhmahor (Janssen & Janssen 2005; 77)

Dated to the Old Kingdom (beginning of the Sixth Dynasty) is the famous wall scene from the tomb of Ankhmahor, believed to represent the operation of circumcision taking place (see Figures 4.33 and 4.34 above). The scene shows a ka-priest carrying out the operation on boys aged about ten to twelve years old, suggesting that this is a religious rite. The prominent position of this scene on the walls of Ankhmahor's tomb suggests that it has special significance for the tomb owner, perhaps representing a pivotal moment in either the life of Ankhmahor himself or an initiation ceremony for his sons. Spigelman (1997; 93-96) has proposed that this scene is more surgical in nature portraying a life-saving procedure, instead of a simple circumcision. He assesses that the image on the left hand side of the scene depicts an attempt to reduce a paraphimosis (a condition in which a swollen and infected prepuce retracts and cannot be returned, causing great discomfort and the possibility of gangrene). Any act that saved Ankhmahor's life or, just importantly, allowed him to father offspring, would be deemed of sufficient significance to adorn the tomb walls. Spigelman believes that this would explain why no other such scenes have been discovered in the thousands of tombs excavated (1997; 96). If the scene is as Spigelman suggests, it reflects a high level of medical understanding and practice available at a very early stage of ancient Egyptian urban life.

Fig 4.35 – New Kingdom circumcision scene
from the Temple of Mut, Karnak
(www.touregyt.net)

A similar scene of New Kingdom date can be found at the Temple of Mut at Karnak (Luxor). It is much damaged and only the lower part of the scene remains (see Fig 4.35 above). It portrays two boys being held from behind. In front of them, a man is squatting and operating on the foremost boy. From the position of the scene within the Temple of Karnak, it is probably that the boys shown are of the royal family (Janssen & Janssen 2005; 77).

Fig 4.36 – Second of three wooden statues of Meryrehashtef from the First Intermediate Period
(www.britishmuseum.org/collectionimages/AN00316/AN00316385_001_m.jpg)

Statues from the Old Kingdom also depict men and boys that have undergone this rite of circumcision. Discovered in a provincial tomb in Sedment, dated to around 2230 BCE, were three beautiful wooden statues of a man named Meryrehashtef. These statues depicted Meryrehashtef at different stages of his life from boy to man, and in all of these he has clearly been circumcised (see Figure 4.36 above).

While the famous Australian anatomist, Grafton Elliot Smith deduced from his findings in the prehistoric cemetery of Naga ed-Deir, that all adult ancient Egyptian men were circumcised, it would appear that the practice became less common as time went on. Of the New Kingdom royal mummies that have been discovered and examined by Elliot Smith, Amenhotep II, Thutmose IV and Ramesses IV and V were circumcised, however, Ahmose and Amenhotep I were not (Elliot-Smith & Dawson 2000; 131).

The reason for the act of circumcision, according to the Greek historian Herodotus, was cleanliness and purity. He claims that the Egyptians 'preferred purity to air' (Herodotus Bk 2; 104). This claim is given weight by a stela dating to the Twenty-Fifth Dynasty, which states that for local rulers from the Delta failed to gain an audience with the Pharaoh Piankh because they were

'uncircumcised and did eat fish'. A fifth ruler, Nimlot, was granted an audience because he was 'pure and did not eat fish" (Bailey 1986; 16).

Dating to the second century of the Current Era, the Papyrus Tebtunis II 292-293 states that circumcision was still a mandatory measure for priests to undergo in order to ensure their purity, even though the practice of circumcision may have waned as Egyptian history went on (Monserrat 1991; 44).

Female circumcision in ancient Egypt is far more controversial and less certain than that of their male counterparts. Today, female circumcision is carried out in strict secrecy and, if this was also the case in ancient Egypt, it could explain the lack of evidence for the practice. A single textual source from the Middle Kingdom has been used by some authors as evidence for female circumcision during the Pharaonic Era (Knight 2001; 330, Strouhal 1997; 29). This inscription on the Twelfth Dynasty sarcophagus of Sit-hedj-hotep, currently housed in the Cairo Museum (Egypt) describes a magical spell, in which a magician that is activated when he anoints himself with certain bodily substances from an uncircumcised girl and uncircumcised bald man.

> *But if a man wants to live, he should recite it (the spell) every*
> *Day, after his flesh has been rubbed with the balephd (translation unknown)*
> *of an uncircumcised girl and the flakes of skin of an uncircumcised bald*
> *man (de Buck & Gardiner 1961; 448-450).*

The idea that this text is evidence for female circumcision during the Pharaonic Period is heavily dependent on the translation of 'm' meaning 'uncircumcised'. While Strouhal (1997; 29) and Erman & Grapow (1982; 70) agree with this translation, Faulkner (1962; 42) makes no mention of it, instead translating 'm' as 'smear'.

While in the fifth century BCE, Herodotus writes of the practice of male circumcision (Bk 2; 36, 37, 104), he is silent on the idea of female circumcision in ancient Egypt. However, around 25 BCE, the Greek Geographer, Strabo, visited Egypt and Kush and claimed that one of the most zealously pursued customs was 'to raise every child that is born and circumcise the males and excise the females' (17.2.5). However, it is possible that he was commenting on practices in the Kushite region, rather than those of ancient Egypt.

While textual evidence, albeit scant, may support the theory that female circumcision was carried out in ancient Egypt, it must be noted that no female mummy, including the Kellis 1 bodies, has thus far displayed evidence of this practice.

Of the 27 male mummies from the Kellis 1 cemetery, nine were confirmed as circumcised. Within this group, the ages ranged from approximately fifteen to 50 years, matching the belief that it was seen as a rite to be taken at the end of childhood. Males under the age of eleven show no evidence of circumcision, while in the older males, it is more likely that circumcision could not be confirmed than be absent (Aufderheide et al 2003; 140). No specific age can be attached to the practice; however, most writers refer to it being carried out in the second decade of life (Strouhal 1997; 28). The fact that a third of the male mummies had been circumcised (in a further eleven, circumcision could not be confirmed or denied), confirms the observation that circumcision was not as widespread during the Greco-Roman Period as it was in earlier times (Predynastic – Old Kingdom), however, as can be witnessed, it was certainly not an uncommon practice.

Of the ten case studies, four of the eight examined male mummies were circumcised (Mummies A1, A5, A101 and A126). It is difficult to form conclusions regarding this practice relating to social status at this site, as no cultural objects (other than textiles) were associated with these bodies. According to Aufderheide et al (2003; 140), Mummies A1, A5 and A101 were spontaneously mummified while Mummy A126 had undergone artificial mummification, however, lungs, liver and intestine remained suggesting that the embalmers demonstrated little care in this procedure, or, despite the abdominal incision site, Mummy A126 was not artificially mummified and the incision was used as an entry portal for the introduction of liquid resin into the body cavities, as suggested by the autopsy report (Aufderheide 1998f; 7). If all four bodies were spontaneously mummified, hierarchy is certainly not indicated.

According to some scholars, circumcision had waned in popularity by the Roman Period, being mandatory now only for priests. While it would be a leap to suppose that all four mummies had been priests, it is certainly possible that one or two of the four had been, as Kellis had a large temple complex dedicated to the god Tutu (see Chapter 1.2.2). However, this can't be

confirmed due to the lack of information regarding the individual lives of the Kellis 1 Mummies. All that can be stated is that the population of Kellis still performed the ritual of circumcision during the early Roman Period. While limited numbers of bodies have been examined from Kellis 1, one third of the male mummies from the cache of 49 had undergone the operation, all at an age well above infancy. This figure could be higher due to the number of mummies on which circumcision could not be confirmed or denied. This suggests that circumcision, possibly maintained as a rite of passage into adolescence, still had distinct significance in the Roman town of Kellis, at least within the pagan population. Undoubtedly less popular than in earlier times but certainly not uncommon.

Mummy A1 may not have contributed much in the way of a histological nature; however, by exploring a feature of the body reported by another investigative means, it is possible to discover more about the Kellis population.

Mummy Identification Number	A1
Individual Age	13 – 17 years
Sex	Male
Current Examination Methods	Histology
Previous Examination Methods	Gross Anatomical Examination/Autopsy
Soft Tissue Preservation % (autopsy)	96
Samples Used	Scalp, Rib, Liver, Femur, Muscle, Skin (ear)
Previous Palaeopathological Findings	Dental Caries on 2 Teeth
Current Palaeopathological Findings	None Found
Cause of Death	Not Known
Mummification Type	Four

Table 4.2 – Revised Minimum Standards Case Report – Mummy A1

4.4 - RESULTS – MUMMY A4
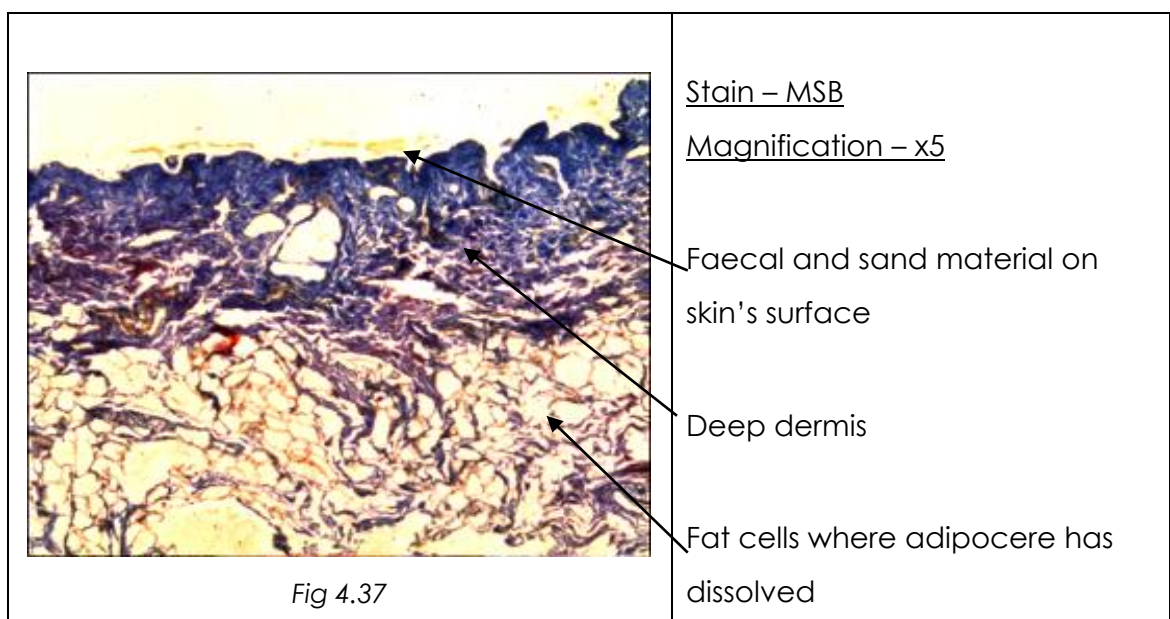
4.4.1 - Skin (Ear)

The ear skin sample from Mummy A4 displayed a good level of preservation. Although the epidermis had decomposed, the body had desiccated before any real degradation of the deeper tissue layers had taken place.

In place of the epidermis, a layer of what was assumed to be resin remained. However, after microscopic examination, it proved to be faecal matter, including starch from ingested plant products and the well-preserved remains of a parasite egg. This had adhered very firmly to the external surface of the sample suggesting that it had become attached very soon the epidermis had putrefied.

The cartilage of the ear was present and the preservation level was such that remnants of nuclei were still visible within the chondrocytes.

Part of the sample displayed adipocere, probably representing the fatty tip of the ear. In other parts of the sample displayed nerve bundles.

Despite the autopsy report stating that resin had been painted onto the skin's surface, there was no evidence of this at a microscopic level.

Fig 4.37

Stain – MSB
Magnification – x5

Faecal and sand material on skin's surface

Deep dermis
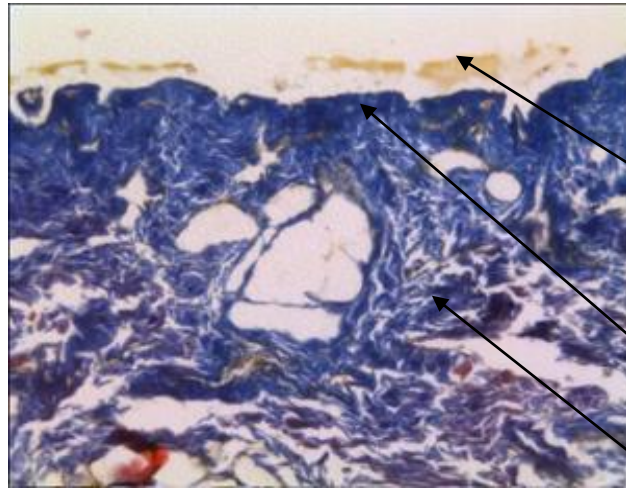
Fat cells where adipocere has dissolved

Fig 4.38

Stain – MSB

Magnification – x10

Faecal and sand layer on skin's surface

Dermis

Deep dermis
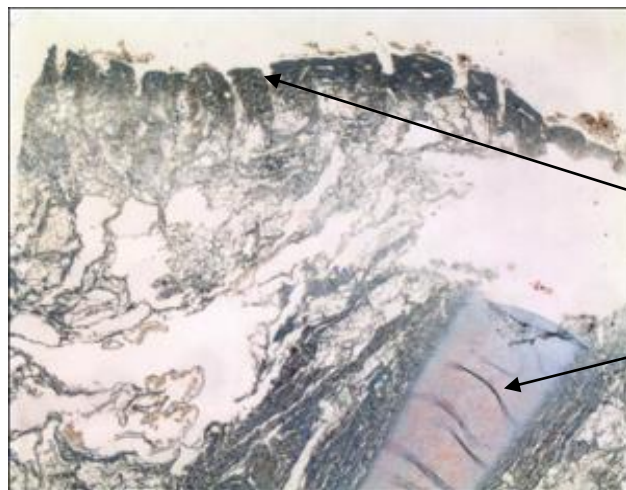
Fig 4.39

Stain – MSB

Magnification – x1.6

Pegged appearance where epidermis would have been

Ear cartilage
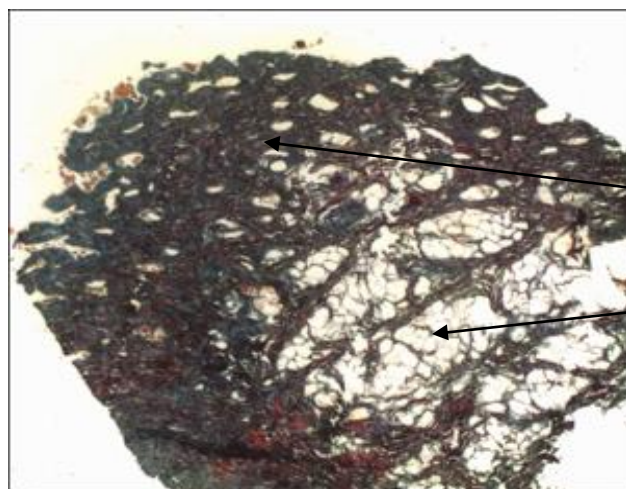
Fig 4.40

Stain – MSB

Magnification – x2.5

Deep dermis

Fat cells where adipocere has dissolved
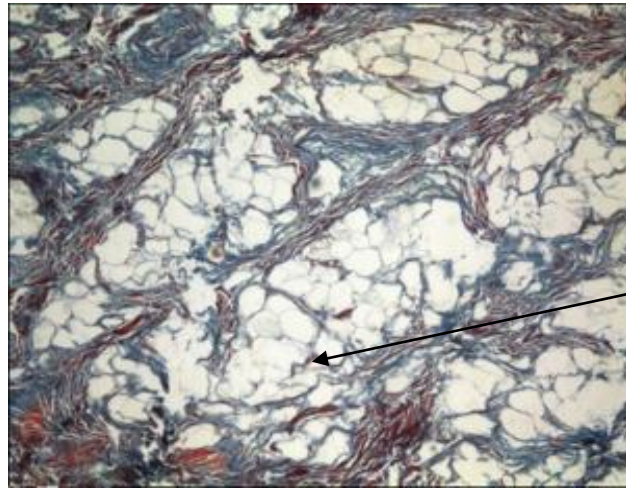
Fig 4.41

Stain – MSB

Magnification – x5

Fatty tip of the ear

Walls of fat cells where adipocere has dissolved
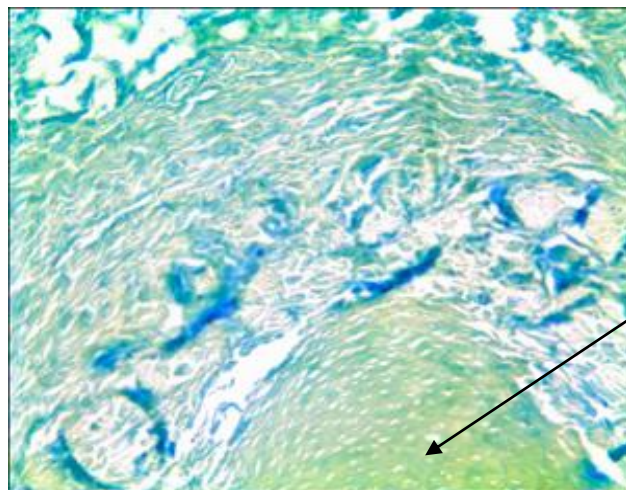
Fig 4.42

Stain – Toluidine Blue

Magnification – x10

Tip of the ear

Ear cartilage
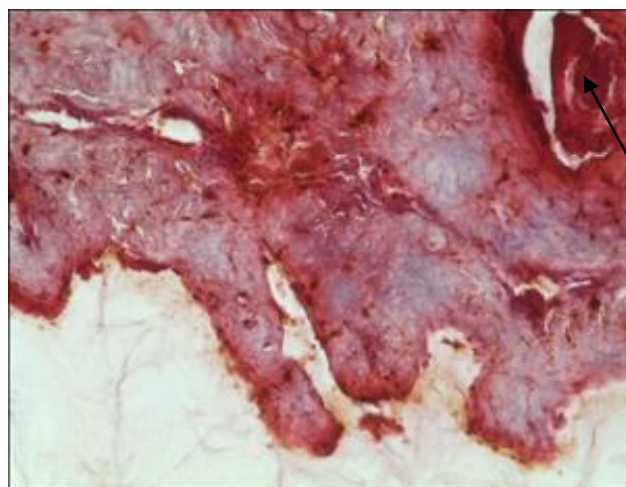
Fig 4.43

Stain – Gram

Magnification – x20

Poorly preserved hair follicle
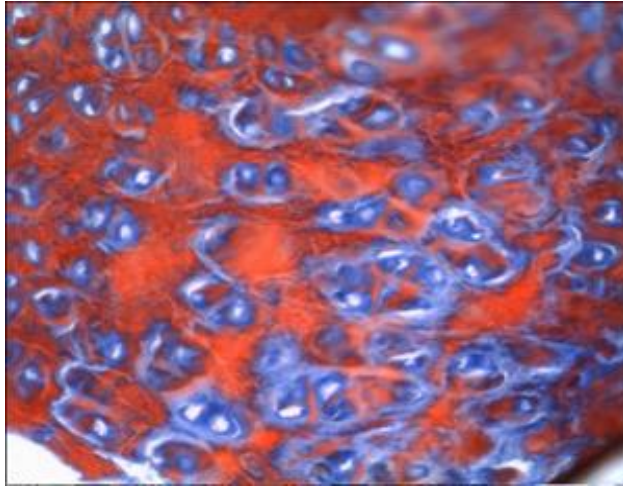
 Fig 4.44	<u>Stain – MSB</u> <u>Magnification – x20</u> Ear Cartilage
 Fig 4.45	<u>Stain – MSB</u> <u>Magnification – x40</u> Ear cartilage showing remains of nuclei within cells
 Fig 4.46	<u>Stain – Toluidine Blue</u> <u>Magnification – x20</u> Nerve bundle
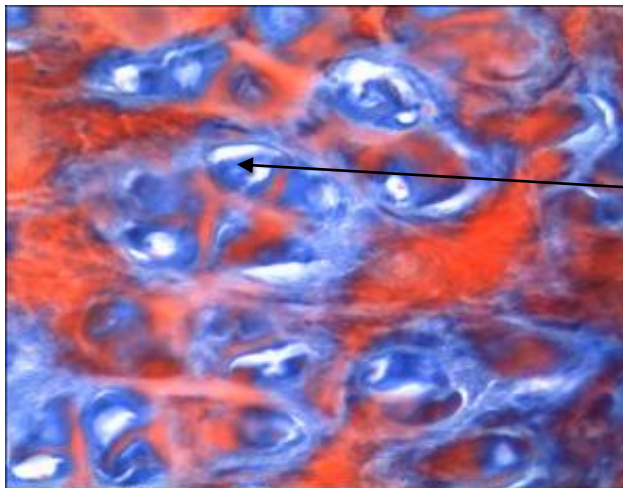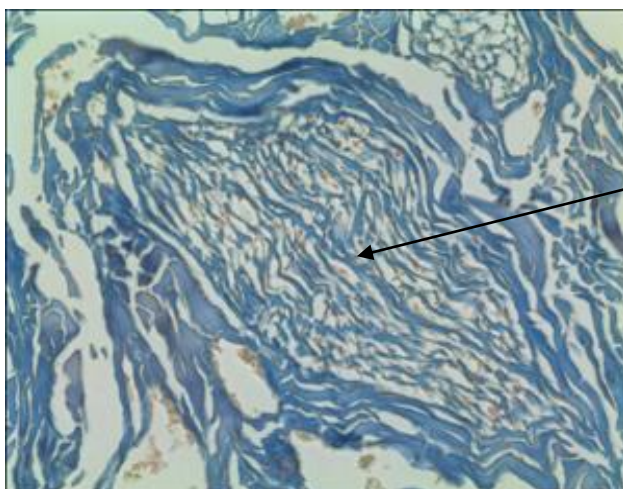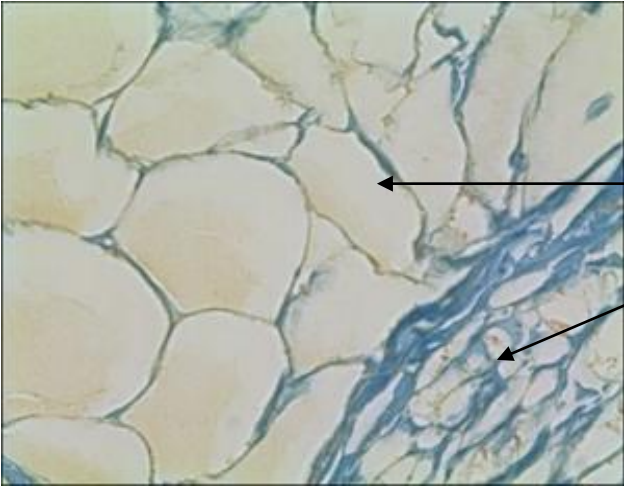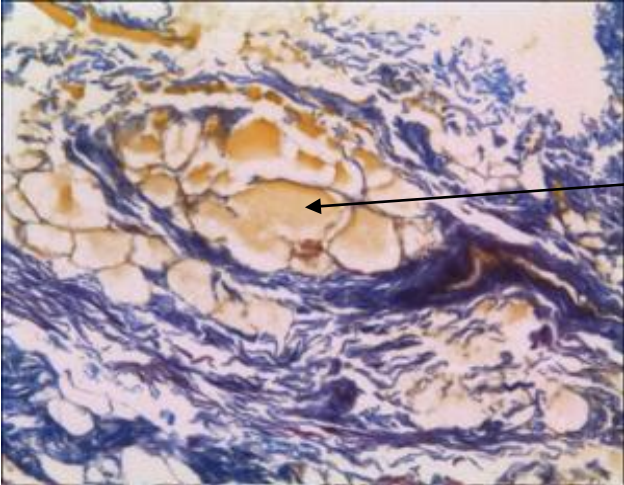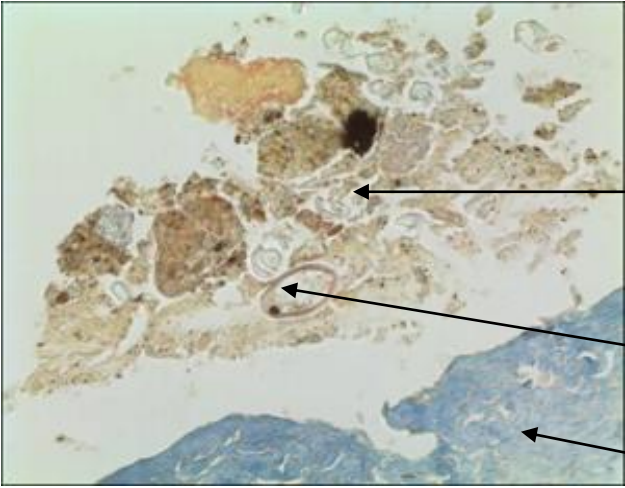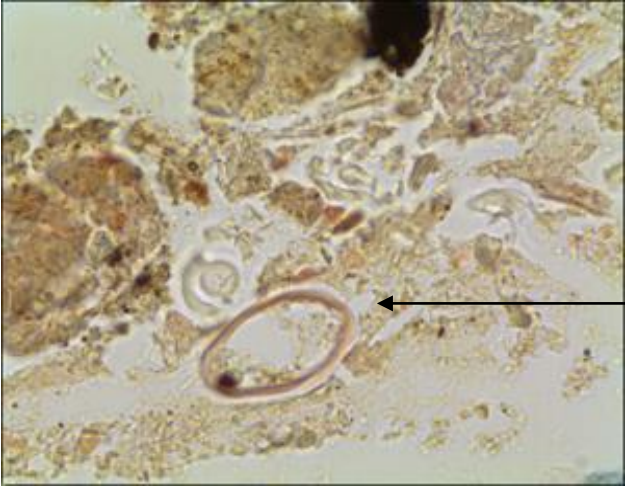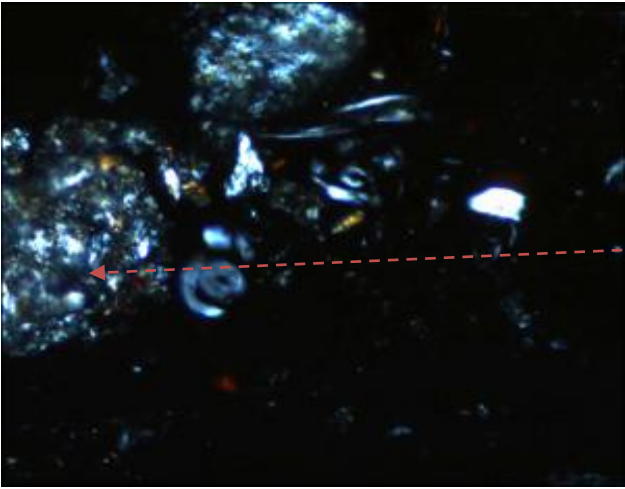
Fig 4.47

Stain – Toluidine Blue

Magnification – x40

Fat cells, empty of adipocere

Nerve bundle

Fig 4.48

Stain – MSB

Magnification – x10

Possible xanthema (fatty cyst)

Fig 4.49

Stain – MSB

Magnification – x40

Unknown pollen on the surface of the skin

Fig 4.50

Stain – MSB

Magnification – x20

Sand and faecal matter of skin's surface

Shell of Schistosome ova

Dermis

Fig 4.51

Stain – MSB

Magnification – x40

Faecal and sand layer

Schistosome ova with terminal spike

Fig 4.52

Stain – MSB

Magnification – x40

Polarised Light Microscopy

Sand layer

4.4.2 - Scalp

The sample of scalp from Mummy A4 was badly preserved, or possibly not well rehydrated and fixed.

Despite the poor preservation, hair follicles can be seen as well as a thin layer of empty fat cells.

Fig 4.53

Stain – Toluidine Blue

Magnification – x5

Badly degraded hair follicles

Fat cells
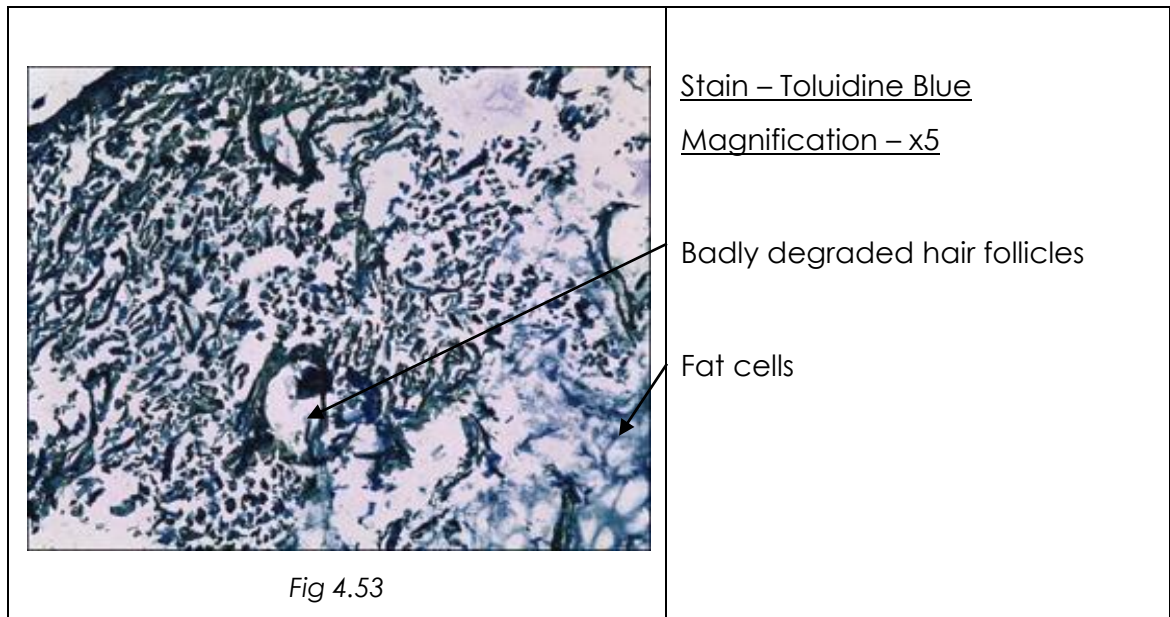
4.4.3 - Breast (Chest wall)

The sample of Mummy A4's breast tissue was badly preserved. Once stained and examined, it became clear that the sample was not breast tissue but more likely to be from the chest wall as it displayed the collagen fibres of dense connective tissue.

No pathologies could be identified.
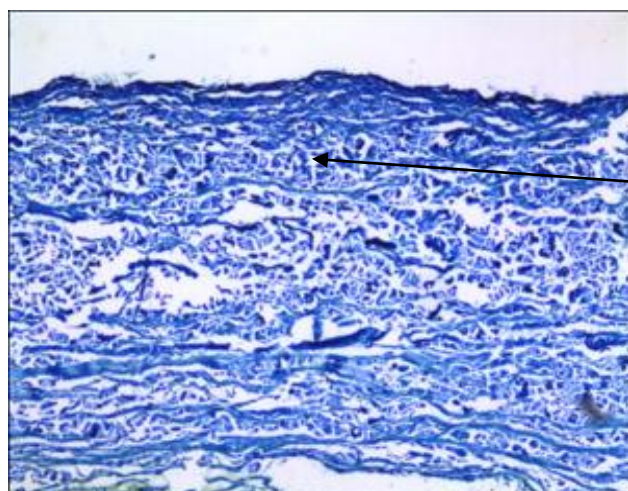
Fig 4.54	Stain – Toluidine Blue Magnification – x5 Dense connective tissue
Fig 4.55	Stain – Gram Magnification – x5 Badly degraded chest wall
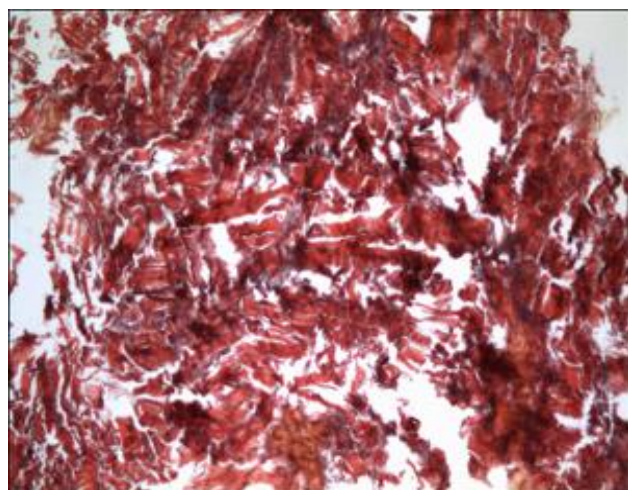
4.4.4 - Liver

The sample of liver from Mummy A4 was not well preserved, although like the lung, it did display a more than normal amount of fibrosis.

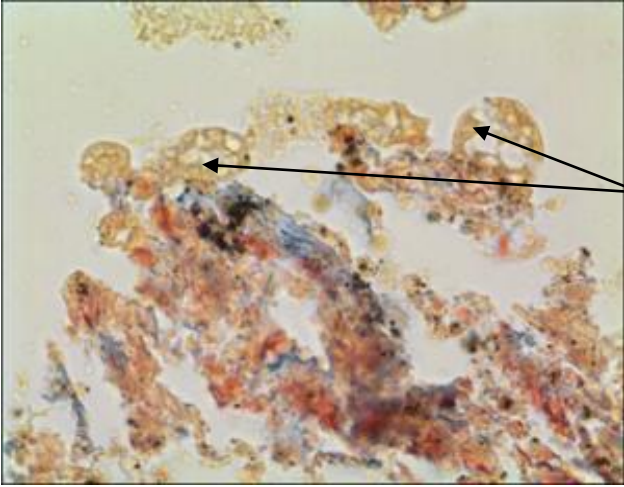There was also in evidence a biological entity, possibly some sort of worm. This entity was present during life as there had been a noticeable tissue reaction.

No other ante-mortem pathologies could be identified.
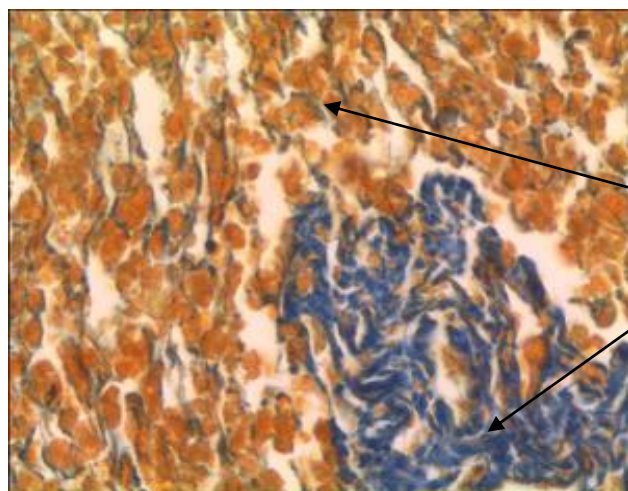
Fig 4.56	<u>Stain – MSB</u> <u>Magnification – x40</u> Reticulin fibres (blue) Fibrosis (collagen)
Fig 4.57	<u>Stain – MSB</u> <u>Magnification – x10</u> Poorly preserved liver Hepatic portal
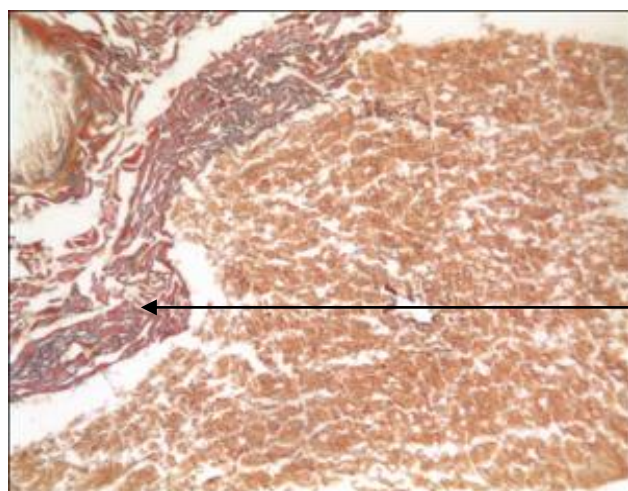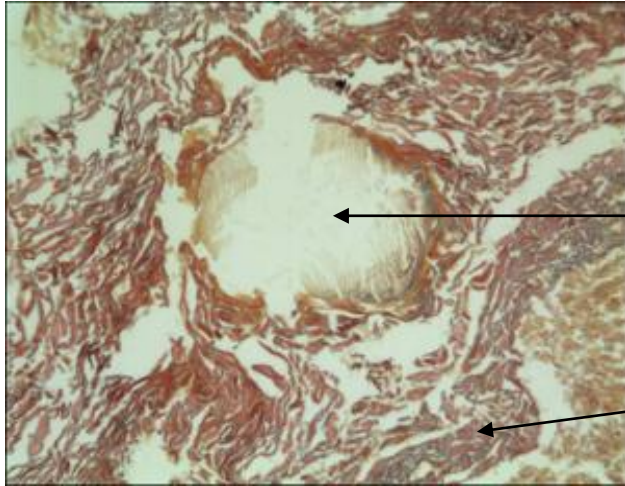
Fig 4.58

Stain – MSB

Magnification – x20

Possible parasite present during life because there has been a tissue reaction

Fibrosis

4.4.5 - Lung

The lung tissue from Mummy A4 was not well preserved, although a large quantity of soot and silica was recognisable.

The lung tissue was quite fibrotic, containing more collagen than a normal, healthy lung. Also identified was a possible mycetoma (fungus ball).

One of the lung samples comes from quite high up in the lung as evidenced by the large number of visible air sacs.
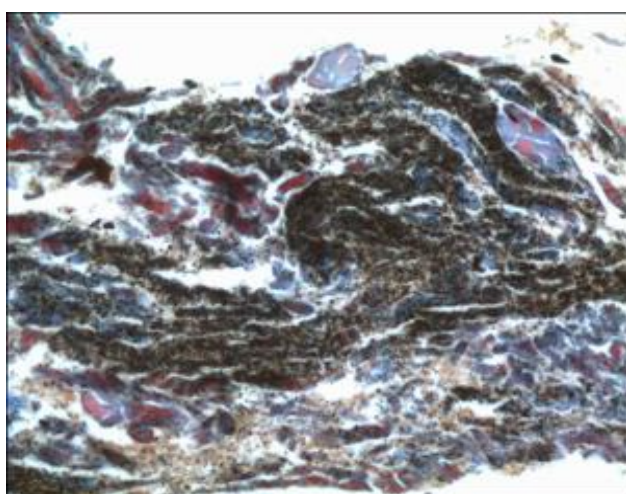
 Fig 4.59	Stain – MSB Magnification – x20 Large quantity of carbon-type pigment
 Fig 4.60	Stain – MSB Magnification – x20 Polarised light Large quantity of silica-type particles
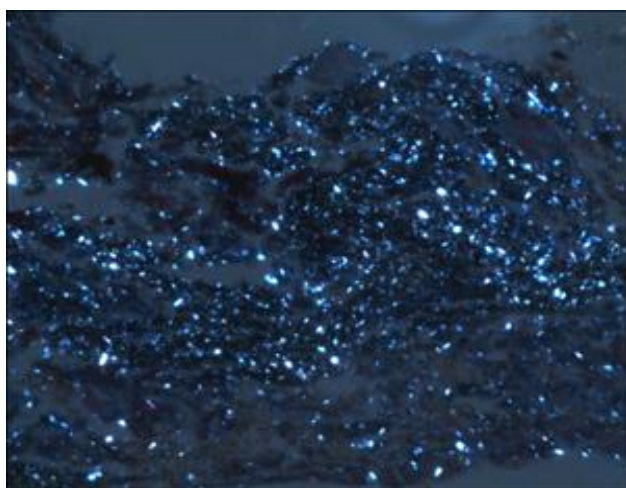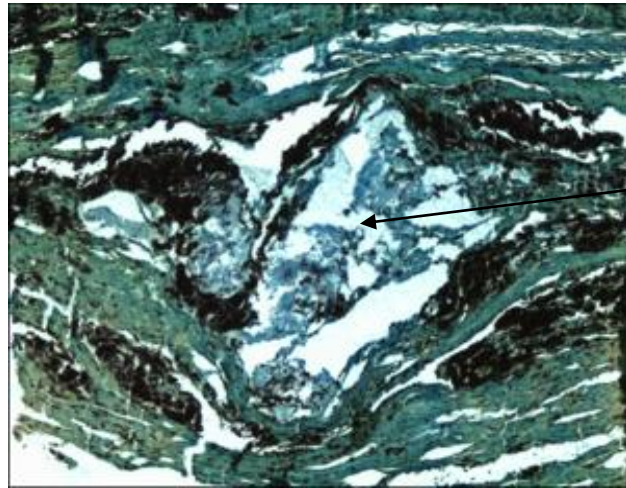
Fig 4.61

Stain – Toluidine Blue

Magnification – x5

Possible mycetoma
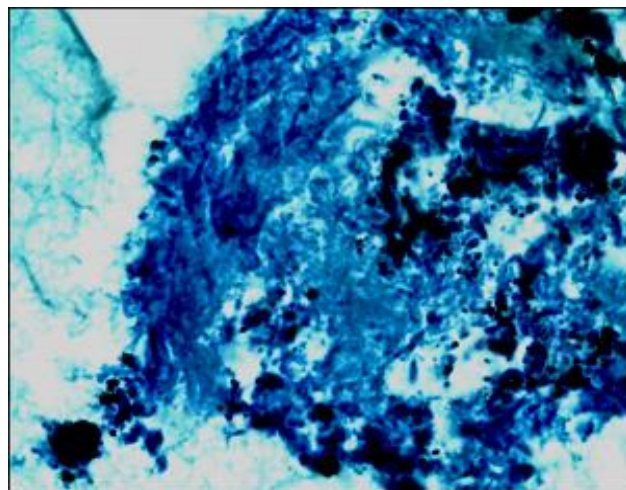
Fig 4.62

Stain – Toluidine Blue

Magnification – x40

Fungal ball (mycetoma) within which the mycelia (stems) can be seen
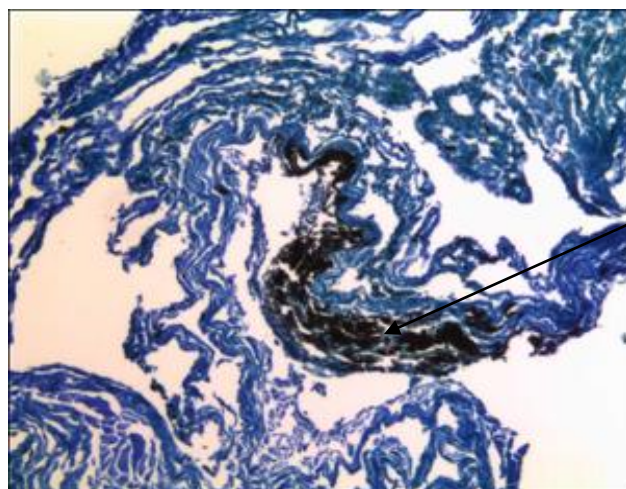
Fig 4.63

Stain – Toluidine Blue

Magnification – x10

Carbon-type particles trapped in macrophages
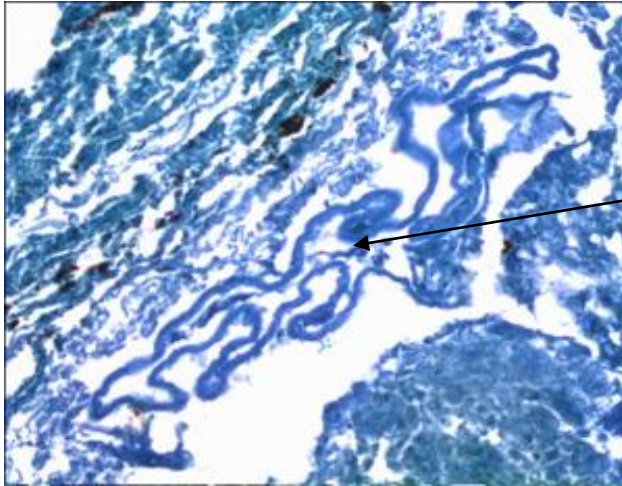
Fig 4.64

Stain – Toluidine Blue

Magnification – x20

Possible worm case (post-mortem)
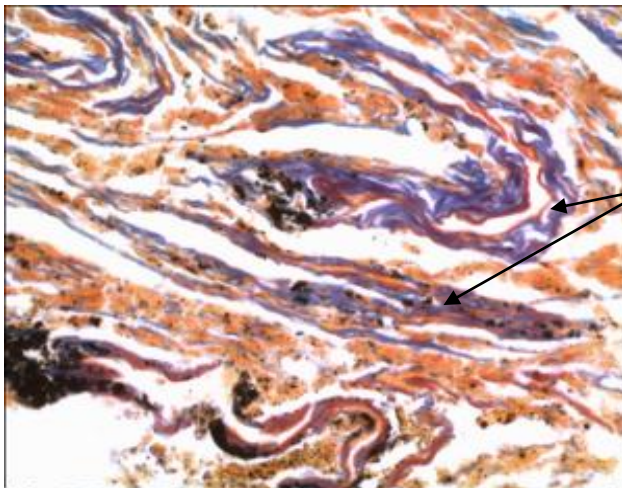
Fig 4.65

Stain – MSB

Magnification – x20

Airsacs
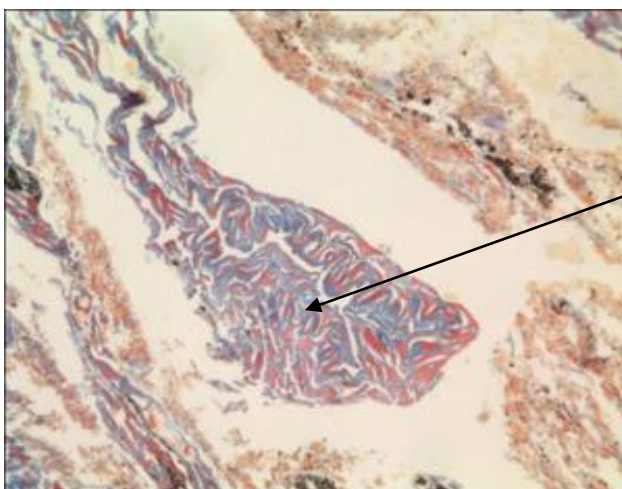
Fig 4.66

Stain – MSB

Magnification – x10

Bronchiole

4.4.6 - Muscle

The muscle sample from Mummy A4 was in a poor state of preservation; however adipocere was still visible within the cells.

There were no identifiable pathologies.
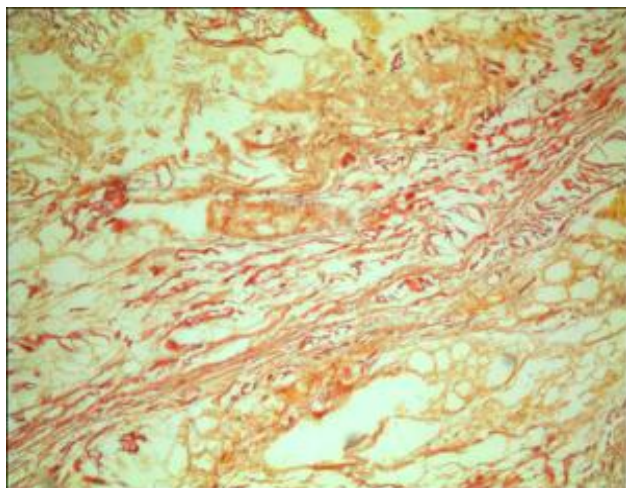
Fig 4.67	Stain – MSB Magnification – x5 Degraded muscle tissue
Fig 4.68	Stain – MSB Magnification – x20 Adipocere still visible within fat cells
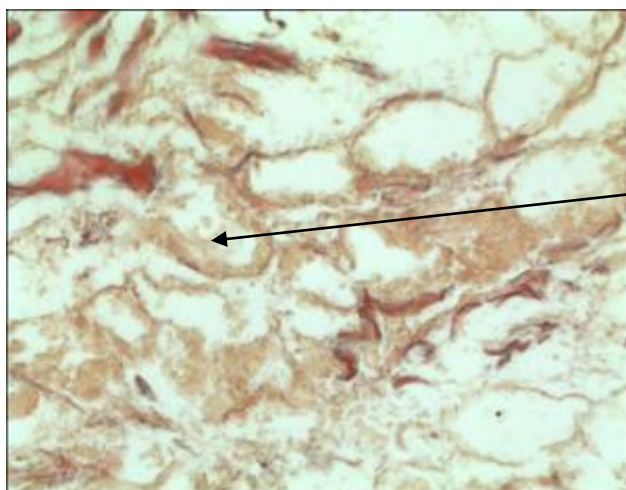
Fig 4.69

Stain – MSB

Magnification – x40

Fungi

4.4.7 - Bone (Rib) (Intercostal Ligament)

The rib sample from Mummy A4 was not bone but intercostal ligament. Due to the high content of collagen within intercostal ligament, it proved to be in a good state of preservation.

No pathologies could be identified in this sample.
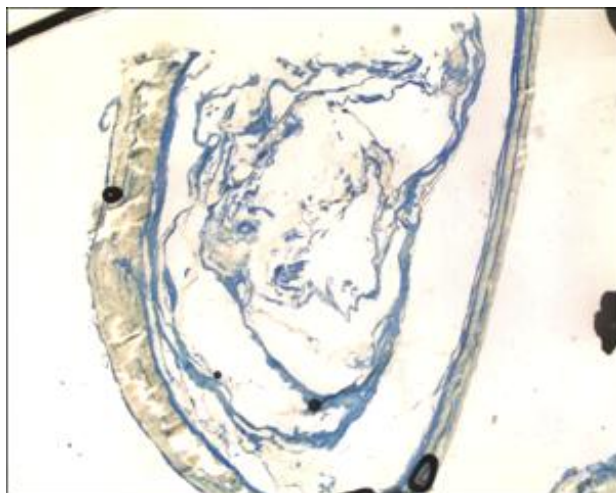
 Fig 4.70	Stain – Toluidine Blue Magnification – x1.6 Overview of rib (ligament) sample
 Fig 4.71	Stain – Toluidine Blue Magnification – x10 Z Stack Well-preserved collagen fibres within intercostal ligament
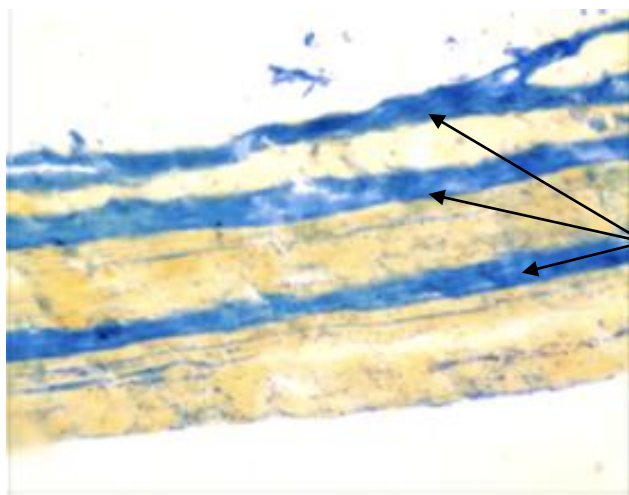
4.5 - THE NOT-SO-BEAUTIFUL BURIAL IN ROMAN EGYPT – DISCUSSION OF MUMMY A4

The soft tissue samples, with the exception of skin, from Mummy A4 were not well preserved, however some macro and microscopic elements could be identified.

The lung tissue, while quite degraded, demonstrated quite a large quantity of both carbon- and silica-type particles. A4 was a female of an estimated age of only twenty to 22 years at time of death and the amount of pigment in her lungs appears to be a bit more than would be expected for someone of this age. However, as most of the carbon pigment in the lungs of the ancient Egyptians has been attributed to indoor hearths, it is possible A4 had domestic duties that kept her mostly inside in close proximity to these smoky fires.   There were the remains of a worm case within the lung tissue, most likely a post-mortem addition as there has been no tissue reaction. However, there appeared to be some tissue reaction around what could have been a fungal infection. Fungal infections in the lungs cause pulmonary aspergilloma, formed when the fungus *apsergillus* grows in a clump in a lung cavity, which was previously damaged due to illness, or invades previously healthy tissue and forms an abscess. The person affected may have no symptoms (especially early on), as the disease progresses symptoms include weight loss, chronic cough, feeling rundown and tired. Coughing of blood (haemoptysis) can occur in up to 50-80% of affected people (Cannon 2008; 204-205).

Of the approximately 100 000 species, relatively few fungi have become adapted to living as parasites of human (or even mammalian) hosts, the most common of these being superficial or cutaneous mycoses, which are annoying but not life threatening. Serious fungal infections are rare among people with healthy immune systems; the *Aspergillus* species is one of these rare forms, primarily affecting the lungs. Aspergillus is a group of molds that are found in inorganic matter, transmission of fungal spores to human host is by inhalation (Sherwood-Pike 2008; 1053).

Further work (specific staining, aDNA) would have to be undertaken before this diagnosis for the fungal body in the lung of Mummy A4 could be confirmed.

The muscle and liver samples were only just identifiable as such due to degradation. The breast tissue sample was also in a bad state of preservation; however, it was clear that it was more likely to be part of the chest wall, rather than breast tissue, due to the thick collagenous content.

By contrast, the skin sample was well preserved. The epidermis was absent; there were no signs of Mummy A4 being wrapped (Cartmell 1993; 2) so the absence of the epidermis, instead of being removed when unwrapped, is likely to be from decomposition before being placed within the hot sand of the tomb. As the rest of the skin sample is in a very good state of preservation, the body had been allowed to decompose for only a short time period. Most of the soft tissues from Mummy A4 that were badly preserved were highly metabolically active during life, and even this short period of time before burial within the tomb may have meant that autolysis had started to take hold.

On the surface of the skin where the epidermis had been, a layer of debris had adhered very firmly to the dermis. At first appearance, it was thought to be a coating of painted resin, as had been noted in the autopsy report (Cartmell 1993; 7), however, under polarised light microscopy (plant material) and higher magnification (parasite ovum), it became clear that this was faecal matter. It is likely this material became attached to the ear of Mummy A4 when the body was placed in the tomb, which had faecal matter within it, alternatively, the body could have been stored somewhere where there was faecal matter present, especially if the body was stored with others, waiting to be transported to the tomb. At death, often the bowels evacuate and if Mummy A4 was with other newly deceased bodies, transfer would be likely. The ancient Egyptians would like us believe that the process of moving into the Afterlife was flawless and the stylised and idealised images they present to us belie the reality to that was. The mummification process was not neat, and with the hot weather, decomposition began almost immediately after death. Concepts of sanitation and hygiene were not properly understood or of great importance. And these factors combined meant that the burial of the dead was rarely a clean process.

The parasite egg had the remains of a terminal spike, only just visible. The shape, size and presence of the terminal spike strongly suggests that it *Scistosome haematobium*. This means that to whomever the faecal matter

belonged suffered from the parasitic disease schistosomiasis. It is impossible to know how heavy the parasitic load for this individual was with a sample in this context; however, schistosome ova are a relatively common finding in ancient Egyptian remains. The implications of such findings in the Kellis mummies will be discussed further in Chapter 4.7.

Research on ancient Egyptian mummification over the different periods of Egyptian history has been undertaken for the last 100 years, and a repetition here of such a large corpus of work would be of little use. Instead, the section below will attempt to give a brief comparison of the mummification and burial methods of the Kellis 1 mummies (both spontaneous and artificial) with the descriptions in the above-mentioned research, especially regarding the some of the histological information that is now available. An in-depth analysis is not possible due to the state of the Kellis 1 tombs; the few cultural objects that have been excavated are rarely related to an individual mummy and such artefacts as amulets are missing, as in any textual information. All bodies from the Kellis 1 Cemetery had been looted in antiquity.

4.5.1 – Mummification and Burial

In prehistory, like most Neolithic peoples, the Egyptians were content to bury their dead directly into the hot, dry sand. If the bodies remained above the water table, in shallow graves, the desert sand would desiccate them quickly and thoroughly, leaving naturally mummified bodies that were well preserved. This method of burial remained popular and widespread for the poorer classes, as can be evidenced by many of the Kellis 1 mummies, until the introduction of Islam in 641 CE (Ghalioungui 1973; 160).

The reason for the introduction of artificial mummification (such as Types Six and Seven from the Kellis 1 cemetery) is still not entirely understood. It is assumed that as society became more hierarchial and/or burial customs became more complex, burial and tomb developments occurred in such a way that they deceased body no longer came into direct contact to the preserving qualities of the hot desert sand. It is also possible that the bodies buried in the sands were subject to scavenger animals such as the jackal, and artificial mummification is the result of steps taken to minimise this problem (David 2008; 12).

*Fig 4.72 – In the earliest times, bodies had direct
contact with the desert sand
(http://egyptologyscribbles.files.wordpress.com)*

*Fig 4.73 – Burial development
started with the bodies being
placed in containers like boxes
David 1999; 151)*

*Fig 4.74 – Tomb development in the Predynastic Period also
Deprived the body of contact with the desiccating sand
(http://egyptologyscribbles.com/2011/02/06/burial-customs-in-predynastic-egypt/)*

Now that the desert sand was no longer able to desiccate the bodies, new techniques had to be developed in order to retain the deceased in as lifelike form as possible. These techniques included:

- The application of resin (introduced - Predynastic Period)
- Linen wrapping of the bodies (introduced – Predynastic Period)
- Desiccation of the body with natron salt (introduced – Old Kingdom)
- Visceral organ removal (introduced – Old Kingdom)
- Brain removal (introduced – Middle Kingdom)
- Internal and external application of fragrant oils (introduced – New Kingdom)
- Subcutaneous packing (stuffing inserted under the skin of the legs, arms, face, neck) (introduced – Third Intermediate Period)

- Use of artificial eyes, false hair and painting of faces (red for men, yellow for women) (introduced – Third Intermediate Period) (David 2008; 13-16).

The cemetery has been dated to the end of the Ptolemaic to early Roman Period based on the objects found within the tombs so the mummified bodies within the Kellis 1 are at the end of over 3000 years of mummification.. Radiocarbon dates proved unreliable due to the application of resin-bitumen mixture onto the bodies, giving dates much earlier than expected (Aufderheide et al 2004a; 91-92).

The origin of the Ptolemaic Period occurred with the conquest of Egypt by Alexander the Great in 330 BCE. The new Greek-Macedonian immigrants played a dominant role in the administration of the country, however, Egyptian religious and cultural traditions (including mummification) remained active and many of the new settlers adopted the Egyptian customs. The Roman conquest and occupation led to far more profound changes to the economy and society but again, there was little decline in the established religion or funerary practices until the third century CE. Many of the innovations that aided the preservation of the soft tissues during the Dynastic Era had already been discarded or forgotten. While technical progress was limited, mummification was now extended to the whole of society. It was a time of both demographic growth and an increase in the number of mummies. The great number of mummies from this period that survive today is down to the sheer volume produced, as well as being less ancient than mummies from the Dynastic Era (Dunand & Lichtenberg 2006; 72).

For the poorer members of society use of the simplest methods were employed in the mummification process. The most expensive treatments, however, were still available. In the Kellis 1 Cemetery, Aufderheide et al (2003; 139) recorded eighteen of the 49 mummies to have had this high-class treatment, however, it should be noted that some of the 'artificially' mummified bodies are questionable (see Chapter 4.1.2). Six of these mummies have visceral organs remaining. Of the ten case studies examined in this project, only two were artificially mummified (A126 and A129). The soft tissues from these mummies were not well preserved (the bone samples were in a fair state of preservation), which may mean that there was a time delay between death and the mummification process, which allowed the process of decomposition (by

autolysis and putrefaction) to commence. Many of the mummies show signs of hasty treatment, and at the bottom of the quality scale, there are some mummies, which once unwrapped prove to be no more than a jumble of mismatched bones.

A specific practice of this time was to guild the body with gold leaf. While none of the mummies examined for this project displayed evidence of this, two mummies from the Cemetery (tomb 5) had the remains of gold foil applied directly onto the skin of the hands, arms and face (Birrell 1999; 35). The gilding has a religious significance as gold was referred to as the flesh of the gods in the Embalming Ritual, still used in the Roman Period. Mummification in the Graeco-Roman Period is often describes as more a social and commercial enterprise than a religious one (David 2000; 374), however, it is clear from this innovation that the religious element was still important during the later periods, at least for those individuals that could afford it. In a cemetery in the neighbouring oasis of Kharga, one Roman Period cemetery (Ain Labakha) had twelve mummies (adults and children) out of the 70 excavated bearing traces of gold leaf (Dunand & Lichtenberg 2006: 78).

The position of the Kellis 1 mummies does not vary from the usual Graeco-Roman arrangement; arms and legs were extended, with hands usually placed on the outside of the thighs, sometimes over the genital area. As all the tombs in the Kellis 1 Cemetery had been looted, some bodies were prone instead of supine.

The use of amulets decreases in the Graeco-Roman Period and the most recent excavations of the cemeteries from this time, such as the Kellis 1, have failed to find any, although the complete disappearance due to looting cannot be ruled out as many examples of Graeco-Roman funerary amulets are on display in museums, many from looted tombs (Dunand & Lichtenberg 2006; 80).

Cartonnage was used widely in the Graeco-Roman Period and evidence of this has been found in the Kellis 1 tombs, with scenes from the traditional Egyptian funerary context.

The dissectors at autopsy suggested that resin had been applied to the Kellis 1 mummies sometime after desiccation had taken place (Aufderheide 2003;

149), however the over-enthusiastic use of resin, on the skin's surface and poured into the body cavities is a feature of the Graeco-Roman mummification practice (David 2000; 374). Each of the ten case study mummies was reported, at the time of autopsy, to have a layer of resin painted onto the skin. However, during the course of the histological examination, no evidence of resin was identified on the skin or any other tissue sample. The reason for this is unknown. Only one mummy sample (A106) used for comparative purposes had any evidence of resin. The coprolite samples from this mummy consisted of both coprolite and resin, but these were in no part mixed together.
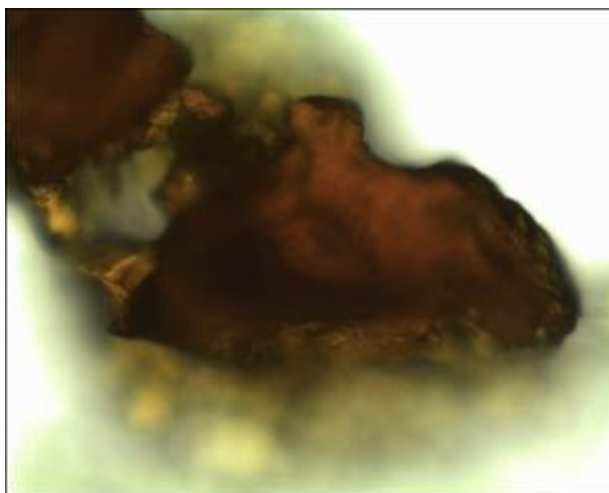
Fig 4.75 – Resin in a coprolite sample – Mummy A106

The preservation of the samples from the ten cases studies varied and do not seem to suggest any relation to mummification method. After histological examination, it was possible to suggest whether there had been a delay between death and burial or mummification by assessing the preservation state of organs such as the liver and lung. The liver very quickly decomposes if the autolysis and putrefaction processes are not halted very quickly (by desiccation) after death and lungs usually desiccate quite swiftly so by examining the state of these two organs, an indication of the length of delay is possible. However, in some cases, preservation was mostly due to the diseased state of the organ (for example, the liver in A5, the heart in A108 and the lungs in A102) and no information relating to death and burial delays can be made. It is possible were no permanent embalmers in Kellis, and the delay between death and mummification for artificial mummies could be explained by the wait for the embalmers to arrive from another town.

Eight skin samples were examined, on which three had the epidermis preserved. Mummies A1 and A5 displayed no evidence of textile wrappings, and none of the Kellis mummies had been subjected to natron desiccation so it would seem that these two mummies had been very quickly desiccated in the hot dry tomb sand, which left the epidermis in situ (Currie, 2009; 234). The other samples from these mummies were of fair to very good states of preservation so rapid drying of the corpse seems likely. Only fragmented remains of wrappings remained on Mummy A102 and it is possible that textiles were applied to the body at some point after initial desiccation.

Poor preservation level of the bodies in the Kellis 1 Cemetery is not down to mummification practices alone; as stated above, all tombs within the Cemetery had been thoroughly looted and bodies disarticulated and even destroyed as the robbers searched for anything of value that may have been placed on them. These intrusions most likely occurred soon after the tombs had been sealed. This is, of course, not unique to Kellis, even the greatest of pharaohs could not escape the greed of the tomb robbers who had inside knowledge of what was buried with whom; many mummies have been lost because of this action (Peet 1925: 38).

The state in which the excavators found the Kellis 1 mummies does not allow for assessments to be made about social status in Kellis. The tombs are simple, as was usual in the Graeco-Roman Period, the tomb contents mostly displaced and the bodies in much disarray. Histologically speaking, preservation levels do not follow that the most expensively mummified bodies (A126 and A129) are the best preserved; preservation appears to be more dependent on how quickly the bodies were buried in the sand. It is not also possible to confirm the care, or lack thereof, with which the embalmers carried out their profession, although the many visceral organs remaining in situ within the artificially mummies suggest that the highest standards of mummification were not achieved here. However, it is also possible that some of the artificial mummies have been wrongly identified at the time of autopsy and should belong to the category of spontaneous mummification. Of the eighteen mummies recorded as artificial, only seven had an abdominal evisceration incision, and even these could have been mistaken for resin portals, which are not uncommon within the Kellis 1 cache (Aufderheide et al 2003; 140).

The faecal material on the ear of Mummy A4 suggests that either the tomb was unclean or bodies, were for a period of time, placed on top or close to each other and waste material was transferred. The state of Mummy A4 confirms that not everyone enjoyed a beautiful burial in Roman Egypt, or probably at any time for that matter.
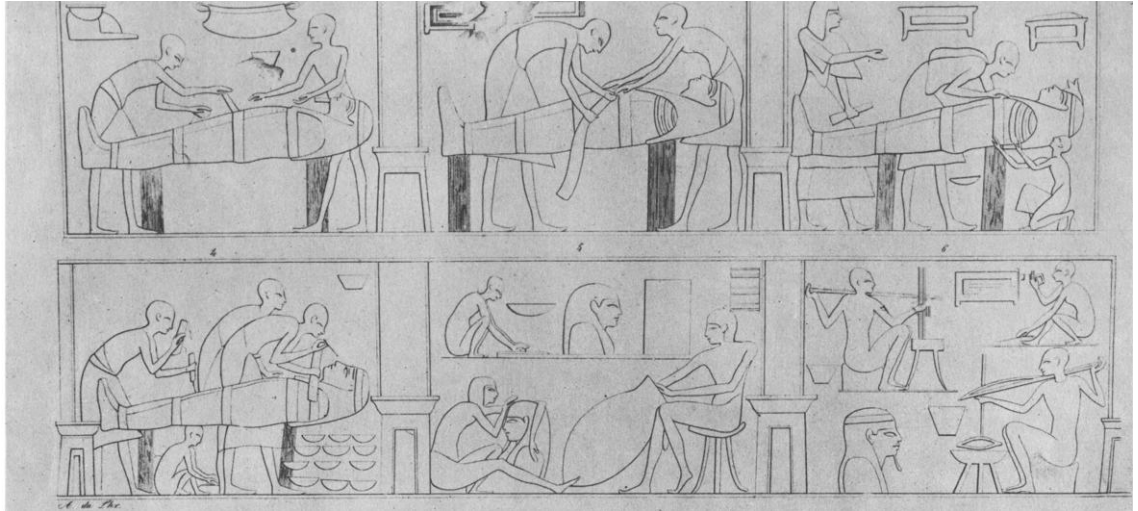
Fig 4.76 – The idealised mummification scenes from the tomb of Amenemope
(Dawson 1927; pl XVIII)

Mummy Identification Number	A4
Individual Age	20 – 22 years
Sex	Female
Current Examination Methods	Histology
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	56
Samples Used	Breast, Liver, Lung, Muscle Scalp, Skin, Rib
Previous Palaeopathological Findings	None Found
Current Palaeopathological Findings	**Higher than normal levels of fibrosis in lung and liver samples**
Cause of Death (autopsy)	Not Known
Mummification Type	Four

Table 4.3 - Revised Minimum Standards Case Report - Mummy A4

4.6 – RESULTS – MUMMY A5

4.6.1 – Skin (Ear)

The skin sample from Mummy A5 displayed a good level of preservation, although it demonstrated a small degree of putrefaction due to the presence of visible bacteria.

The remnants of nuclei could still be seen in some cells and parts of the epidermis were still present. This is an unusual finding as most if not all nuclei are removed at autolysis and putrefaction as is the epidermis. This finding indicates that there is good preservation of these tissues.

A cyst can be seen within the dermis, most likely an epidermoid cyst. These are benign cysts that are commonly found on the face, neck and upper trunk; they can also be located behind the ears, which is where this skin sample came from. They form when a hair follicle or pore becomes blocked, in this case most probably from irritation and cyst formation by a small silica particle. Most epidermoid cysts are asymptomatic (www.bad.org.uk/site/805/default.aspx).

No other pathologies could be identified.

Stain – Toluidine Blue
Magnification – x20

Epidermis sloughing off

Dermis

Deep dermis
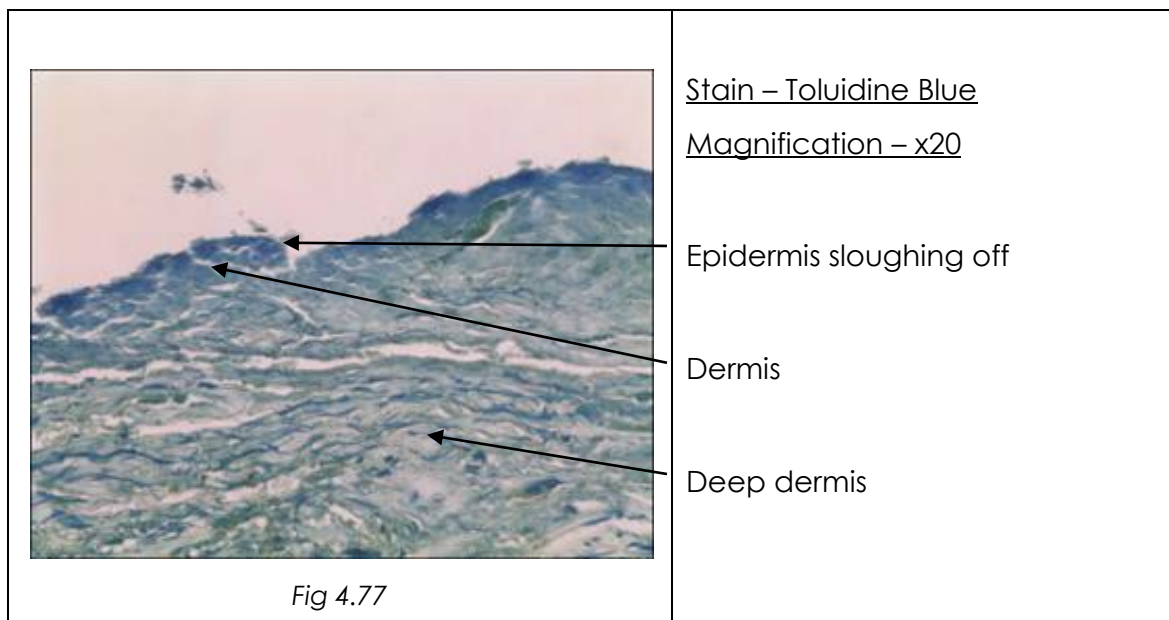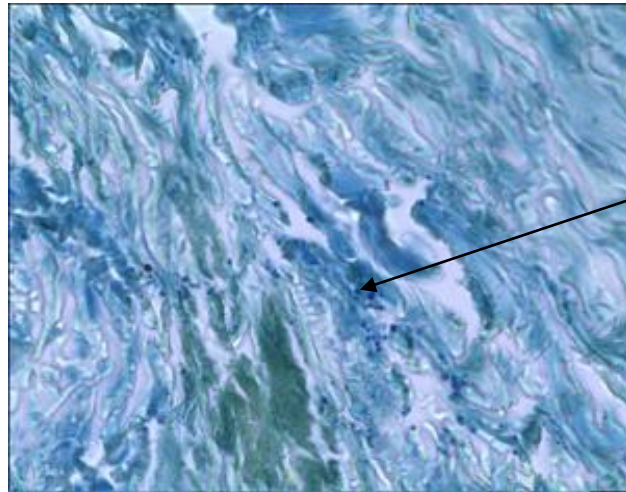
Fig 4.77

Fig 4.78

Stain – Toluidine Blue

Magnification – x40

Bacteria (dark blue dots)
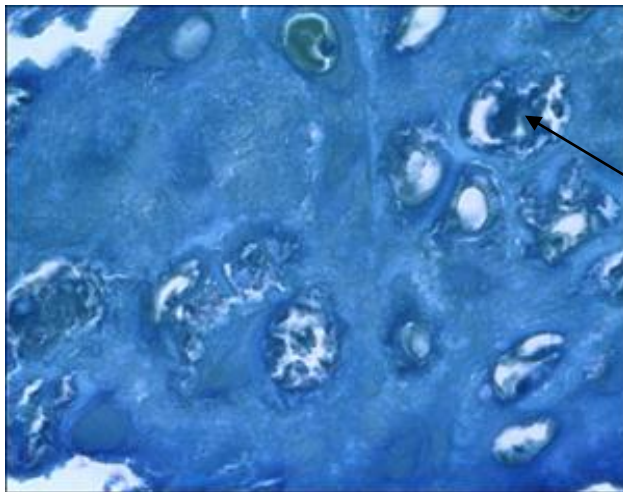
Fig 4.79

Stain – Toluidine Blue

Magnification – x40

Cells with remains of nuclei
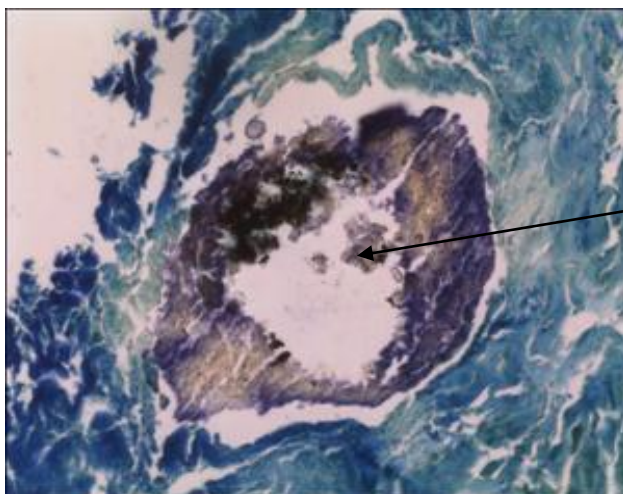
Fig 4.80

Stain – Toluidine Blue

Magnification – x20

Possible epidermoid cyst (sand encapsulated by tissue)
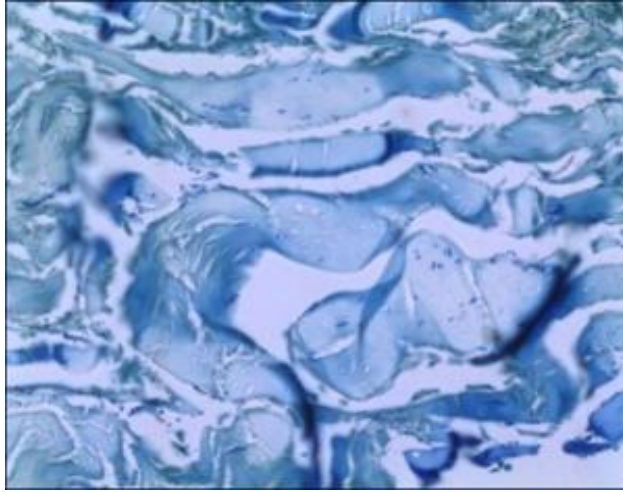
Fig 4.81

Stain – Toluidine Blue

Magnification – x20

Thick collagen of the deep dermis

4.6.2 - Heart

The heart sample from Mummy A5 was not well preserved and no pathology could be identified.

A single coronary artery with a bifurcation was visible. Arteries and veins are made up of connective tissue, which has already stated, are very resistant to autolysis, putrefaction and environmental changes. The artery in this sample remains despite all the surrounding tissue being in an advanced level of degradation.
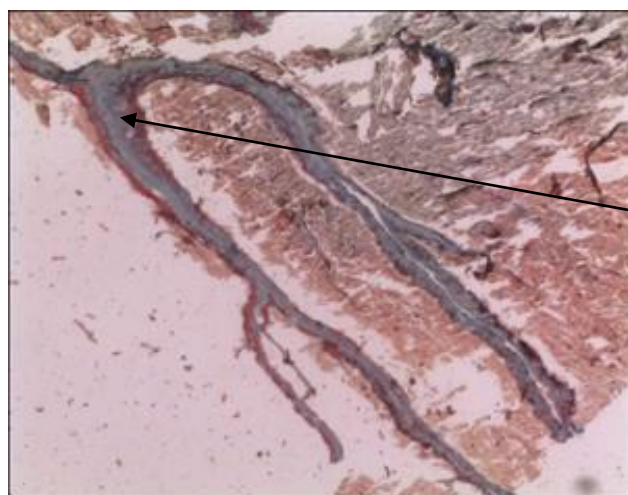
Stain – MSB
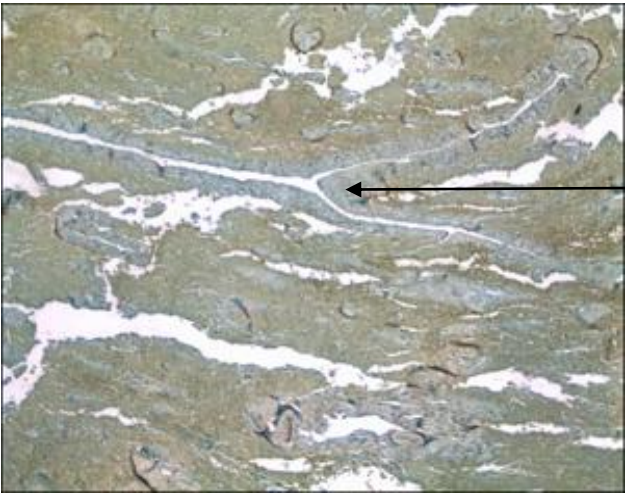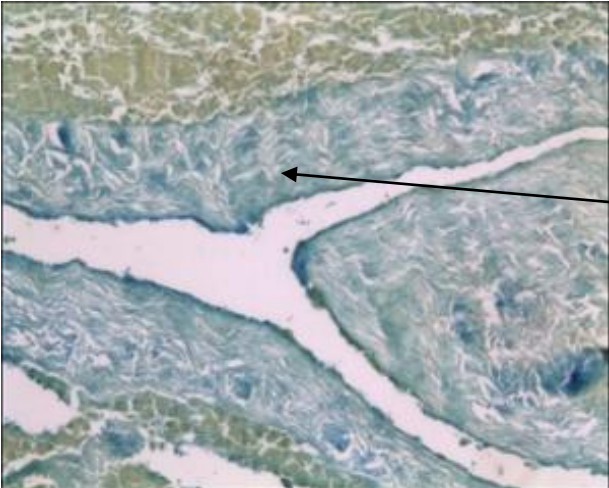
Magnification – x2.5

Coronary artery showing bifurcation, which is simply the junction of two vessels merging into one

Fig 4.82

4.6.3 - Liver

The liver sample of Mummy A5 displayed a relatively excellent state of preservation, being highly fibrotic indicating an advanced state of cirrhosis. It is this diseased state, which gives the sample the appearance of being well preserved. The level of fibrosis is far above the normal limits, the presence of which will be discussed in Chapter 4.7.

In normal liver, the reticulin fibres are not as visible as they are in this sample. Reticulin fibres are very fine intercellular fibres forming a network amongst and around the cells of many vertebrate tissues, including the liver, kidneys, nerves, muscle and glands. They consist largely of a type of collagen and in this fibrotic liver; they are larger than they would be in a healthy liver.

Fig 4.83

Stain – Toluidine Blue
Magnification – x1.6

Fibrosis around vessel (collagen) (blue)

Fig 4.84

Stain – Toluidine Blue
Magnification – x10

Fibrosis around vessel (collagen) (blue)
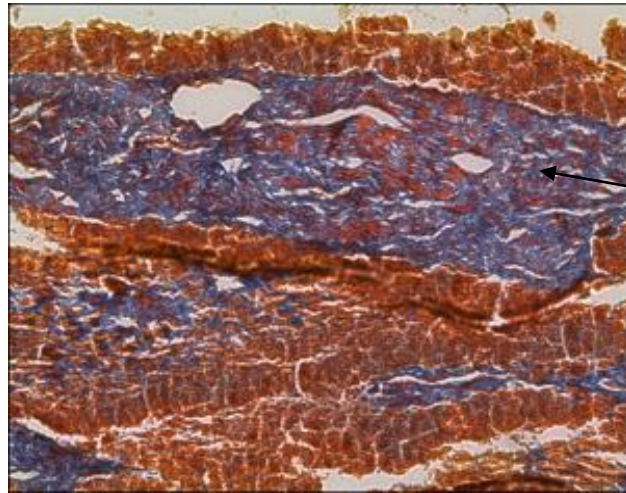
Fig 4.85

Stain – MSB

Magnification – x10

Fibrosis (collagen) (blue)
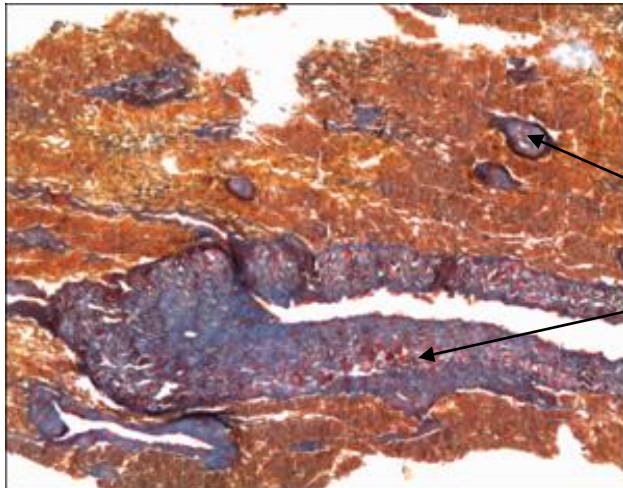
Fig 4.86

Stain – MSB

Magnification – x5

Granulomas

Fibrosis (collagen) (blue)
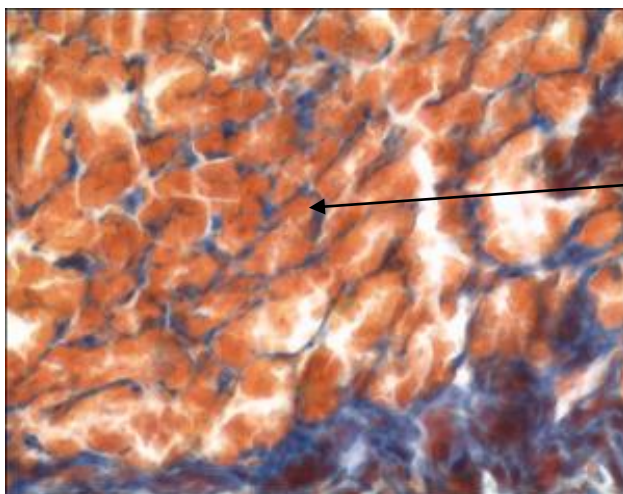
Fig 4.87

Stain – MSB

Magnification – x40

Reticulin fibres (blue lines)

4.6.4 - Muscle

The muscle sample from Mummy A5 was not only muscle but also dense connective tissue, most likely tendon, or intercostal ligament. It is not well preserved.

Within the degraded muscle sample is a cyst. Cysts, such as this, are shell-like enclosures that contain small organisms in a resting stage. The location of the larva within the muscle is suggestive of *Trichinella spiralis,* a condition caused by the ingestion of inadequately cooked pork.
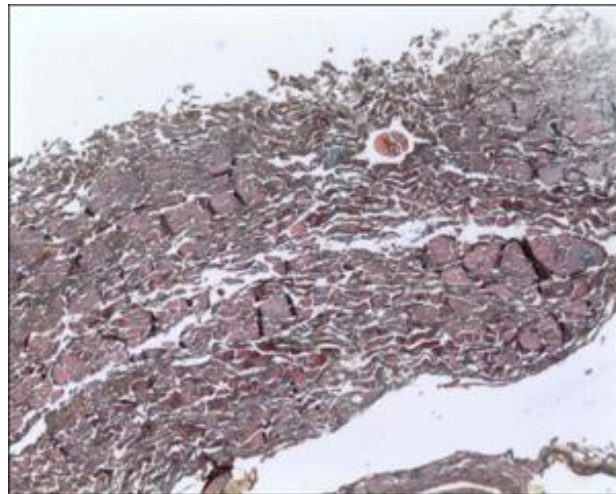
 Fig 4.88	<u>Stain – MSB</u> <u>Magnification – x5</u> Overview of muscle sample
 Fig 4.89	<u>Stain – MSB</u> <u>Magnification – x40</u> Possible cyst or parasite ovum (nematode) Scale bar = 25 microns
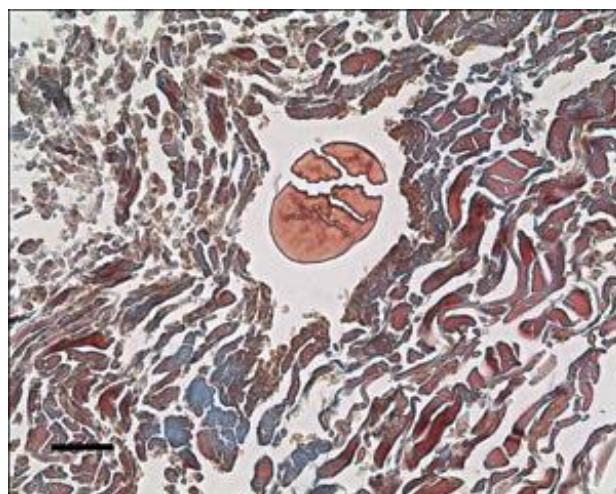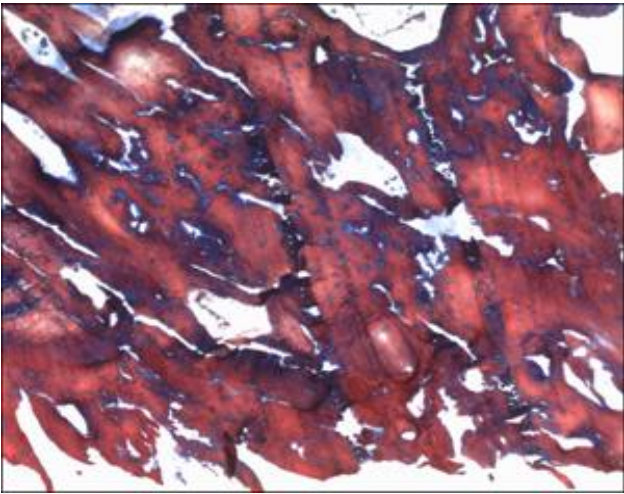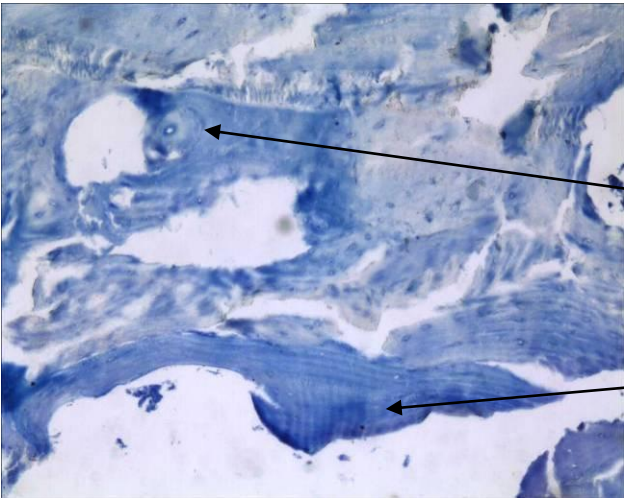
4.6.5 - Bone (Rib)

The decalcified rib sample from Mummy A5 showed bacteria that have produced protease enzymes, which, in turn, started to digest the matrix

Large parts of the sample had been destroyed by these acids and protease secreting bacteria, which meant it was not possible to identify any pathologies that may have been present.

Despite the poor preservation, striations on the lamella bone could be visualised.

Fig 4.90	Stain – MSB Magnification – 2.5 Badly preserved bone sample showing post-mortem fractures
Fig 4.91	Stain – Toluidine blue Magnification – x5 Haversian system Darker blue edge showing bacteria invading and changing the bone matrix

4.7 - NOT FROM HERE – DISCUSSION OF MUMMY A5

Mummy A5 was a male aged 40 to 50 years at the death.

The samples from Mummy A5 displayed a variety of preservation levels. The skin sample still had parts of the epidermis visible, which suggests a short time-span between death and burial. During autopsy, it could not be determined whether wrappings had been used to cover the body at the time of its placement within the tomb. However, the remaining epidermis would suggest that no wrappings had been employed as if they had, the epidermal layer would probably have come away when the bandages were removed.

The heart, muscle and bone samples were not well preserved. The reasons for the good skin preservation yet the degradation of these samples is unknown, although it could be the result of Mummy A5 dying in winter when the temperatures in the Dakhleh Oasis fluctuate greatly (see Chapter 1.2.1.2). This would not enable the rapid desiccation of the internal organs, while the skin, especially of the ear, from where this sample came, was still able to dry quite quickly, once in the sand. Within the heart, muscle and liver, the only tissue that remained intact was that of connective tissue or in the case of the liver sample, fibrotic elements.

Bacteria were present within the skin and rib samples. Those within the skin did not have time to inflict much damage before desiccation had taken place, however, the invading bacteria had destroyed large areas of the bone sample.

Within the muscle sample, a single cyst-like entity was found. A cyst, such as this, was discovered in the intercostal muscle sample from the Twentieth Dynasty mummy Nakht. The investigators of Nakht believed that the cyst was a larval form of the parasite *Trininella spiralis*, an infection that is caused by the ingestion of inadequately cooked pork (De Boni et al 1977; 471). The implications of this will be discussed in Chapter 4.7.

The main sample of interest from Mummy A5 was the liver. Only a small area of liver sample examined demonstrated a preservation level above poor. However, at first appearance, the liver sample from A5 was in a very good state of preservation. It soon became evident that this was possible due to a diseased state. The liver was extremely fibrotic (all of the fibrosis stained blue)

and this fibrous material helped hold the sample together. Cirrhosis, such as this has been previously recorded in ancient Egyptian studies, as with *Trichinella spiralis*, in the mummy of Nakht. In Nakht's case, it was likely caused by a heavy *Schistosome* sp. infection (Millet et al 1998 102-104).

Mummy A5 lived well into, if not a bit beyond, the average age of an ancient Egyptian. Like many mummies studied previously, A5's parasitic load was not concentrated on one species but, the evidence suggests at least two; more could possibly be discovered if coprolite samples had been available for histological examination.

4.7.1 – Parasites and Human Health

The Macquarie Dictionary (2009; 1212) defines parasites as 'an animal or plant that lives on or in an organism of another species (the host), from the body of which it obtains nutriment'. Those parasites that cause damage to their human host are referred to as 'pathogens', and the resulting condition from this damage constitutes disease. Parasites that require a human host for at least part of their lifecycle have probably been present for as long as humans themselves. In Egypt, research has proved that parasitic infections have been part of life at least throughout the last 5000 years (Contis & David 1996; 253).

Today intestinal parasites are distributed throughout the world, with many regions (mainly developing countries) suffering high prevalence rates. In countries where intestinal parasites are endemic, they cause significant morbidity and mortality (WHO 1987; 7, Haque 2007; 387).

Parasites that inhabit the human gastrointestinal tract fall into two groups: protozoa and helminths. Protozoan parasites are unicellular and can multiply inside the human body. Today, they cause more gastrointestinal infections than the helminths in developed countries. Species include *Giardia intestinalis, Entamoeba histolytica, Cyclospora cayetanenensis* and *Cryptosporidium* sp. Helminths are multicellular worms that cannot usually multiply within the human body. In term of human infection, the most common helminths are:

1) Nematodes (roundworms)
2) Cestodes (tapeworms), and
3) Trematodes (flatworms).

In developing countries, parasitic infection caused by helminths is more prevalent than that of protozoa. Today, one species of roundworm - *Ascaris* sp. - infects approximately 1.3 billion people (Haque 2007; 387, Markell et al 1999; 16).

Today, in many countries endemic parasite infection is closely related to economic and social development practices. Most gastrointestinal parasites thrive in settings with one or more of the following conditions:

1) Warm temperatures
2) Humidity
3) Poor sanitation
4) Dirty water, and/or
5) Substandard and crowded housing (WHO 1987; 7, Harhay 2010; 220).

Current infection rates are highest in the children of Sub Saharan Africa, followed by those of Asia and Latin America. It is estimated that approximately one quarter of Sub Saharan children are infected with one or more of the nematode worms (Harhay 2010; 220).

In terms of the available evidence of parasitic infection in ancient cultures, the robust shells of the helminths have confirmed the presence of infectious disease, even if the human host remains are poorly preserved or, in some cases, absent (Loreille et al 2001; 1101). The findings of helminth ova are in line with previous research (Tapp 1979, Reinhard et al 1992, Cockburn et al 1998, Loreille et al 2001, Horne 2002) and will be further discussed in Chapter 4.5.1.3. The species of helminths discovered during this project come from the nematode and trematode phyla.

4.7.1.1 - The Nematodes

Nematodes (common name – roundworms) are elongated, cylindrical worms with well-developed digestive tracts, usually attenuated at both ends. The male roundworm is frequently considerably smaller than the female. While most nematodes are free-living, a small subset parasitise humans, animals and plants because intermediate hosts are needed for the larval development of some forms. The nematodes of humans include intestinal (for example, *Ascaris* sp.) and tissue-inhabiting species (for example, *Trichinella* sp.) (Markell 1999; 15).

4.7.1.2 - Trematodes

Today, trematodes (flukes) that cause human infection are most common in the Middle East, Asia, South America and Africa. Humans become infected when they consume food or water that is contaminated with the intermediate hosts, such as fish and aquatic animals (Harhay et al 2010: 222). However, in the case of schistosomes, larval forms of the parasite ore released by freshwater snails (genus *Biomphalaria)*, enabling them to penetrate the skin of people in the water (http://www.who.int/tropic/schistosomaisis/en/).

Death from trematode infection is rare and light infections are often asymptomatic. However, schistosome infection is a chronic and debilitating disease that affects more than 207 million people worldwide. In addition to this, 750 million people are currently at risk in 74 endemic countries (Harhay 2010; 223).

4.7.1.3 - Archaeoparasitology of Ancient Egypt

It is not possible to estimate the parasitic infection rates in ancient Egypt, however, the results of investigations of the human remains, combined with the information given in the ancient medical texts, lead us to strongly conclude that the ancient Egyptians were far from being strangers of intestinal parasites and suffered a fairly high rate of infection from a variety of helminths, as do the Egyptians of today.

Analysis of mummies from ancient cultures, such as Egypt, demonstrates the diversity of parasites that could, and did, infect humans. Ancient Egyptian mummy studies have discovered *Schistosoma haematobium, Schistosoma mansoni, Dracunulus medinensis* (guinea worm), *Trichuris trichiura* (whipworm), *Ascaris lumbricoides* (giant intestinal roundworm), *Trichinella spiralis* (pork worm), *Strongyloides stercoralis* (threadworm) and *Taenia* spp. (tapeworm).

The great diversity of parasites found in human remains from Egypt can be explained by the idea that many parasites have an African evolutionary homeland, as well as the diverse, and water-related, activities of the ancient Egyptians themselves (Reinhard 1998; 380).

The Nile, and its branches, were, and are, a great focus of Egyptian life. In purely practical terms, it provided drinking water, transport, irrigation and

washing facilities. In other areas of Egypt, such as the Fayum and the Oases, underground water springs provided much the same resource.

Fig 4.92. – Washing, playing and fishing in the Nile (author's own photograph)

Unfortunately, this frequent and intimate contact with the Nile waters also enabled the same frequent and intimate contact with endoparasites that flourished within it (Filer 1995; 11).

The study of parasites from ancient cultures (archaeo or palaeoparasitology) can, with other factors, give insight into the density and appearance of a population, as well as being important from a medical perspective. As parasitism is dependent upon environment and host behaviour, analysis of the interaction of ancient parasites and humans leads to information regarding environmental stresses and cultural development, such as, hygiene, sanitation and nutritional adequacy (Bouchet et al 2003; 47).

The establishment of agriculture and the domestication of animals (sixth millennium BCE), as opposed to the hunter-gatherer subsistence, in ancient Egypt, probably had a more significant effect on the parasite-host relationship than any other factor. For the first time, man became tied to the land, animals moved into the same ecological niche, populations increased and areas could now become contaminated with infected faeces and as Cockburn (1971; 46) stated there was now 'an almost direct route from one intestine to another'.

Ancient Egypt from around 5000 BCE therefore, had many of the conditions favourable to human intestinal parasites – a static human and animal

population, dependence on an infected water supply, poor sanitation, warm temperatures and high humidity (in areas close to water).

4.7.2 - Schistosomes

Schistosomiasis, also known as Bilharziasis, is the second most prevalent tropical disease in Africa after malaria. The disease involves impairment of the metabolism of infected individuals (www.who.int/mediacentre/factsheets).

The *Schistosoma* sp. are blood rather than intestinal flukes, however, they can cause severe intestinal complications. The three most important species of schistosome are:

1) *S. mansoni* (intestinal schistosome)
2) *S. japonicum* (intestinal schistosome), and
3) *S. haematobium* (urogenital schistosome)
   (www.who.int/mediacentre/factsheets).

Eggs of *S. mansoni* and *S. japonicum* are generally found in the faeces and while *S. haematobium* eggs can also be occasionally seen in faeces, they more usually occur in urine. Female schistosome worms are long - up to 2.6cm - and slender – about 0.33mm. The male worms are much smaller (0.6 to 2.2 cm long) with flattened bodies. The eggs have sharp spines, which assist in their retention in the blood vessels (Markell et al 1999; 207).

S. mansoni and *S. haematobium* are the species that most effect the population of Egypt today and the results of studies into ancient Egyptian populations appears to very strongly mirror this Millet et al 1998; 99-101, Rutherford 2008; 99-115, Ruffer 1910; 16-20).

Fig 4.93 - S. mansoni ova with the lateral spike (http://www.dpd.cdc.gov/dpdx/HTML/ImageLibrary/Schistosomiasis_il.htm)

Fig 4.94 – S. haematobium ova with terminal spike (http://www.dpd.cdc.gov/dpdx/HTML/ImageLibrary/Schistosomiasis_il.htm)

4.7.2.1 - Transmission and Life Cycle of Schistosoma sp.

For agricultural and fishing communities, schistosomiasis is a particular concern. It also affects women doing domestic chores (such as washing clothes) in snail-infested water. The hygiene and play habits of children make them especially vulnerable (www.who.int/tropic/schistosomiasis/en/).

Once in the body, the schistosome larvae develop into adult worms, which then live in the blood vessels where the female releases her eggs. The eggs are either evacuated from the body in urine or faeces, or trapped within the body tissues, causing an immune response as well as progressive damage to internal organs (http://www.who.int/tropic/schistosomiasis/en/).
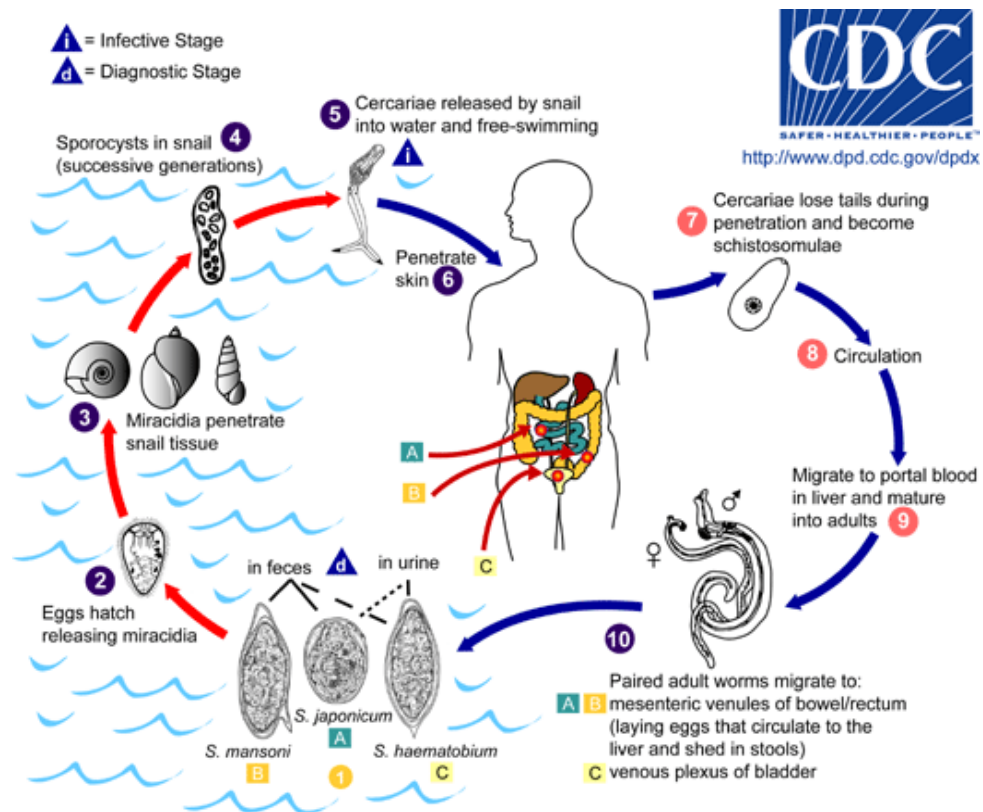
Life Cycle:

Fig 4.95. – Life cycle of the Schistosome sp. (www.dpd.cdc.gov/dpdx/Default.htm)

4.7.2.2 - Symptoms of Schistosoma sp. in Humans

The symptoms of schistosomiasis are not caused by the worms, but rather to the body's reaction to the eggs. Intestinal schistosomiasis (caused by *S. mansoni* and *S. japonicum*) manifests in diarrhoea, abdominal pain and blood in the faeces. In advanced cases, liver fibrosis and enlargement are common. This is, in turn, frequently associated with the accumulation of fluid in peritoneal cavity and hypertension of the abdominal blood vessels. In such cases, the spleen may also become enlarged. The main symptom of urogenital schistosomiasis (*S. haematobium*) is blood in the urine (haematuria). Advanced cases exhibit fibrosis of both the bladder and ureter, as well as kidney damage. In men, urogenital schistosomiasis can also damage the prostate, seminal vesicles and other organs. Women may suffer genital lesions, vaginal bleeding and nodules in the vulva. Both types of schistosomiasis can cause anaemia (http://www.who.int/tropic/schistosomiasis/en/).

Chronic schistosomiasis affects people's ability to work and learn, can stunt growth and in extreme cases, cause death. Currently, in Sub Saharan Africa, 200 000 deaths a year are attributed to schistosomiasis (http://www.who.int/tropic/schistosomiasis/en/).

4.7.2.3 - Ancient Schistosomiasis and Modern Findings

The discovery of a *S. haematobium* ovum on the ear of Mummy A4 (see Chapter 4.4) and the extremely fibrotic liver of A5 is strongly suggestive of schistosomiasis infection amongst the population of Kellis, however it is by no means unique. A number of previous studies have uncovered the similar findings.

In 1910, in the British Medical Journal Marc Armand Ruffer announced that he had discovered numerous ova of *Schistosoma haematobia* in the kidneys of two mummies of the Twentieth Dynasty (Ruffer 1910; 16-20). From this time onwards, schistosomes (either *haematobium* or *mansoni*) have been found in ancient Egyptian remains housed in museums throughout the world (for example, Millet et al 1998; 99-101, Rutherford 2008; 99-115, Ruffer 1910; 16-20).

One of the most publicised scientific studies of ancient Egyptian human remains was that of the mummy Nakht, a teenaged weaver from the Twentieth Dynasty (1186- 1069 BCE). The forensic examination of Nakht was a joint,

interdisciplinary study between the Royal Ontario Museum (where Nahkt was housed), the Toronto Academy of Medicine and the Detroit Group of the Paleopathology Association (Millet et al 1998; 91).

During the 1974 autopsy of Nakht, small samples of tissue (lung, liver and intestine) were collected in order to be viewed histologically. While examining the liver sample, it became clear that Nakht suffered from cirrhosis, the cause of which was easy to identify as some portal areas contained the calcified ova of *Schistosome haematobium* (Millet et al 1998; 99). This is not dissimilar to the findings from Mummy A5, the liver of which was highly fibrotic and with probable schistosome granuloma (see Figures 4.85 and 4.86)
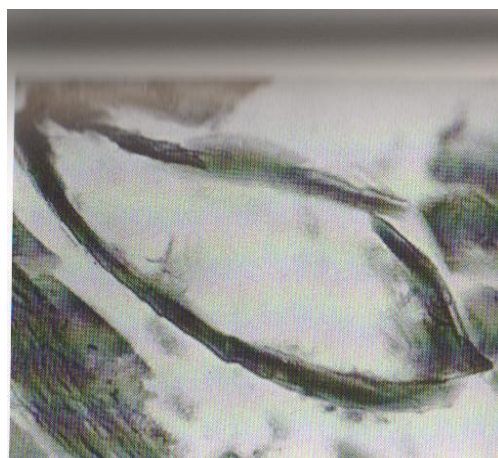
Fig 4.96 - Schistosome haematobia found in the mummy Nakht (Millet et al 1998; 99)

In 2005, Dr Patricia Rutherford analysed a number of samples from ancient Egyptian mummies for evidence of schistosomiasis using immunocytochemistry. Immunocytochemistry is a method in which antigens in tissue sections are demonstrated by using antigen/antibody interactions (Rutherford 2008; 100). Dr Rutherford analysed samples from 24 mummies, of which six (25 percent) displayed positive results for schistosome antigens. The samples used were mainly bladder tissue, chosen because they had shown areas of calcification during radiography (undertaken at an earlier date). It is unsurprising then that the species of schistosome identified in the Manchester project was the *S. haematobium* (Rutherford 2008; 110-111).
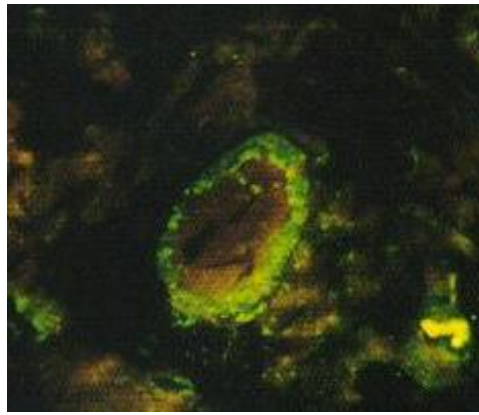
Fig 4.97 - Schistosome haematobia found in mummy 1766 using immunocytochemistry (David and Archibold 2000; 159)

Mummies from Nubia have also shown evidence that the population suffered from schitosomiasis. Hibbs (2011) has recently examined over 230 mummies from the ancient Nubian populations of Wadi Halfa and Kulub Narti (inhabited 350-550 CE). This study found the prevalence to be 26.1 and 9.4 percent respectively (Hibbs et al 2011; 293). The schistosome in these Nubian mummies was *S. mansoni*. One of the many interesting aspects of this study is that the highest prevalence was not amongst the child category, which has proven to be the case in all modern day research, but in the mature adult category for Wadi Halfa, and for Kulab Narti it fluctuated erratically and did not follow any age pattern (Hibbs et al 2011; 294).
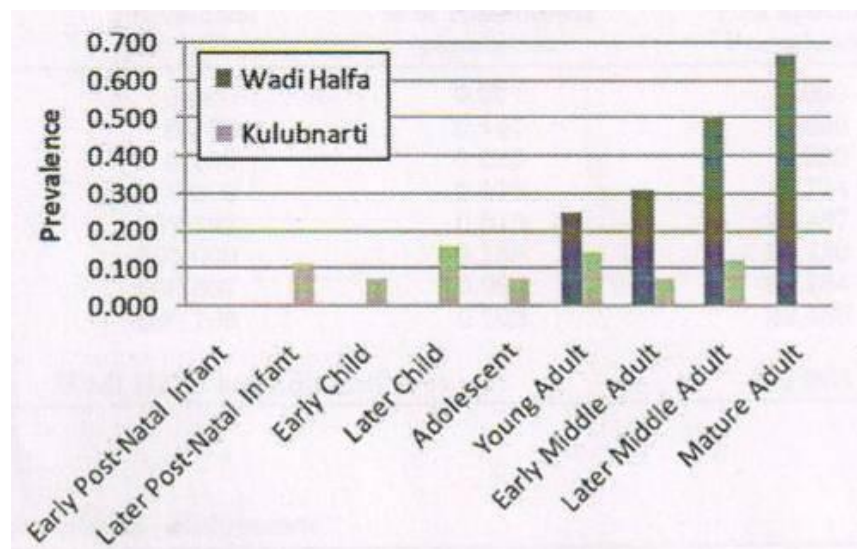
Fig 4.98 - Prevalence of S. mansoni in ancient Nubian populations (Hibbs et al 2011; 293)

With the discovery of the possible *S. haematobium* ovum on the ear of A4, the extremely fibrotic liver of A5 and the numerous *Ascaris* sp. in the coprolite material of A101 (see Chapters 4.4 & 4.12), it was decided to examine other

available samples of coprolite material in order to find further evidence of parasitic infection. One other coprolite sample from the Dakhleh mummies was accessible – Mummy A106 (Chapter 2.1.15). When analysed, it displayed *Ascaris* sp. ova, although not of the quantity found in the sample of A101 (see Chapter 4.12). Also within the A106 coprolite sample was a single entity, possibly the ovum of a *S. mansoni*. Although clearly misshapen, the entity had an obvious lateral spike, albeit much more centrally positioned than the usual *S. mansoni* spike, which is commonly found closer to the terminal end of the ovum (Salfelder 1992; 155).

Stain – MSB

Magnification – x20

Crystallised internal structure

Possible lateral spike

Scale bar = 50 microns

Fig 4.99 – Possible S. mansoni ovum in A106 coprolite sample
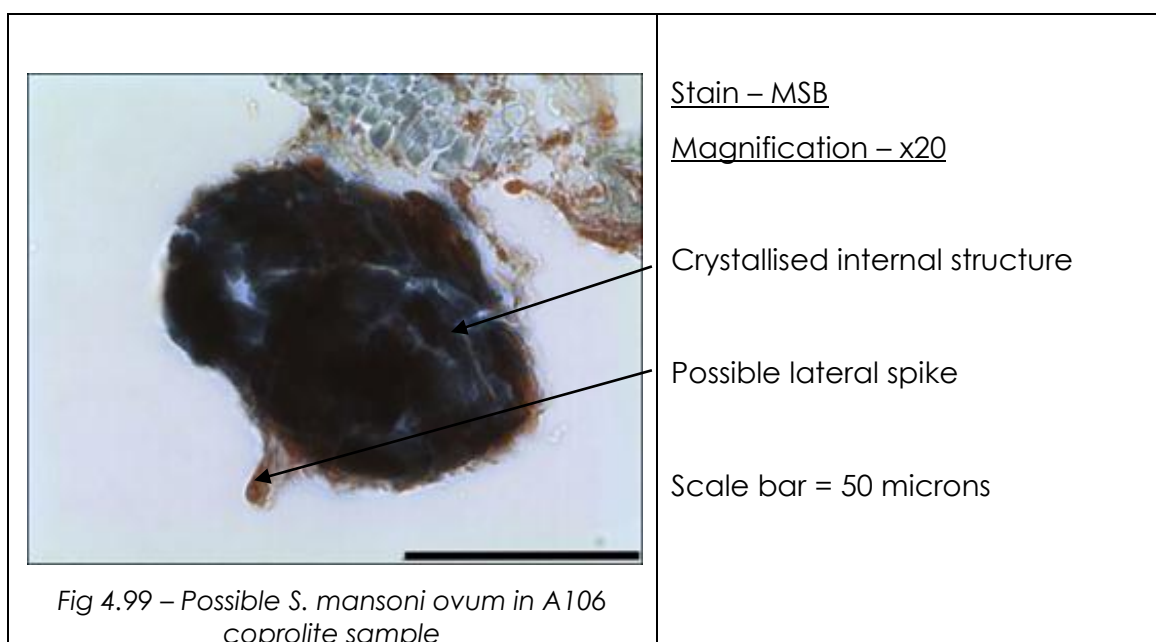
An explanation for this unusual positioning of the lateral spike may be possible with an understanding of how sectioning can distort an object's appearance.

In modern diagnostic histology, it is practical experience that enables an ability to manipulate the microtome in way that produces a sample in perfect orientation (Anderson & Gordon 1999; 63). While practical experience is, of course, also an advantage when sectioning ancient tissue, with some types of mummified tissue, it is impossible to judge orientation until seen under the microscope. With some samples, such as skin, it is possible to orientate the sample to an optimum position at the time of embedding, however, the majority of ancient samples are brown, brittle and indiscernible and therefore impossible to position with certainty.

The well-preserved Late Period (747 – 332 BCE) mummy of Asru, housed at the Manchester Museum (United Kingdom) had already been extensively studied as part of the Manchester Museum Mummy Project (David 1979; 10). Despite Asru's viscera being extremely degraded, the Manchester Museum Mummy Team was able to detect worms of the schistosome genus within the intestinal walls (Tapp 1979; 99).

When paraffin wax-embedded samples Asru's intestinal contents were examined for this project, they had degraded to the extent of being unidentifiable and of no diagnostic value. When viewed after embedding the sample in LR White acrylic resin, the section had identifiable entities, including a possible *S. haematobium* ovum.

Stain – Toluidine Blue

Magnification – x40

Resin Section

Parasite Ovum

Possible degraded terminal spike

Scale Bar = 25 microns
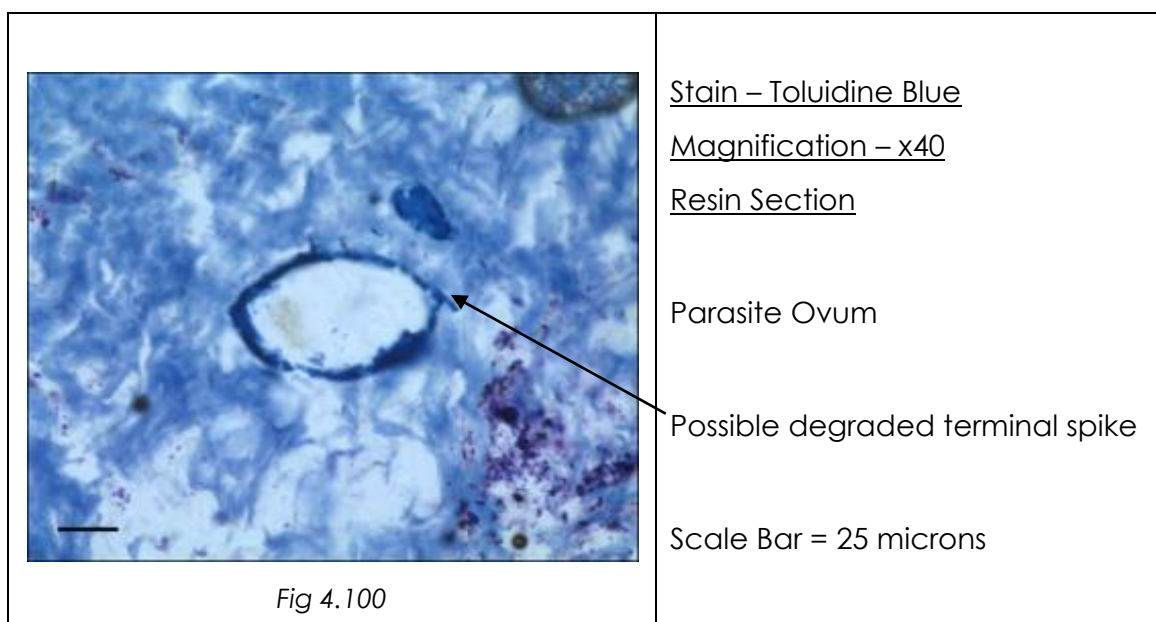
Fig 4.100

The terminal spike is so degraded and the shape is obviously ovaloid, at first, the ovum appears to be more likely to be that of *Trichuris trichiura* (whipworm) (see Figure 4.101).
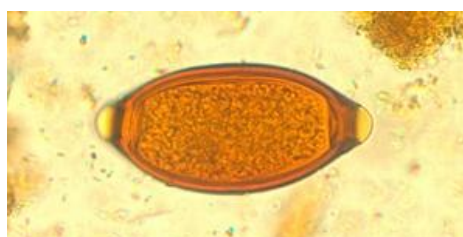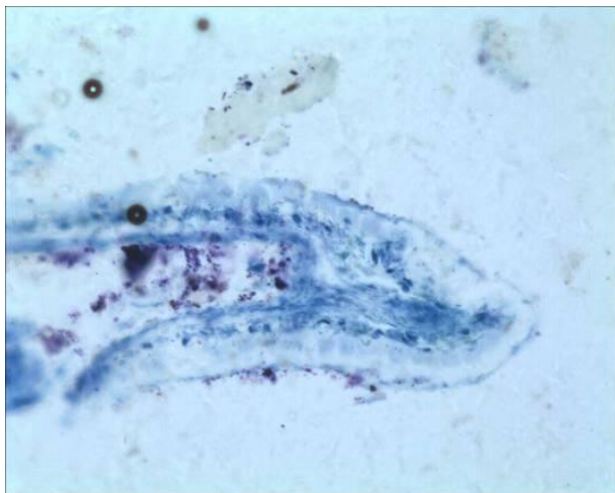
Fig 4.101 – Ovum of a Trichuris trichiura (www.dpd.cdc.gov/dpdx/HTML/ImageLibrary/Trich uriasis_il.htm)

This ovum, however, does not show any signs of the very distinctive two polar prominences (Salfelder 1992; 101). It is more likely to be that of a *S. haematobium* – the shape is characteristic and the remains of the spike are in the right position for this species of the parasite. It cannot be confirmed unless further analysis is undertaken using techniques, such as ancient DNA or immunocytochemistry; however, the most likely diagnosis is an infection of unknown veracity of Schistosomiasis caused by *S. haematobium* (Kathryn Else pers. comm.).

In the same section, the remains of a worm were also visible.

Fig 4.102	Stain – Toluidine Blue Magnification – x20 Resin Section Remains of a worm in the intestinal contents of Asru

Unfortunately, only a terminal end of the worm has been sectioned, and the internal structure is much degraded so a positive identification is not possible; however, due to its close proximity to the *S. haematobium* in Asru's intestines, it can be strongly suggested that this is the worm of the same species.

4.7.2.4 - Ancient Egyptian Artistic and Textual Sources for Schistosomiasis

The textual and artistic sources from ancient Egypt appear, at first sight, to agree with scientific results for the presence of schistosomiasis, at least during the Pharaonic Period. Images of ancient Egyptians, both nobles and peasants, at work or leisure also display the daily contact with water sources, such as the Nile, that would act as the infection site.

Figs 4.103 & 4.104 – Images showing peasants and nobleman alike in their contact with the waters of the Nile (courtesy of the British Museum)

Both sculpture and painted and relief style tomb art have examples of ancient Egyptians seemingly afflicted with umbilical hernia, scrotal swelling, gynaecomastica and hepatospleomegaly, although identification cannot be confirmed with any certainty. These are symptoms resulting from the enlargement and fibrosis of the liver. One such image is that of the Naos of Bak and his wife Taheret from the Eighteenth Dynasty (1550 – 1069 BCE) (see Figure 4.105 below).
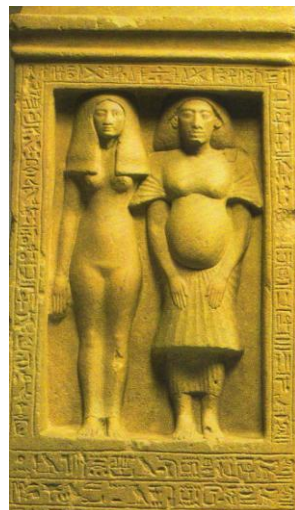
Fig 4.105 - Noas of Bak and his wife, Taheret (www.astrodoc.net/ andere/berlinaegmus4a.htm)

Bak is portrayed with a distended abdominal area and large breasts, which some scholars (Nunn 1996: 82-83, Ebeid 1999; 215-225) believe to be the result of schistosoma infection. Ebeid (1999; 220) states 'Bak with his gynaecomastia and hepatosplenomegaly with possible ascites and endema of the lower legs represented a case of bilharzial hepatosplenomegaly'.

Bak's statue with its enlarged breasts, swollen stomach and legs, if indeed a representation of schistosomiasis symptoms would have to exhibit a rare consequence of severe chronic hepatosplenic *Schistosomiasis mansoni*. The symptoms of umbilical hernia and scrotal swelling referred to by Nunn (1996; 82) and Ebeid (1999; 200) could possibly be the result of sever ascites, however, gynaecomastica, swollen legs and scrotum and umbilical hernias are not typical of any form of schistosomiasis found today (Salfelder 1992; 151, Dunne, pers. comm.). It is possible that the pathology and progression of the disease then is different to that of today.

It is also possible that images, such as that of Bak, are the result, not of schistosomiasis, but another parasitic infection altogether. Lymphodema, which causes gynaecomastica, swollen legs and abdomen, etc, is a classical sign of filariasis. Today, there are three filarial worm species that parasitise many millions of people, mainly in Africa, Asia, America, Australia and Mediterranean countries. The microfilariae (larvae) can be found in the lungs and lymph nodes of human causing obstruction or, lymphodema (Safelder 1992; 126-128). While certainly not as common a find as *Schistosome* sp. ova in ancient Egyptian (and Nubian) mummies, Tapp and Wildsmith (1992) discovered filarial worms in the soft tissues of the groin of the Twentieth Dynasty (1186 – 1069 BCE) Leed's mummy, Nesy-amun (United Kingdom).
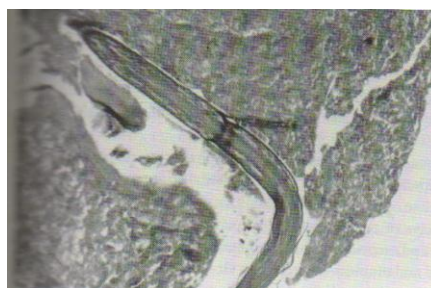
Fig 4.106 – Filarial worm found in the groin of Leed's mummy (Sandison & Tapp 1998; 41)

There is further, and possibly more reasonable explanation for the image and this is simply that it was the artistic tradition of the time. Bak was the chief sculpture of Akhenaten, and was, in his own words, taught his craft by the king himself (Aldred 1968; 102). The Amarna style is extremely distinctive and unconventional in terms of the artistic canon of ancient Egypt; the change lies in the proportions of the human body, especially those of the royal family and the king himself. By the time his reign was well established, Akhenaten was portrayed with a long neck, sagging belly and large breasts and, as a matter of course, his officials would follow the same pattern (Robins 2008; 150). Bak may be doing just this.

The counter argument for this explanation is that Bak's wife is depicted normally and that the representation of Bak is contrary to the Egyptian representation of obesity (see Figure 4.107 below) (Ebeid 1999; 220).
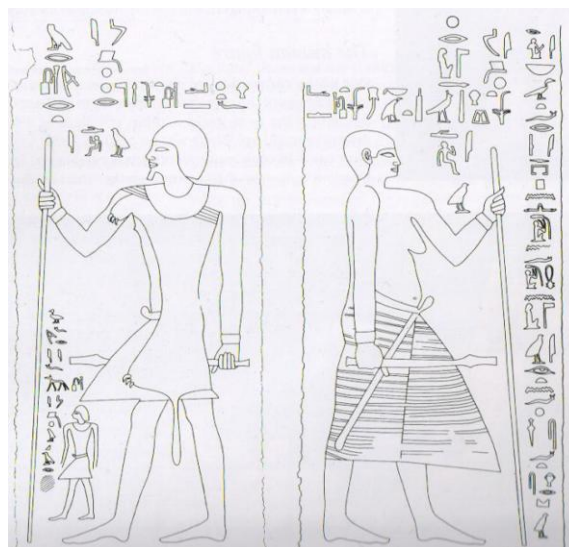
Fig 4.107 - Figure of Idu from the door-jambs of his tomb chapel.
On the left hand side, Idu is shown in the ideal of young adulthood.
On the right hand side, he is shown as an older man, with pendulous breasts and
spreading waistline, a sign of prosperity (Robins 2008; 76)

It can also be argued that Bak was sculptor in Akenaten's court before the new Amarna conventions had been established (Ebeid 1999; 220), however, with artistic objects from Amarna, it is not possible to be certain about the meaning behind the art.

One of the most controversial figures in the study of ancient Egypt is that of Akhenaten (1352 – 1336 BCE) himself. Representations of Akhenaten, especially as his reign progressed, show him with swollen hips, enlarged breasts, elongated head and protuberant abdomen. Many explanations for this unusual

appearance have been offered up, one of which is an infection of schistosomiasis (Reeves 2001; 47). This diagnosis, however, should be thought of as highly suspicious as both Akhenaten's father (Amenhotep III) and his grandfather (Thutmose IV) also have some images with pronounced breasts and abdomens, and during this time, especially in the reign of Amenhotep III, that artistic trends inclined towards femininity (Reeves 2001; 46, Robins 2008; 139).
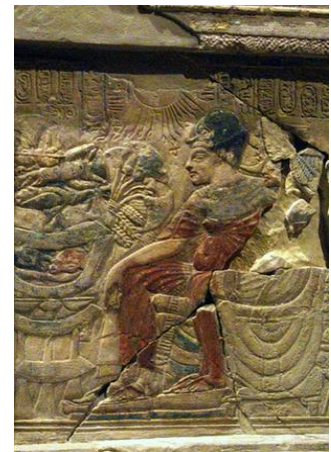
Fig 4.108 – Thutmose IV
(http://euler.slu.edu/~bart/egyptianhtml/kings%20and%20Queens/TuthmosisTiaa.jpg)
(left to right)
Fig 4.109 – Akhenaten (Amenhotep IV) (www.deepspirits.com/ancient-sages/akhenaten/images/akhenaten.jpg)
Fig 4.110 – Amenhotep III
(http://farm2.static.flickr.com/1108/981527382_baadce927c.jpg)

4.7.2.5 - The Medical Papyri and Schistosomiasis

Whenever the medical papyri are discussed, warnings are very quickly issued regarding the problems of translation (Ghalioungui 1987; 8, Nunn 2006; 30, Manniche 2006; 65, Reisner 1904, Campbell 2008; 217-8). The main reason for these warnings is that many words do not occur outside the papyri, especially those of plants used as part of the remedies, this leaves translations at best vague, and at worst, impossible (Campbell 2008; 217). Unfortunately, early translators of the papyri went beyond what could be known, often giving false meaning in order to fit the scientific results. An example of this practice, and one that has perpetuated in articles on the subject to this day, is Ebbell's belief that the âaâ disease in the Ebers papyrus was haematuria and in turn, the hrr.w worm as that of a schistosome.

 (âaâ hieroglyph)

The first remedy in the Papyrus Ebers to refer to the, and the one that Ebbell (1937; 12) claims as the condition of blood in the urine (haematuria) is Prescription 62. In this remedy, the cause of the haematuria 'in the belly' is the presence of hrr.t worms. This is the only time these worms are mentioned, and therefore have no connection to the other remedies concentrating on the âaâ.

Another useful remedy as made for the belly. Reeds 1; sama-plant 1; grind well, cook in honey. Eaten by a man who has hrr.wt-worms in his belly. It is âaâ which created it (them). It (they) will not perish by another remedy (Ebers, 62 – author's own translation)

One of the problems with the âaâ disease being diagnosed as haematuria is the other contexts with which it is associated within the Ebers Papyrus. Prescriptions 221 – 241 of the Ebers are also focused on the elimination of the âaâ disease. The parts of the body that are affected by the âaâ are the belly and heart (for example, Prescription 236). If, as Ebbell (1937) has asserted (and many following him), âaâ is translated as haematuria, this makes no sense; the heart cannot possibly suffer 'blood in the urine'. A more likely and plausible translation is the one given by Ghaliougui (1987; 75-80) of 'poison matter'. While, admittedly a more vague translation than haematuria, contextually it is a much better fit.

Another for expelling poison matter (âaâ) in the heart. Mandrake 1/16; ibw 1/32; cook in sweet beer and drink in four days.

Ebbell's conviction that âaâ was haematuria was, in part, based on the identification of the hrr.t worms being of the *Schistosome haematobium* genus (1937; 12). On first reading, this seems a plausible explanation, however, on closer inspection, it becomes clear that too much modern understanding of this particular parasitic infection has been forced upon the ancient text.

It was not until 1861 that a German physician, Theodor Bilharz, after whom the common name of the disease, Bilharzia, is named, identified a schistosome

worm. It is, therefore, suspect to think that the Egyptians had not only identified these parasites but had also related them to the clinical cause of haematuria.

It is far more likely that the ancient Egyptians did not associate the symptoms of schistosomiasis as being caused by the schistosome parasites, but recognised and treated the symptoms individually, with little understanding of causality.

The main symptom of *S. haematobium* of, as stated above, blood in the urine. The story of Napoleon's troops calling Egypt the land of menstruating men is often repeated (Nunn 1998; 69). It is therefore surprising that there is no firm evidence in the medical papyri treating this condition. Ebers Prescription 49 (similar prescriptions can be found in Hearst 18, Berlin 165 and 187) is a treatment for expelling of wss, which can be translated as urine. However, throughout the Ebers it is commonly used for the meaning 'to evacuate' and Ghalioungui (1987; 22) translates at such.
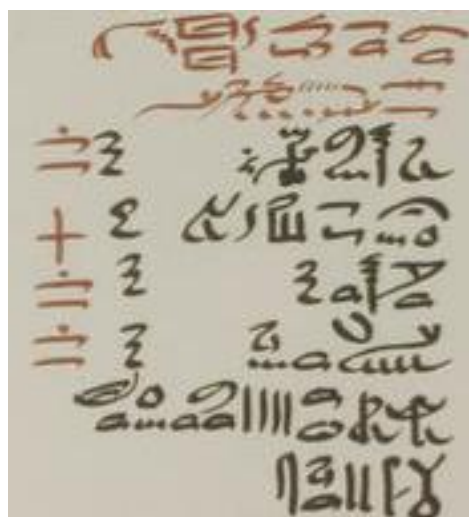
Fig 4.111 – Prescription 49 of the Ebers Papyrus

Another of expelling urine/evacuation of much blood (in red)
Fresh bread 1/8, pounded, oil 1/8, honey 1/8, strained, ingested in four days (in black) (author's own translation)

The section concentrating on urinary complaints can be found further on in Prescriptions 261 to 283 and none of these mention blood.

The main clinical sign of *S. mansoni* infection is diarrhoea. Prescriptions 44 to 48 in Ebers are strongly suggestive of the condition although they do not use a specific term for diarrhoea but instead the word 'evacuation' (wsst).

4.7.2.6 – Implications of Schistosomiasis in Mummy A5

Initially, the discovery of schistosomiasis in Mummy A5, while interesting, was not surprising. As has been evidenced above, schistosomiasis is a common finding in the study of ancient Egyptian human remains. However, within the life cycle of the schistosome parasite, the miracidia, (a larval form of the parasite) can only survive by penetrating and further developing within a mollusc host. Here the larvae undergo a series of changes, finally emerging as motile carcaria larvae, the form in which the parasite infects vertebrates either by penetrating the skin or by ingestion of contaminated water. The mollusc that plays host to the *S. mansoni* is of the snail of the genus *Biomphalaria*, and for *S. haematobium* it is *Bulinus* snail (Sturrock 2001; 18).

These snails have been found in both the Sudan and the Nile Valley, and are still present in these locations today. While it has been claimed that shells of the bulinus snail (host of *S. haematobium*) were found in large quantities in the canals of the Dakhleh Oasis in the first half of the twentieth century, no remains of either Biomphalaria or Bulinus genus have been excavated as part of the ancient assemblage from this location (Khahlil 1927; 1235, Hollett & Churcher 1999; 156). In addition, the Dakhleh Oasis Project state that no evidence of the Bulinus snail has been found in the modern faunal assemblage due to the lack of flowing water and that all water tested was slightly saline (Churcher, pers. comm.).

The information from the long-standing Dakhleh Oasis Project indicates that A5 was not originally from the Oasis but a Nile Valley dweller (or an inhabitant of another site that had schistosomiasis), who had at some point in time made the long arduous journey from the Valley to the Oasis.

This is not the first time evidence has been found to show that there was movement between the Nile Valley and the Dakhleh Oasis. In a study of human skeletal material from the Kellis 2 Cemetery (in use from approximately 250 to 450 CE) undertaken by Dupras et al (2001), stable light isotope analysis was able to prove migration to the Dakhleh Oasis to the town of Kellis by two adult males. Evidence such as this and the schistosomiasis present in Mummy A5, is hardly surprising as there was considerable economic commerce between the Nile Valley and Dakhleh Oasis at this time (Dupras et al 2001; 1206, Churcher, pers. comm.). The Oasis inhabitants were known to have grown

olives and dates that were in high demand in the Nile Valley and although women were involved with trade in some capacity, it was the men that conducted the trading caravans and therefore the migration of males to and from Dakhleh would have been not an uncommon occurrence (Bagnall 1997; 10). A5, it seems, was one of these men that did just that.

4.7.3 – Possible Trichinella spiralis in Mummy A5

Within the muscle sample of Mummy A5 was a cyst suggestive of an ova of another form of parasite, the nematode *Trichinella spiralis*. The reasoning behind the identification of *Trichinella* is twofold; firstly the location of the cyst within the muscle fibres is characteristic of the larval forms of this parasite and, secondly, a finding of *Trichinella spiralis* has previously been recorded during the examination of the Eighteenth Dynasty weaver, Nakht (Millet et al 1998; 102-104).

Trichinella spiralis was first named and published by Richard Owen in 1835.

4.5.3.1 – Transmission and Life Cycle of Trichinella spiralis
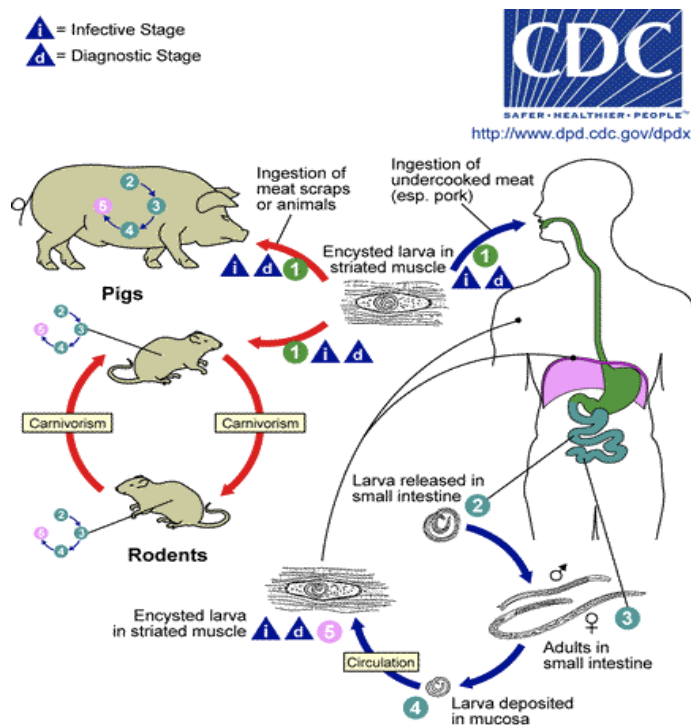
Fig 4.112 – Lifecycle of Trichinella spiralis (www.dpd.cdc.gov/dpdx/Default.htm)

Trichinosis, also known as trichinellosis or trichiniasis, is a disease caused by the ingestion of raw or undercooked pork or wild game infected with the larvae of the parasitic nematode Trichinella spiralis (common name – trichina worm).

There are eight species of Trichinella parasite, however T. spiralis is the most important of those in terms of human infection due to its worldwide distribution.

The disease is not spread by human contact. Trichinella larvae form cysts in meat, when an animal ingests this meat, the stomach acid of the animal dissolves the cyst and the worms are released into the body, maturing as adults in the upper intestine. Here the worms mate and the gravid (egg carrying) female penetrate the intestinal mucosa and deposit the larvae, which then migrate through the bloodstream, eventually becoming encapsulated in the muscles of the infected individual. People become infected when they eat the muscles of these infected animals (Hathaway & Blaney 1947; 250).
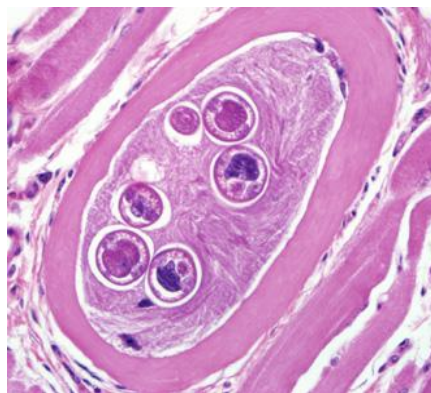
Fig 4.113 – Encysted larvae of Trichinella in muscle
(www.dpd.cdc.gov/dpdx/HTML/ImageLibrary/Trichinellosis_il.htm

4.7.3.2 – Symptoms of Trichinosis

The large majority of Trichinosis infections display either minor or no symptoms and rarely any complications. Ingesting large numbers of larvae results in gastrointestinal symptoms, such as nausea, vomiting and diarrhoea. These symptoms usually manifest themselves 72 hours after initial infection, and can last up to two weeks (Arduengo 2008; 2757).

Corresponding to the second stage of infection, while the larvae migrate through the bloodstream, fever and sweating can occur, as well as oedema (swelling) around the eyes, side of the nose, temples and hands. Once the larvae are encysted, muscle inflammation and pain, and respiratory symptoms (cough and hoarseness) may be observed. Today, many mild cases of trichinellosis are never specifically diagnosed because they are assumed to be the flu or other common illnesses (Arduengo 2008; 2757).

If the infection is severe, the person may have difficulty with coordination, as well as heart and breathing problems. Although rare, death can occur in a few acute cases. However, with mild or moderate infections, symptoms disappear within a few months (www.cdc.gov/ncidod/dpd/parasites/trichinosis.htm).

4.7.3.3 – Pigs and Trichinosis in Ancient Egypt

The inclusion of pork within the ancient Egyptian diet has long been debated. It has been generally accepted that the pig (*Sus scrofa*) was essentially abhorred and not eaten, at least until the New Kingdom but possibly as late as the Graeco-Roman Era.

Certainly, the proclivity of pigs to eat fecal matter as well as much of the garbage disposed by people in urban settings contributed to this rather negative view of pigs being unclean and impure. The parasites, *Trichinella* and *Taenia*, have often been associated with pork consumption; however, it is doubtful that the ancient Egyptians made the connection between eating pork and these diseases.

However, much of the blame for belief that the ancient Egyptians did not eat pork comes from Herodotus, who reports that the Egyptians never touched pigs and if they did so accidently, they would plunge themselves in the river to purify themselves (Bk II, 47). Herodotus' statements appear to be confirmed by, firstly, the paucity of artistic representations of swine on tomb walls as well as the very few textual references, and secondly, on the pig's association with the god, Seth – enemy of Horus and killer of Osiris (Hecker 1982; 59).

Fig 4.114 – Force feeding a pig, Tomb of Kagemni (Sixth Dynasty, Saqqara)
Some people believe this to be a puppy, not a pig (Donovan & McCorquodale 2004, pl 8.2)

Despite the scant artistic and textual references, it seems, from the butchered porcine remains found at many Pharaonic sites, that the pig was consumed, even if done so only by the lower echelons of society. The pig was, and is, a

cheap, efficient source of food for the ancient Egyptians. It has a quick growth rate and is not as demanding for protein and carbohydrates as the more prestigious domestic animals such as cattle, sheep and goats. Pigs do not require grazing land and were, for this reason, probably favoured by common people in ancient Egypt (Ikram 1995; 32).

The study of the body of the Twentieth Dynasty weaver, Nakht, confirms that the ancient Egyptian population ate pork, at least in the New Kingdom. Numerous ova from the parasite *Taenia* sp. were discovered in his intestinal tract. Unfortunately, the ova from *T. solium* (pork tapeworm) and *T. saginata* (beef tapeworm) cannot be differentiated, and therefore the species could not be identified. However, a small cyst was also discovered in the intercostal muscle of Nakht, which was recognised as *Trichinella spiralis* (Millet et al 1998; 102). The identification of this parasite suggests that the *Taenia* sp. found was a pork tapeworm, as both these parasites are caused by the ingestion of inadequately cooked pork (Millet et al 1998; 102).

Nakht was employed as a weaver in the Funerary Chapel of the Pharaoh Setnakht (first King of the Twentieth Dynasty) and it has been suggested that this association gave him access to the meat in his diet, which would normally not be present for someone of the lower class, to which he belonged (De Boni & Lenczner 1977; 117). If the meat consumed had been beef this is a perfectly sensible suggestion, however, it was most likely pork; it is also possible that Nakht's family kept pigs at their domestic location. Nakht's family may have been the in peasantry but as they went to some expense to furnish Nakht with a decorated wooden coffin, they were not at the bottom of the social pyramid.

Porcine remains have been excavated throughout the Dakhleh Oasis at Roman levels including numerous finds at Kellis (Hollett & Churcher 1999; 168). According to Churcher (2002; 106) most noteworthy of the numerous pig finds was the relative immaturity of the animals they came from when compared to the cattle samples, this suggests that the pigs were slaughtered when they approached maturity while the cows were kept for other purposes, such as milk or as draught oxen, and then killed when their usefulness was diminishing. Pig remains were found in domestic, temple and church contexts.

As the distribution of the faunal remains throughout Kellis does not indicate any preferred areas for some animals over others, it is not possible to tell if the

consumption of pork was status or class related, however it does demonstrate that Mummy A5 had access to pork.

It is interesting to note the possibility that Mummy A5 was infected with more than one type of parasite (*Schistosome* sp and *Trchinella* sp.). This does not appear to be uncommon in mummies suffering from parasitic disease. Asru, a Late Period mummy from Manchester Museum had evidence of strongyloides and schistosomiasis, and Nakht had ova from *S. Haematobium, Taenia* sp. and *Trichinella* sp. (Millet et al 1998; 101-102). It is known that there are complex interactions between clusters of diseases, such as tuberculosis and diabetes, and recently a potential linkage has also been identified between the presence of tuberculosis and helminth infestation (J Litttleton, pers. comm.). Mummies studied as part of this project, namely A5 and A101, display evidence of heavy parasitic infection. Also, previous studies have found that tuberculosis was certainly present in Kellis (Dupras et al 2001). Further work in this field has the potential for some very exciting results.

Mummy Identification Number	A5
Individual Age	Approximately 48 years
Sex	Male
Current Examination Methods	Histology
Previous Examination Methods	Gross Anatomical Examination/Autopsy
Soft Tissue Preservation % (autopsy)	96
Samples Used	Liver, skin (ear), Rib, Heart, Muscle
Previous Palaeopathological Findings	None Noted
Current Palaeopathological Findings	**Fibrosis of the liver probably caused by Schistosomiasis** **Possible encysted larval form of *Trichinella spiralis* within muscle**
Cause of Death	Not Known
Mummification Type	Five

Table 4.4 – Revised Minimum Standards Case Report – Mummy A5
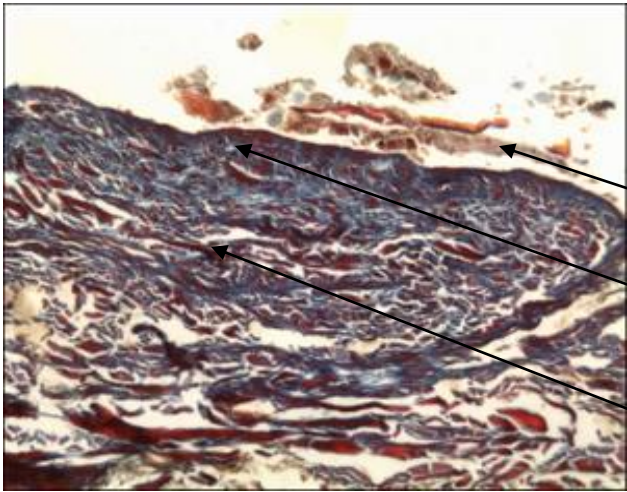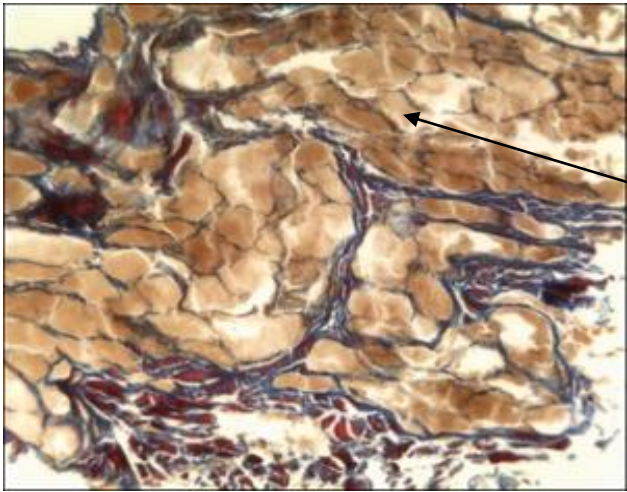
4.8 - RESULTS - MUMMY A8

4.8.1 – Skin (Ear)

The skin sample from Mummy A8 is in fairly good condition, although the epidermis has degraded and is no longer visible. Like some of the other Type Four mummies, there is a layer of sand and debris which has adhered to the skin surface, probably soon after death, at time of burial.

The dermis and adipocere remain and are both easily identified.

No pathologies could be identified.

Fig 4.115	<u>Stain – MSB</u> <u>Magnification – x10</u> Layer of sand and dirt Dermis Deep dermis
Fig 4.116	<u>Stain – MSB</u> <u>Magnification – x10</u> Fat cells with remains of adipocere
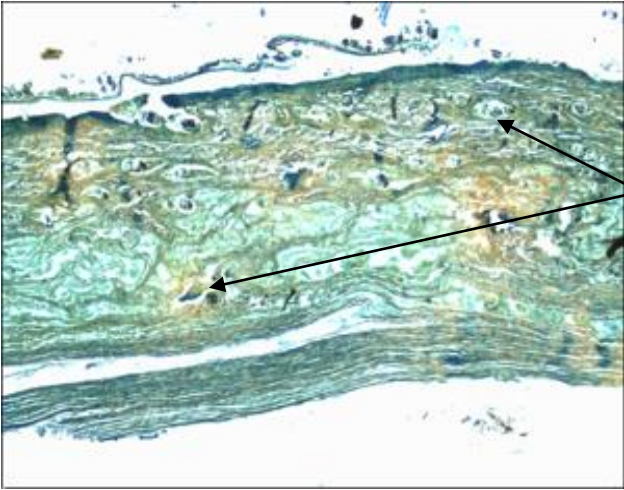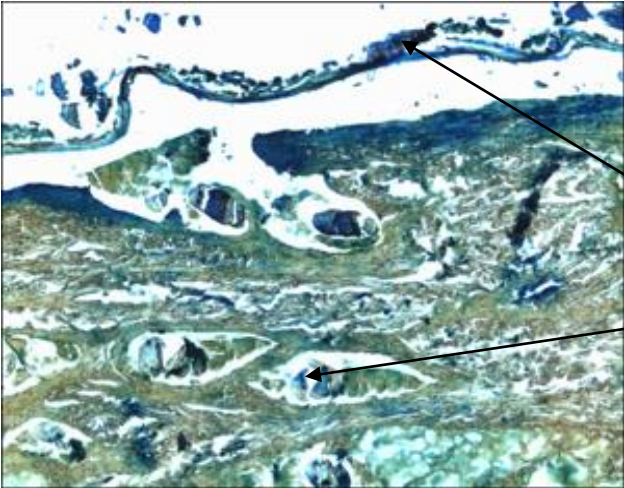
4.8.2 - Scalp

Like the skin sample, the scalp sample from Mummy A8 is in good condition. The keratinised layer can be seen just sloughing off from the rest of the sample.

Big, empty fat cells with the remains of adipocere can still be identified, as can the empty hair follicles with their associated sebaceous glands.

No abnormalities could be found.

The section has been cut at a slightly off centre angle, leaving the hair follicles more ovaloid than round as they should be.

Fig 4.117	Stain – Toluidine Blue Magnification – x1.6 Hair follicles
Fig 4.118	Stain – Toluidine Blue Magnification – x5 Keratinised layer Hair follicles and associated sebaceous glands
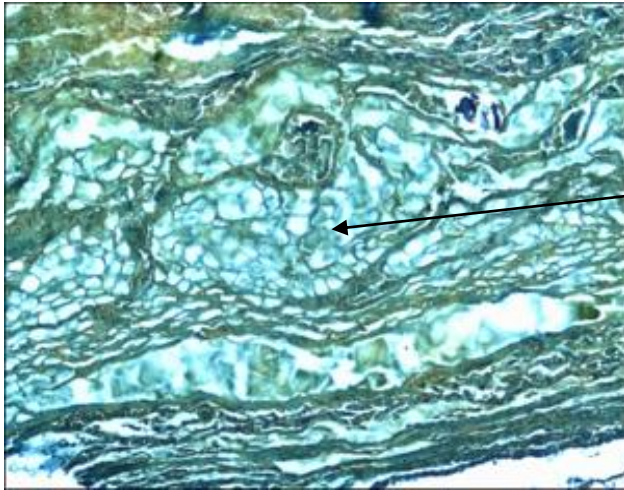
Fig 4.119

Stain – MSB

Magnification – x5
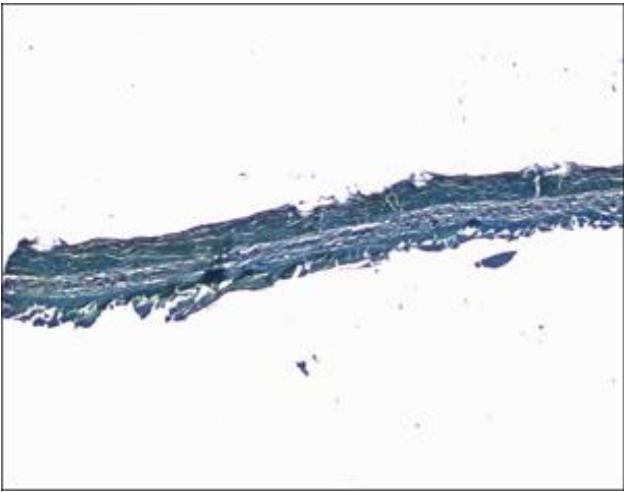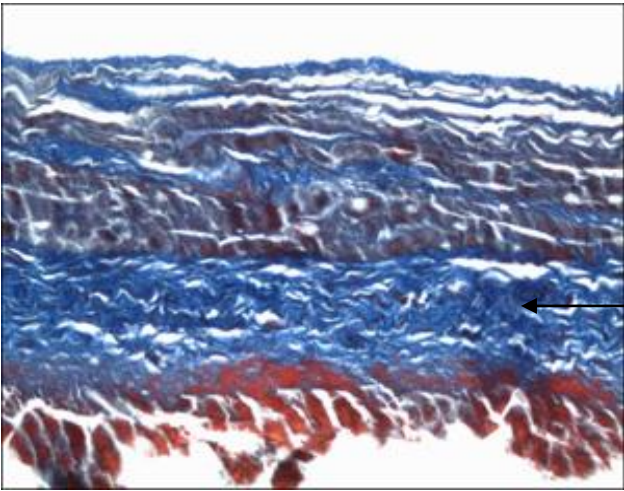
Empty fat cells

4.8.3 - Liver (Bowel)
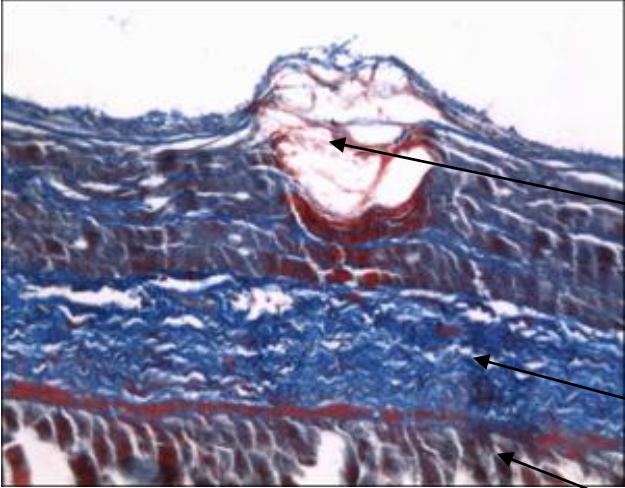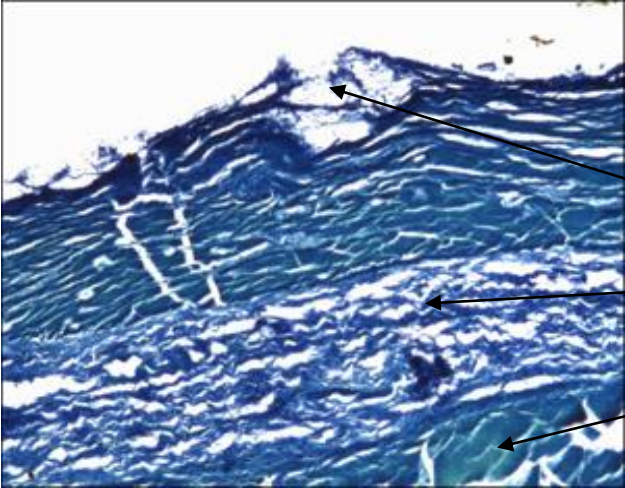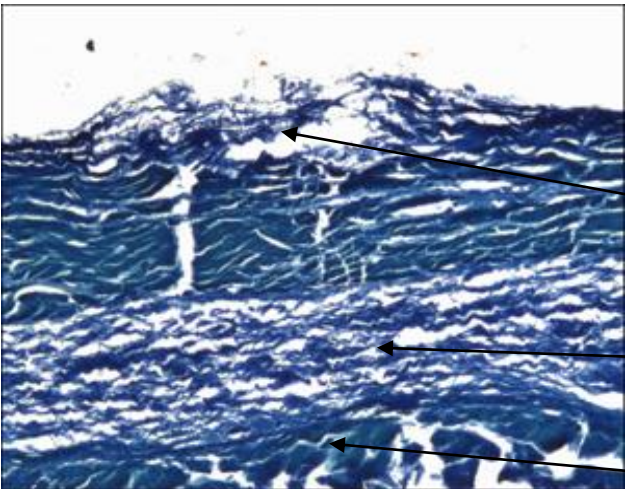
The liver sample from Mummy A8 was very well preserved, however, proved to be bowel. The sample displayed the various layers of the bowel, including muscle and the dense collagenous bowel wall.

A micro-abscess can be seen within the bowel wall. While it is right on the surface of the bowel, it is an ante-mortem pathology as the fibres are displaced but go right around and through it.

No other pathologies could be identified.

 Fig 4.120	<u>Stain – Toluidine Blue</u> <u>Magnification – x1.6</u> Bowel wall
 Fig 4.121	<u>Stain – MSB</u> <u>Magnification – x10</u> Bowel wall Collagen

Fig 4.122

Stain – MSB

Magnification – x10

Pathological entity (ante-mortem), possible mesenteric cyst

Collagen

Muscle

Fig 4.123

Stain – Toluidine Blue

Magnification – x10

Pathological entity

Collagen

Muscle

Fig 4.124

Stain – Toluidine Blue

Magnification – x10

Pathological entity (different site to Figure 4.123 above)

Collagen

Muscle

4.8.4 - Bone (Femur)

The femur sample from Mummy A8 has not been completely decalcified. While some parts of the bone show it to be in a bad state of preservation, on closer inspection, there are areas where the osteocytes can still be identified.

No pathologies can be identified.
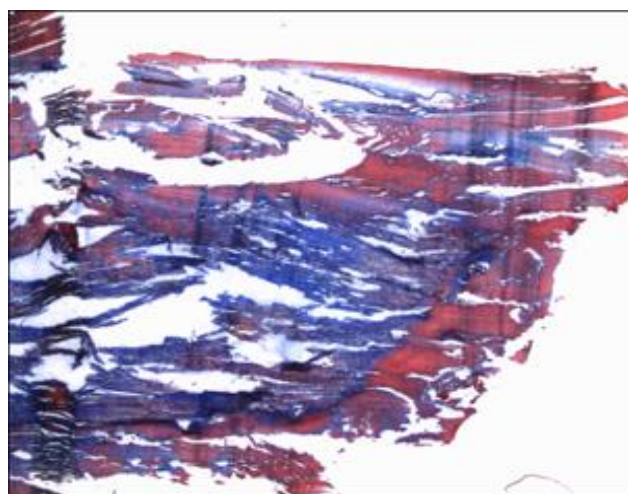
Fig 4.125	Stain – MSB Magnification – x1.6 Badly preserved femur sample
Fig 4.126	Stain – MSB Magnification – x20 Red = bad decalcification Blue = good decalcification Osteocyte
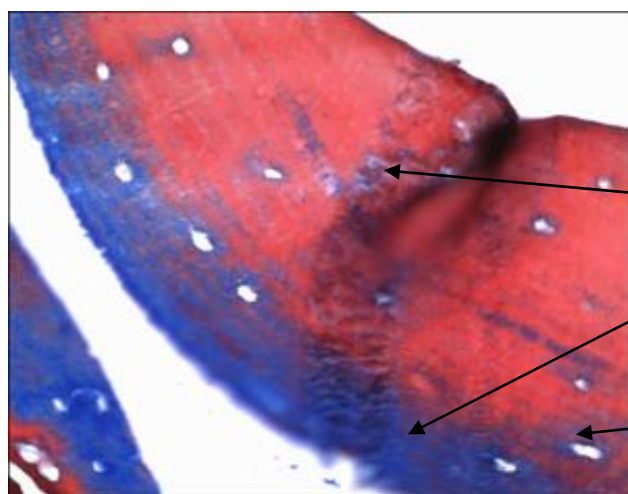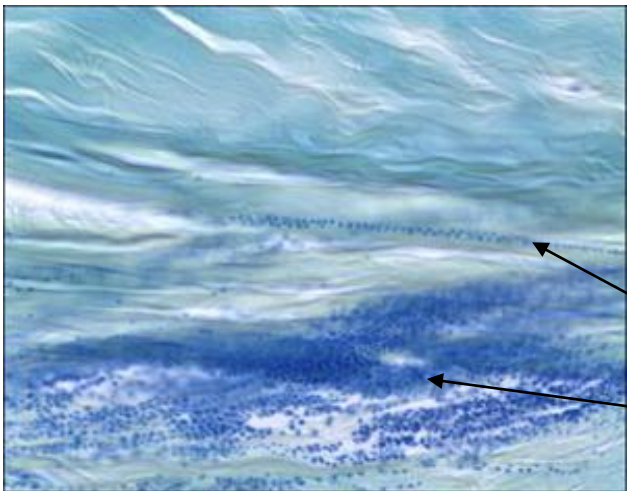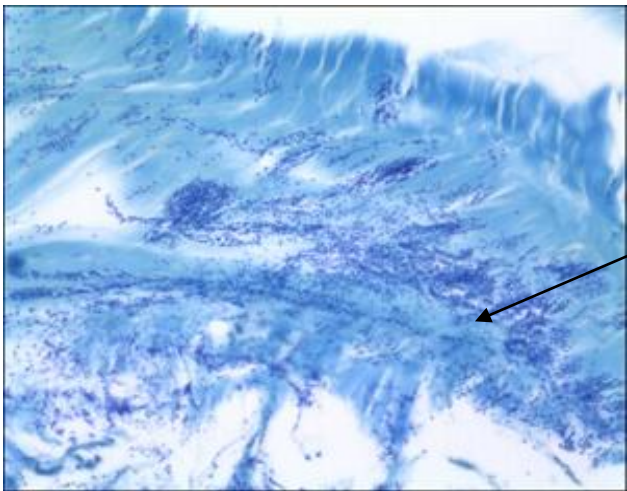
4.8.5 - Bone (Rib and Intercostal Ligament)

The sample labelled rib from Mummy A8 also included some attached intercostal ligament. Bacteria had heavily invaded both the bone and ligament, which had left them very degraded.

The bacteria can be seen in batches or lines because it is difficult for the bacteria to cross collagen, which does not produce the enzymes necessary for solubilisation.

No pathologies could be identified.

Fig 4.127	<u>Stain – Toluidine Blue</u> <u>Magnification – x40</u> Bone and Intercostal Ligament Bacteria (in a line) Bacteria (clumped)
Fig 4.128	<u>Stain – Toluidine Blue</u> <u>Magnification – x20</u> Bacteria showing advanced state of post-mortem putrefaction

4.9 - NOT GROWING OLD IN ANCIENT EGYPT – DISCUSSION OF MUMMY A8

Mummy A8 was a child of undetermined sex, aged between eight and eleven at the time of death. The body was missing all the lower extremities; it had been spontaneously mummified in the Type Four pattern.

Most of the samples from this mummy that were histologically examined were in a fair to good state of preservation. The exception to this was the rib sample, which had been heavily degraded by the action of bacteria, numerous quantities of which were still present.

The gross anatomical examination at the time of autopsy found a single ante-mortem pathology – the loss of the second left mandibular premolar tooth (Aufderheide 1993b; 8). The histological examination discovered a cyst within the walls of the bowel, a possible diagnosis of which could be a mesenteric cyst.

Mesenteric cysts are rare intra-abdominal lesions that may vary in presentation from an asymptomatic mass to an acute abdomen. If an acute form, the main symptom is abdominal pain. They occur in people of any age and are mostly asymptomatic. Their exact aetiology is unknown and they can be found anywhere in the intestinal tract from the duodenum to the rectum, however, they generally form within the mesentery of the small bowel (Chung et al 1991; 1306). Today, mesenteric cysts are atypical in children, and often misdiagnosed as appendicitis. Although rare, mesenteric cysts in children, especially between the ages two to ten years, can cause an acute intestinal obstruction (Christensen et al 1975; 352). Unfortunately, a confirmation of a diagnosis of this for A8 is not possible; however, A8 does fall into the correct age category for complications due to this condition.

Other than the possibility of a mesenteric cyst, Mummy A108 had little in the way of recognisable pathology, however, as a child; A8 was susceptible to a number of infections that would have been prevalent where hygiene was poor. Growing up in ancient Egypt was no guarantee of growing old.

4.9.1 – Children in Ancient Egypt

Infant mortality was high in ancient Egypt, just how high is unknown due to a custom among families from a range of social classes of burying their children

within settlements instead of cemeteries (Szpakowska 2007; 33). In some cultures, there is precise age at which a, infant or child would be considered fully human. For ancient Egypt, this is unknown, however, the Graeco –Roman cemeteries that have been excavated in Egypt demonstrate a lack of burials of infants below the age of twelve to eighteen months and perhaps, a status of 'human' and the burial rituals that came with this status came with the ability to walk and talk. Unfortunately, death of newborns and children must have been part of daily life for the ancient Egyptians (Szpakowska 2007; 34). However, despite number of graves being accordingly smaller than what would correspond to the mortality, graves of children have survived in various cemeteries from the Predynastic Period onwards; some displaying deep parental piety and affection (Strouhal 1997; 21). While most grave goods in the Kellis 1 cemetery could not be related to individual bodies, the number of child burials was significant. Eighteen of the 49 mummies were children under the age of twelve (Aufderheide et al 2003; 139).

While infant mortality rates were high, families were usually large (probably averaging about five surviving children) and children of both sexes were wanted and valued, not merely for emotional reasons. Children were a necessity for parents; in the absence of social security, older members of society became dependent on the younger generation. It was the eldest son who was expected to build, or complete, a tomb for his parents and then furnish it with offerings. Usually, he also took over the position his father held in the workforce when he retired becoming. The son was 'the staff of old age', at first assisting his father carry out his duties and finally to succeed him (Janssen & Janssen 2005; 131).

The most important element for a child to survive infancy was nutrition, which, in the Pharaonic Period, was supplied for the first three years of life by mother's milk. If a mother could not supply breast milk, or was a member of the elite, a wet nurse would usually be employed. If not, infants were fed milk from sheep, goats or cows (Dupras et al 2001; 204). In a study of human remains in the cemetery around the mastaba of Ptahshepses in Abusir (Late to Ptolemaic Period), it was found that three- to four-year old children died more frequently than their younger counterparts. This was interpreted as the change from breast milk to solid foods, reducing the infant's immunity and bringing about an increase of intestinal infections (Strouhal 1997; 23). This cannot be confirmed

by the child mummies from the Kellis 1 Cemetery as the range of ages is too varied, and the sample size too small, to be of any statistical use.

From tomb scenes and surviving artefacts and textual evidence, ancient Egyptian children did not differ greatly from those of today; they played games, owned toys and kept pets (Janssen & Janssen 2005; 36).

Fig 4.129 – Model feline toy with articulated jaw, New Kingdom (courtesy of the British Museum)

Life for the ancient Egyptian child was not all play and they were gradually introduced into the adult world by role-play. In rural areas of Egypt today, children as young as three-years old run errands and feed animals; by the age of twelve they fill essential roles in agriculture and the household. Boys attend herds and help till the fields, while girls look after their younger siblings, probably much the same as they did in ancient times (Janssen & Janssen 2005; 42). And, as children do today, they imitated their elders.

Fig 4.130 – Young girl imitating the mourners in the tomb of Ramose (author's own photo)

While   obviously vital

additions to the household in terms of work and the parent's need for care as they grew older, textual and artistic evidence shows that children were also held in great affection. One such depiction comes from the mastaba of the vizier Ptahshepses at Abusir; it is probably a representation of Ptahshepses and his young son. Ptahshsepses is seated with the young boy on his lap, the boy's arm resting on his father's shoulder. Such scenes were not part of the royal repertoire until Akhenaten's reign in the Eighteenth Dynasty where scenes of affection between Akhenaten, his wife Nefertiti and their six young daughters were common (Strouhal 1997; 27).

Fig 4.131 – Akhenaten kissing his young daughter (Strouhal 1997; 20)

In these scenes, from the Old Kingdom onwards, children are usually depicted with shaved heads or hair worn extremely short, apart from a single plaited sidelock, considered to be the archetypal symbol of youth (Janssen & Janssen 2005)
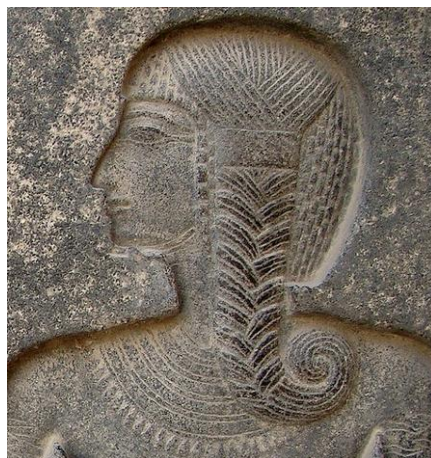
Fig 4.132 – Sidelock of youth (http://imageshack.us/photo/my-images/641/ramesesasyouth.jpg/sr=1)

The eighteen child mummies in the Kellis 1 cache showed no evidence of this sidelock. Of the three sub-adult case studies, A8 had black un-styled hair about eight centimetres long; A102 had short reddish brown hair and A129 with abundant unstyled brown hair (Aufderheide 1993b; 4, Cartmell 1998b; 4, Aufderheide 1998g; 4).

As stated above, infant mortality was high, however, if a child made it to the age of five, he or she could pretty much look forward to a full life (Brewer & Teeter 2007; 114). This does not correspond to the child mummies in Kellis 1, with fourteen of the eighteen sub-adults estimated over the age of five at the time of death. One of the main causes of death must have been the infectious diseases that spread due to poor hygiene and sanitation, although such diseases leave little evidence on human remains, skeletal or mummified. Septicaemia would have been a common occurrence with severe dental abscesses and infected wounds and parasitic diseases would be a major health problem, as they still are today. One condition that affects adults but is most usually associated with childhood is cribra orbitalia, a bone lesion of the orbital roof indicating anaemic stress. Although a study of skeletal remains from the Christian Kellis 2 Cemetery by Fairgrieve and Molto found that 54.6 percent of the population (adults and children) suffered from this condition, none of the 49 mummies from the neighbouring pagan-Roman cemetery of Kellis 1 demonstrated any signs of it (2000; 319-331).

As stated above, septicaemia would have been common in ancient Egypt, although there is a lack of evidence in the written sources and human remains to confirm this. Respiratory and gastro-intestinal tract infections are today the two most common causes of septicaemia (Pacheco 2008; 2431). Zink et al (2000; 1614-1618) examined an infant mummy (approximately eighteen months of age) excavated from the Tomb of the Nobles in Thebes-West most likely dated to the Third Intermediate Period. The body displayed macroscopic signs of anaemia and vitamin C deficiency (cribra orbitalia) indicating poor living conditions. By obtaining a sample of sterile metatarsal bone and successfully extracting ancient bacterial DNA, this study was able to confirm the presence of pathogenic and apathogenic bacteria, such as *Escherichia coli,* providing evidence of bacteremia. These findings suggest that the infant, who already had chronic anaemia and vitamin C deficiency, acquired a gastrointestinal infection, which finally led to a systemic spread of the pathogenic bacteria

(Zink et al 2000; 1614-1618). This is the first published study of this kind, and twelve years later it is still not an oft-used technique, however, the possibilities of future work of this type are exciting and could go a long way to help understand child and infant death in ancient Egypt.

 The eighteen sub-adult mummies of the Kellis 1 cemetery, including one foetus displayed little in the way of pathologies when examined by gross anatomical examination, other than some dental caries and ante-mortem tooth loss and no cause of death could be found. The three mummies histologically examined as part of the current project (A1, A102 and A8) have yielded further information, however, only Mummy A102 had a possible cause of death – aspiration pneumonia (see Chapter 4.15). We know from the excavated human remains that infant and child mortality was high in ancient Egypt but further work is needed in this area to understand exactly the reason for this, or at least to confirm our suspicions.

The sub-adult burials in the Kellis 1 Cemetery give no hint at status. There is also no suggestion that these children were treated in an inferior manner to the adult counterparts. Of the eighteen sub-adult mummies, seven had been artificially mummified, a percentage only slightly higher than that of the adults. Evidence of wrapping with linen textiles was found on half of the child mummies, approximately the same percentage as the adults. Soft tissue preservation scores ranged from zero to 100 percent and bone preservation from eight to 100 percent. Only one child had not been excerebrated (only one adult had not been excerebrated) and two had splints through the cranium and spinal canal as a method of reconstruction after looting of the Cemetery had taken place. Eleven mummies had hair remaining, and none showed any evidence for the sidelock of youth hairstyle. Five of the eighteen sub-adult mummies had not been circumcised; circumcision was unable to be determined on the other thirteen.

Eighteen sub-adult mummies is a small sample size and it really isn't possible to make any generalisations regarding the relationship between the treatment of the bodies after death and status during life. Whether or not a pattern would become clear if more mummies were examined is something to be investigated when further excavations of the Kellis 1 Cemetery take place.

Fig 4.133 – Family scene from Deir el-Medina (Strouhal 1992; 25)

Mummy Identification Number	A8
Individual Age	8 – 11 years
Sex	Undetermined
Current Examination Methods	Histology
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	32
Samples Used	Liver, Scalp, Skin (ear), Rib, Femur
Previous Palaeopathological Findings	None Found
Current Palaeopathological Findings	**Cyst in Bowel Wall**
Cause of Death	Not Known
Mummification Type	Four
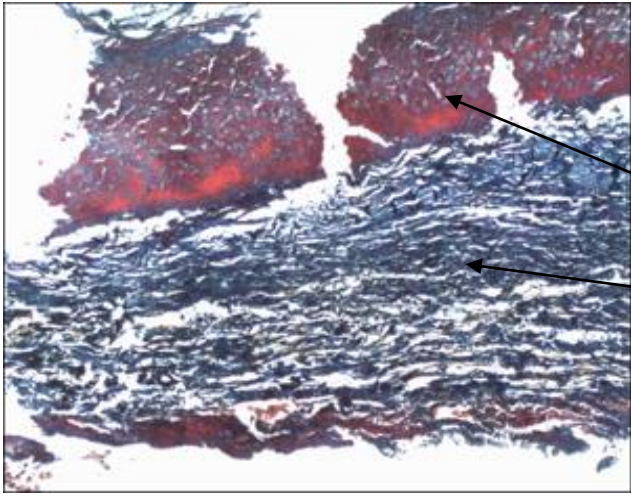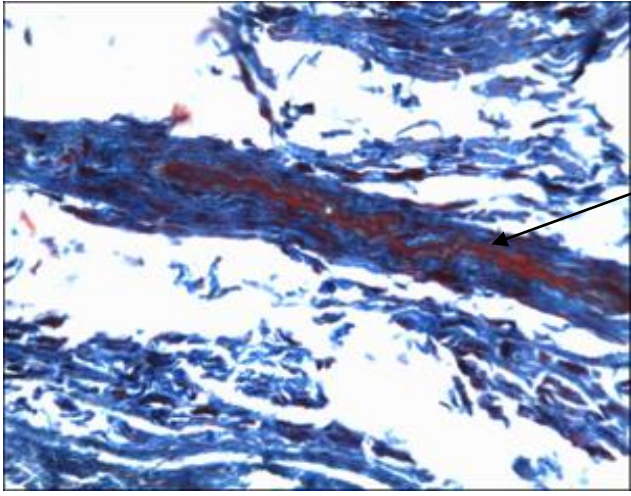
Table 4.5 – Revised Minimum Standards Case Report – Mummy A8

4.10 - RESULTS - MUMMY A13

4.10.1 - Skin (Ear)

The skin sample from the ear of Mummy A13 contained both skin and cartilage. The skin was in a poor state of preservation and it is very hard to distinguish the layers of dermis, deep dermis and subcutaneous tissue. No epidermis remained and no hair follicles or sweat glands could be identified.

Due to tissue degradation, no pathologies could be identified.

	Stain – MSB Magnification – x2.5 Cartilage Skin
Fig 4.134	
	Stain – MSB Magnification – x10 Vessel within the dermis
Fig 4.135	

4.10.2 - Colon

The sample of colon from Mummy A13 was also badly preserved and it was impossible to identify any elements other than thick collagenous walls. No intestinal contents were present.

Due to the degraded state of the tissue, no pathologies could be identified.
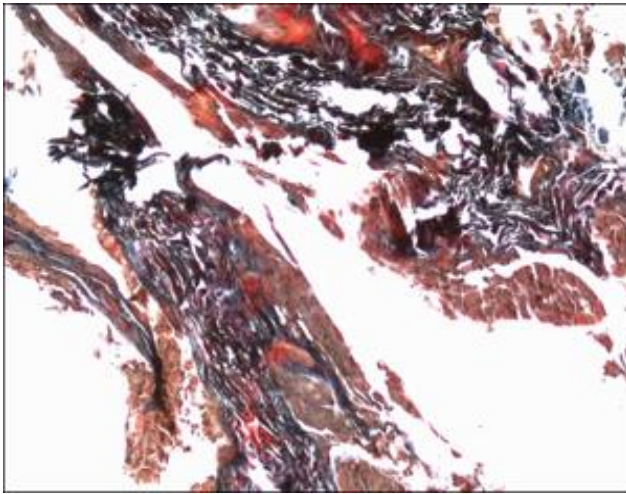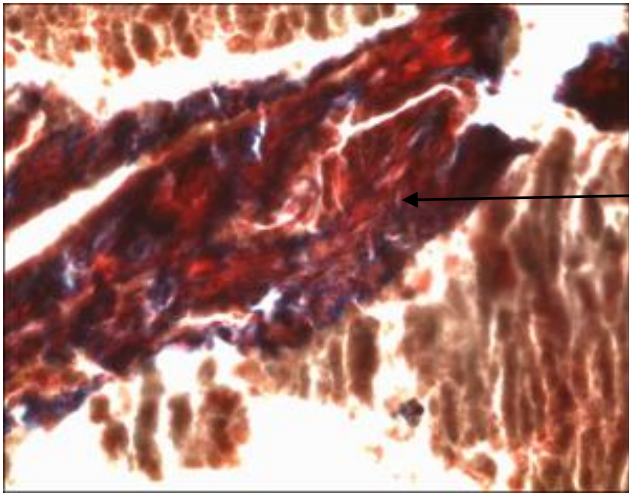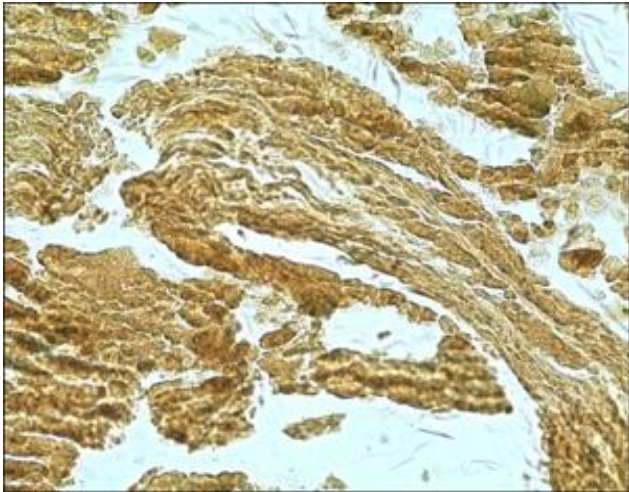
	Stain – MSB
Fig 4.136	Magnification – x5
	Badly preserved bowel sample

4.10.3 - Liver

The liver sample from Mummy A13 was extremely degraded. In one section, which was stained with toluidine blue, the sample was too degraded for the stain to bind to any of the tissue elements (see Figure 4.138 below), leaving structures impossible to visualise.

 Due to degradation, no pathologies could be identified.

Fig 4.137	Stain – MSB Magnification – x20 Unidentifiable vessel within degraded liver sample
Fig 4.138	Stain – Toluidine Blue Magnification – x20 Badly preserved liver sample

4.10.4 - Lung

The lung sample from Mummy A13 was not well preserved. Despite this, it displayed a large quantity of anthracotic- and silica-type particles within the tissue.

No other abnormalities could be identified.
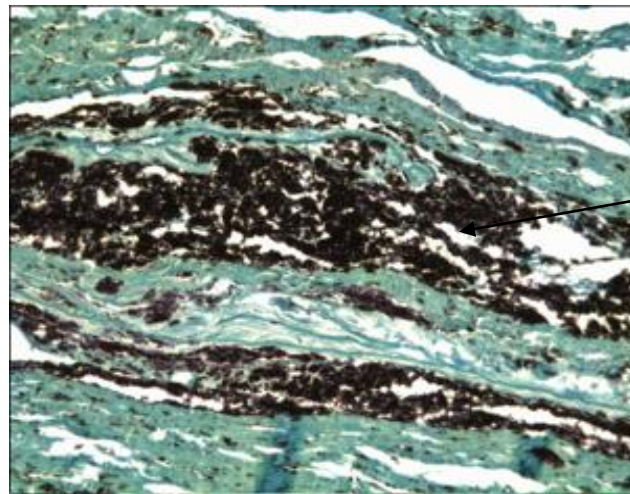
 Fig 4.139	Stain – Toluidine Blue Magnification – x10 Carbon-type pigments
 Fig 4.140	Stain – Toluidine Blue Magnification – x10 Polarised Light Microscopy Birefringent silica-type particles

4.10.5 - Muscle

The muscle sample from Mummy A13 was, like all the other soft tissue samples from this mummy, extremely degraded.

The remains of a worm can be identified, which has obviously burrowed into the sample at some point after death.

No other components or pathologies could be recognised.
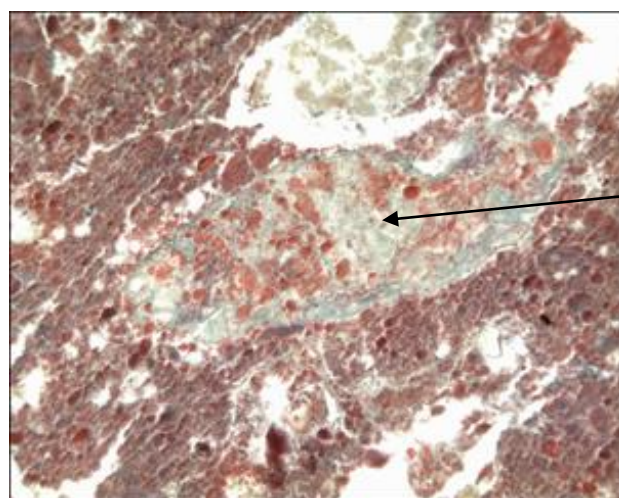
Stain – MSB

Magnification – x10

Post-mortem worm

Fig 4.141

4.10.6 - Bone (Rib)

The rib sample from Mummy A13 was in an extremely good state of preservation, the visualisation of structures as good as it would be in a modern bone sample. The sample was blocked out in acrylic resin (LR White), which could be the reason it appears in such good condition; the paraffin wax may not have been hard enough to support the sample.
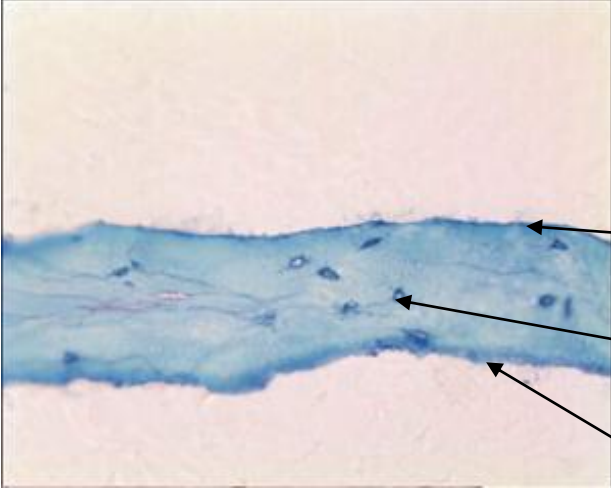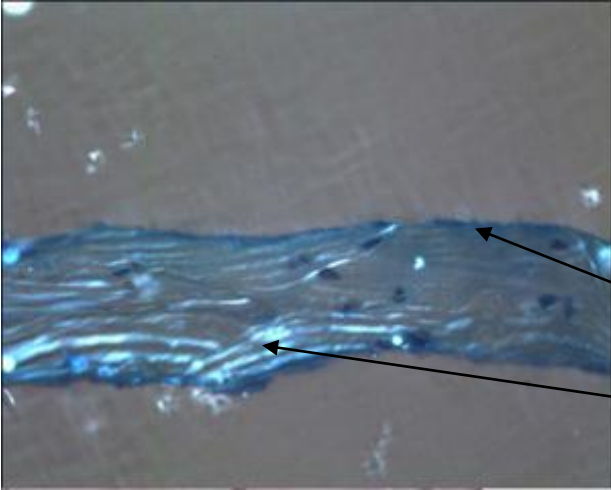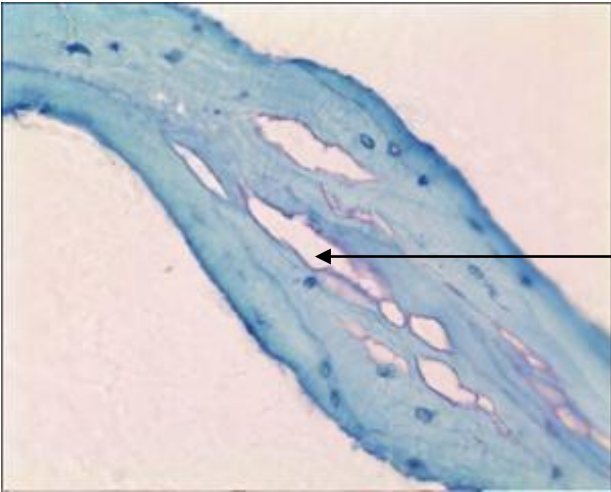
This sample is an excellent example of how bone grows. The top layer (in dark blue) is a reversal line where the osteoid would have been if a) the sample hadn't been decalcified and b) osteoid had survived the archaeological process. The bottom layer is scalloped showing the process of resorption.

When polarised light microscopy was applied the lamellae, or layers of collagen that have been laid down and mineralised, were clearly seen as birefringent lines running throughout the bone sample.

The intercostal ligament displays bacteria, which the bone does not (bacteria finding it difficult to cross lines of collagen), however in Figure 4.145, areas of the bone clearly show evidence of being eaten away by either fungi or bacteria.

Stain – Toluidine Blue
Magnification x2.5
Resin Section

Intercostal ligament

Bone
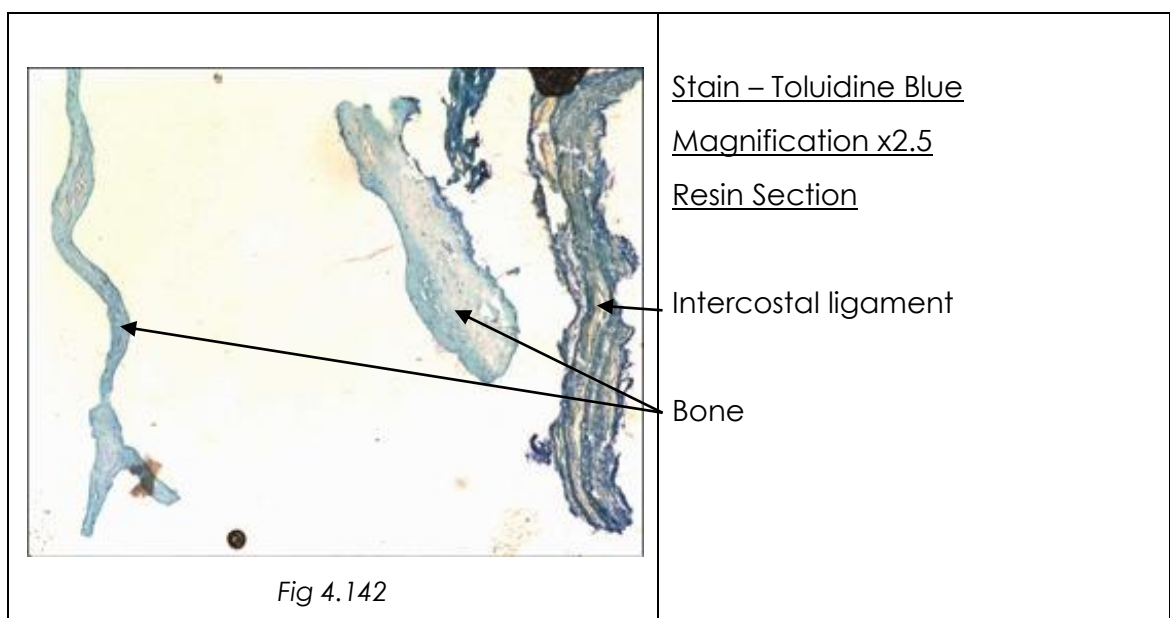
Fig 4.142

Fig 4.143

Stain – Toluidine Blue

Magnification – x20

Resin Section

Reversal line

Osteocytes and associated canaliculi

Resorption

Fig 4.144

Stain – Toluidine Blue

Magnification – x20

Resin Section

Polarised Light Microscopy

Reversal line

Lamellae (birefringent)

Fig 4.145

Stain – Toluidine Blue

Magnification – x20

Resin Section

Sections of bone digested by fungi or bacteria
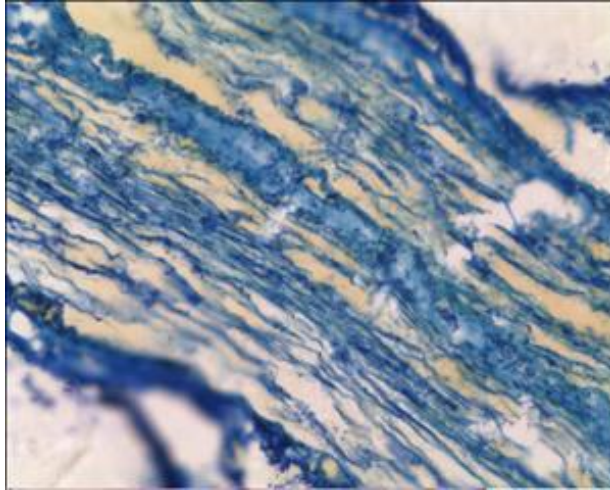
Fig 4.146

Stain – Toluidine Blue
Magnification – x20
Resin Section

Intercostal ligament with well-preserved collagen fibres (stained blue)

4.11 - GETTING OLD IN EGYPT – DISCUSSION OF MUMMY A13

The soft tissue samples from Mummy A13 were disappointing in terms of preservation levels. All were extremely degraded and did not allow for any detailed analysis. Mummy A13 was mummified in the Type Four pattern (resin on the skin's surface only); other bodies of this mummification type fare much better in relation to preservation (A1, A4, A8, A101, A102 and A108 - although some of the soft tissues from these mummies only survived because of their diseased state). While it is unusual for all soft tissues of a Kellis 1 mummy to be in a good state of preservation (only A1 and A101 in this project) but it is also rare for all tissues to be this degraded. At the time of autopsy, the tissue preservation score was given as 99 percent (Zlonis 1993b: 3), which confirms that gross visual examination is not an accurate method of preservation assessment if the tissue is to be used in other scientific techniques.

The skin sample was lacking an epidermis suggesting that either Mummy A13 was either wrapped and the textiles removed taking the epidermal layers with them, or and possibly the more likely cause given the state of the other soft tissues, the body was left to decompose for some time before the resin was poured on it and buried in the hot dry sand of the tomb (Birrell 1999; 35). All the other soft tissue samples (colon, liver, lung and muscle) also displayed decomposition indicating autolysis and putrefaction had taken hold before being halted by resin application or burial.

The rib sample by contrast was in a wonderful state of preservation, similar to that of fresh tissue, although bacteria have dissolved some small areas within the sample. It demonstrates a healthy bone in the processing of growing. Osteoid would have been deposited on the top of the sample, and at the bottom, osteoclasis has taken place.

Mummy A13 is the eldest in terms of chronological age of the ten case study mummies. His age at death was over 55 years, well above the average life expectancy of an ancient Egyptian, Greek or Roman (Zlonis 1993b; 1). The state of A13's lungs support the age at death estimation. There were large accumulations of carbon- and silica-type particles, expected for someone who had spent 50 or so years breathing in sand and soot.

No pathologies could be identified from the histological examination of Mummy A13. The presence of a disease state cannot be ruled out for the soft tissues, however, they were so badly degraded that none could be visualised, other than the carbon- and silica-type particles in the lungs. The rib sample appeared to be healthy. The autopsy in 1993 recorded dental problems, osteoarthritis and osteophytosis (Zlonis 1993b: 8), all relating to aging; proving that growing old in ancient Egypt could be filled with unpleasant and unwanted degenerative changes, much like it is today, but it was better than the alternative.

4.11.1 – Growing Old in Ancient Egypt

The Teachings of Ptahhotep

My Sovereign Lord:

Old age had arrived, infirmity has descended,
Misery has drawn nigh, and weakness increases.
One must take a nap like a child every day,
The eyes are blurred, the ears are deaf,
And vigour wanes because of weariness.
The mouth is silent and no longer speaks;
The memory is gone and cannot recall even yesterday.
The bones ache through frailty,
Pleasure has become repulsive, and all taste has vanished.
What old age does to men is totally despicable (Simpson 2003; 129-130)

The Egyptians did not like the consequences of growing older, as is clearly illustrated by the passage above, but what was old to an ancient Egyptian?

Although far from numerous, artistic representations of elderly ancient Egyptians occur throughout Egyptian history, especially in the tombs of the elite. These depictions are of both the venerable tomb owner and of the working class, although there are differences in the type of portrayal. For example, the tomb owner will have his grey hair or baldhead covered by a wig, be wearing a mid-calf length kilt, shown with pendulous breasts and a spreading waistline; all intended to confirm him prosperous life. The peasant workmen are often shown

with tufty and/or greying hair, lacking the dignity of the elderly officials (Robins 2008; 76).


Figs 4.147 & 4.148 – The aging nobleman is depicted with dignity, whereas the peasant worker is balding, grey-haired and portly (Donovan & McCorquodale 2004; pl 1.3 &2.7)

In modern times, old age can usually be identified by the age at which a person retires. However, in ancient Egypt chronological age is unlikely to be a factor. It is rarely mentioned in any literary texts or even in autobiographies written on tomb walls, which focus on social and career achievements and the resulting promotions. The life stage at which these were attained is only mentioned in the most general of terms. The exception to this is the magic age of 110 years, reference to which can be found in a number of literary texts (Janssen & Janssen 2005; 167). Unfortunately for the ancient Egyptians, this magic age was rarely obtainable.

Textual sources have proved useful in calculating the average lifespan of the ancient Egyptians at particular time periods. During Old, Middle and New Kingdoms, some officials had biographies placed on their tomb walls, or on temple statues, in order to show how accomplished they were during life. However, no dates of birth are given and any mention of age is rare, beyond vague references to having lived a long life. In the Ptolemaic Period, biographies began to include date of birth, father's name and date of death and sometimes, burial. In a very small study (fourteen males, five females), Grapow calculated the average age of males to have been 54 and women 58. This is exceptionally high until it is realised that all individuals under 25 had been excluded because until that age, a person was not entitled to a biography (Strouhal 1997; 254).

Baratte & Boyeval (1974; 155-264) carried out a more wide-ranging study on the biographical details given on wooden mummy labels dated to the Roman Period. Mummy labels were used during the Graeco-Roman Period and are small wooden, or limestone, writing tablets that actually served as tax receipts and tied around the necks of mummies so they could be identified. The sheer number of mummy labels in collections around the world means they can be used as an invaluable virtual census for Ptolemaic and early Roman Period. Baratte & Boyeval studied 1211 tags (all of which came from the district of Panopolis), of which 279 stated ages at death. From this the average lifespan was 25.4 years (males – 27, females – 22).
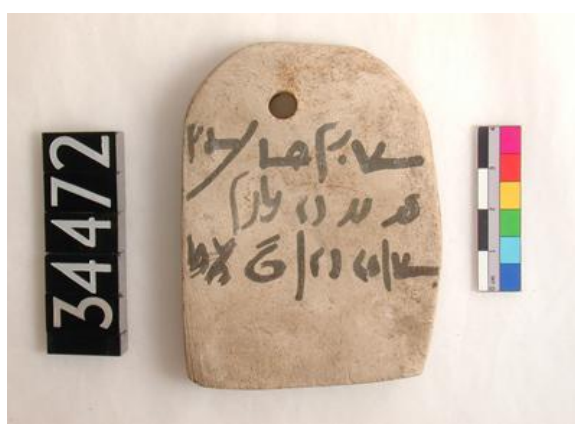
Fig 4.149 – Limestone Mummy Label
(www.digitalegypt.ucl.ac.uk/mlabels/index.html)

Studies of human remains have also proved the reality to be far fewer than 110 years. In a Cemetery of the Late Ptolemaic Period at Abusir, a sample of 296 individuals gave an estimated average lifespan of 19.5 years. The same excavators studied a further 606 bodies from a third to fifth century CE cemetery at Wadi Qitna in Nubia, this time the mean age at death was only slightly better at 20.1 years (Strouhal 1997; 256).

While much is made of the long life enjoyed by the Pharaoh Ramesses the Great, few other of Egypt's rulers reached an advanced age. The radiographic examination of 26 pharaohs and queens, carried out by James Harris and Edward Wente revealed that only Ramesses had reached an age of 55 years, and only three other mummies (Merneptah, Ramesses IV and Amenhotep II) died between 40 and 50. According to the x-ray evidence, the others died between the ages of 20 and 40 (Tutankhamun, who lived for

approximately 19 years, was not included in this study) (Harris & Wente 1980; 206-211).

The small number of Kellis 1 mummies means that lifespan cannot really be assessed for this community. However, of the 49 mummies that have been examined and ages at death assigned, 26 percent of males were over 40 years old at time of death; for females the number is even more impressive with 45 percent of women being over 40 at death, although it must be noted there were only eleven female mummies in the Kellis 1 cache. Even so, at 55, A13 had enjoyed a higher than average length of life.

In the current era, 55 is not considered to be particularly elderly, however, to the ancient Egyptians, at age 40, all expected of a person had been done, he was now deemed elderly and it was time to enjoy the fruits of his labour, as is made clear by this Demotic wisdom text (100 CE) from the Papyrus Insinger (Leiden):

[A man] spends ten years as a child before he understands death and life.
He spends another ten [years] acquiring the instruction by which he will be able to live.
He spends another ten years earning and gaining possessions by which to live.
He spends another ten years up to old age, when his heart becomes counsellor.
There remain sixty years of the whole life, which Thoth has assigned to the man of god (Strouhal 1997; 254).

While wishing to advance to old age, the deterioration of one's body was not welcomed by the ancient Egyptians. In an effort to turn back time, the Papyrus Ebers has twelve prescriptions to cure the loss of hair (Prescription 464-474) and thirteen to prevent hair from turning grey (451-463) (Bryan 1974: 165). However, far more painful than a greying or balding head were the common ailments that have been discovered in most adults of a certain age from ancient Egypt. Mummy A13 is a good example of this. As stated above, he had a large quantity of carbon- and silica-type particles in his lung. This may have caused him no distress, or at worst, breathing difficulties (Aufderheide & Rodriguez-Martin 1998; 265-266). A13 also suffered from skeletal diseases in the form of osteoarthritis and osteophytosis as well as the dental pathologies of caries and ante-mortem loss of eighteen teeth (Zlonis 1993a). In other words, A13 was old

and he would have felt it and, judging by the number of men and women that made into their 40s and 50s at Kellis, he would not be alone.

Histologically speaking, the examination of the tissues from Mummy A13 achieved three points of note. Firstly, it confirmed that tissue preservation score given at the time of gross examination is not always accurate or useful if samples are to undergo a further scientific analysis. Histology and microscopy can give a more precise evaluation of tissue viability for techniques such as ancient DNA retrieval. Secondly, the histological examination of the rib sample demonstrated an excellent example of how normal healthy bone grows and finally, the large accumulation of particulates within the lung sample was consistent with the age at death estimation given in the autopsy report.

Fig 4.150 – The hieroglyph sign denoting old age (Gardiner sign list A20). According to Loeble and Nunn (both medical professionals), the old man is accurately depicted with osteoarthritic nodular joint enlargements in their typical distribution, acromioclavicular, metacarpophalageals of the right hand and a bunion of the first metatarsophalangeal joint of his front foot. The stoop could be due to various causes, the most common of which would be anterior wearing of the vertebral bodies in the thoracolumbar spine (Loeble & Nunn 1997; 450-454).

Mummy Identification Number	A13
Individual Age	55+
Sex	Male
Current Examination Methods	Histology
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	99
Samples Used	Colon, Liver, Lung, Muscle, Skin (ear), Rib
Previous Palaeopathological Findings	Osteoarthritis, Osteoporosis, Dental Caries, Ante-mortem Loss of 18 Teeth
Current Palaeopathological Findings	**Anthracotic-type, Silica-type Particulate Accumulation in Lungs**
Cause of Death	Not Known
Mummification Type	Four

Table 4.6 – Minimum Standards Case Report – Mummy A13

4.12 - RESULTS - MUMMY A101

4.12.1 – Skin (Ear)

The skin sample from the ear of Mummy A101 was in a good state of preservation, although there was no remaining identifiable epidermis, suggesting the mummy had been wrapped at the time of burial.

Hair follicles were displayed but no hairs remained within. The chondrocytes in the cartilage of the ear still had the visible remains of nuclei.

No pathologies could be identified.

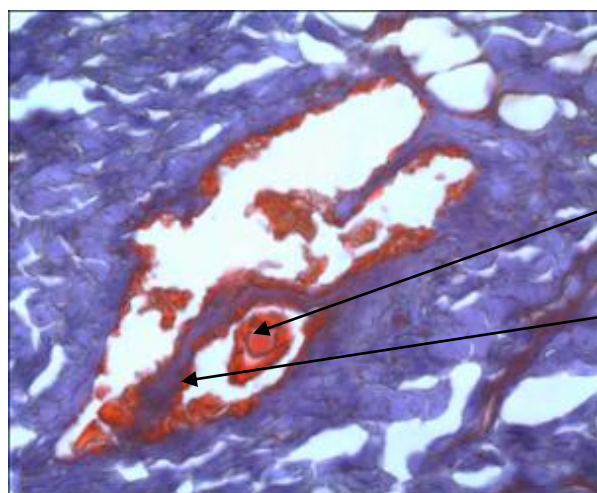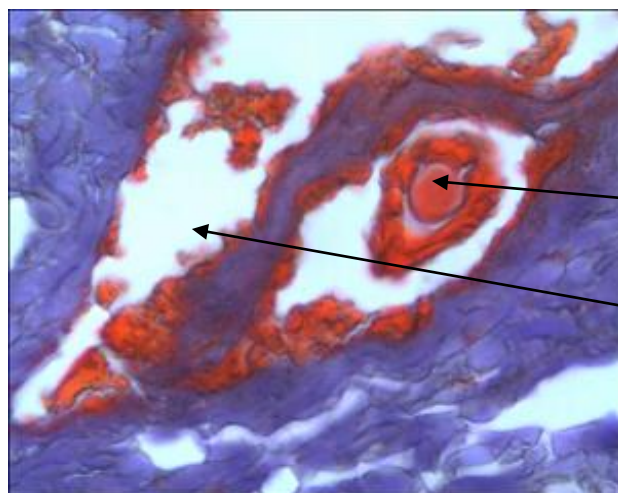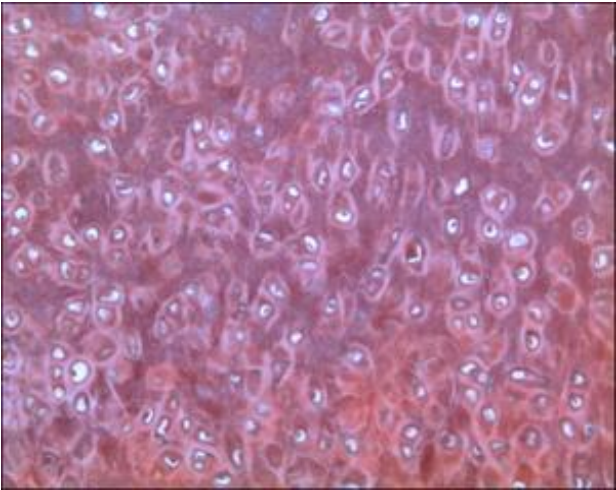|	
Fig 4.151	<u>Stain – MSB</u> <u>Magnification – x20</u> Hair follicle Sebaceous gland
Fig 4.152	<u>Stain – MSB</u> <u>Magnification – x40</u> Hair follicle Sebaceous gland
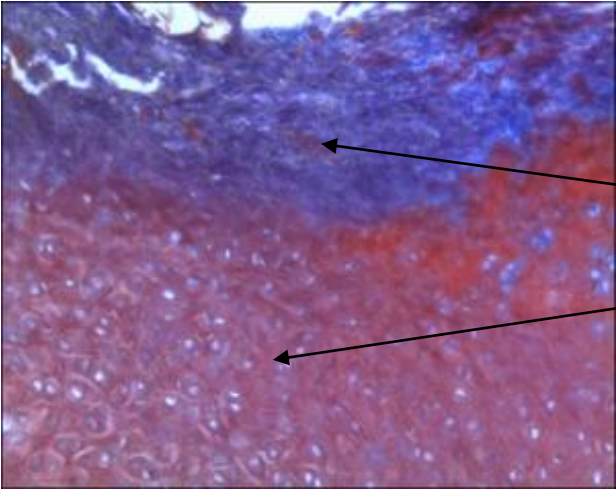
Fig 4.153

Stain – MSB

Magnification – x10

Dermis

Cartilage

Fig 4.154

Stain – MSB

Magnification – x20

Cartilage with cells still containing nuclei within the chondrocytes

Fig 4.155

Stain – MSB

Magnification – x40

Cartilage

Chondrocyte cells with nuclei

4.12.2 - Coprolite

The coprolite sample from Mummy A101 displayed an excellent state of preservation. Plant remnants were still identifiable, as were the remains of parasite ova.

The visible plant remnants included seeds from cereal plants and soft, fleshy fruit and/or vegetable as evidenced by the large, thin-walled, empty cells.

It was clear from this coprolite material that Mummy A101 was heavily infected by intestinal parasites as the remains of a large quantity of helminth ova could be seen throughout the sample.

Fig 4.156	<u>Stain – Haematoxylin and Eosin</u> <u>Magnification – x5</u> Parasite ova Plant material

Fig 4.157

Stain – <u>Haematoxylin and Eosin</u>

Magnification – x2.5

Outer part of seed

Starch

Parasite ova

Fig 4.158

Stain – <u>Toluidine Blue</u>

Magnification – x10

Outer seed coat

Starch

Fig 4.159

Stain – <u>Toluidine Blue</u>

Magnification – x10

Starch

Parasite ova

Stain – Giemsa

Magnification – x10

Sieve tube (plant material)
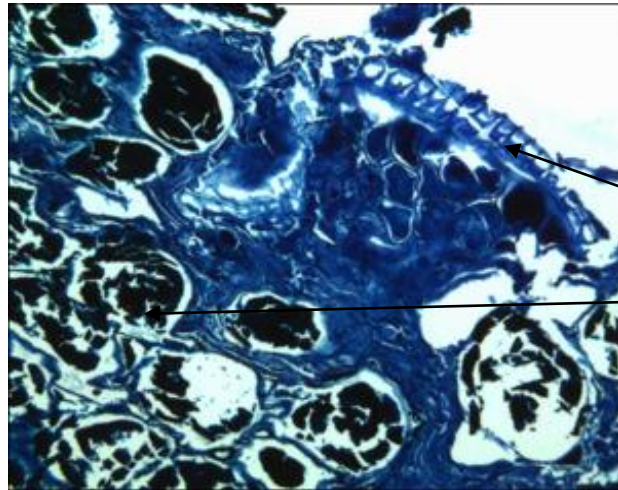
Parasite ova
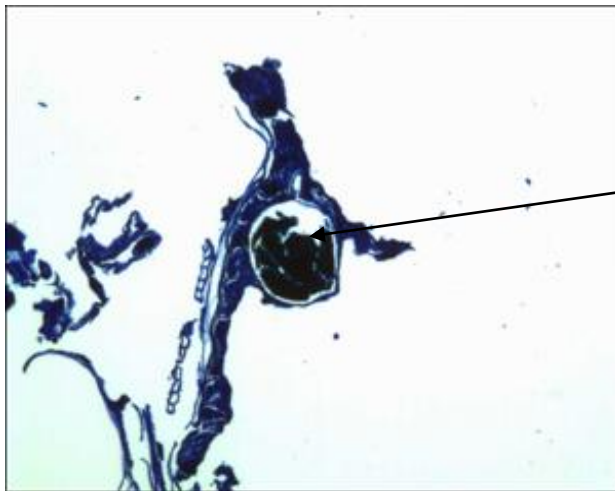
Fig 4.160

Stain – Giemsa

Magnification – x10

Parasite ovum
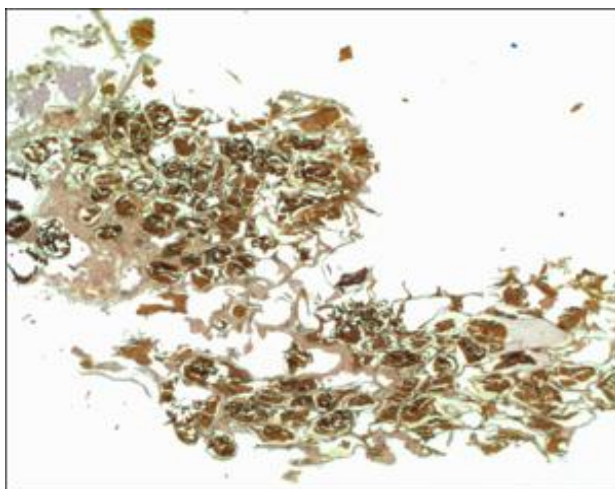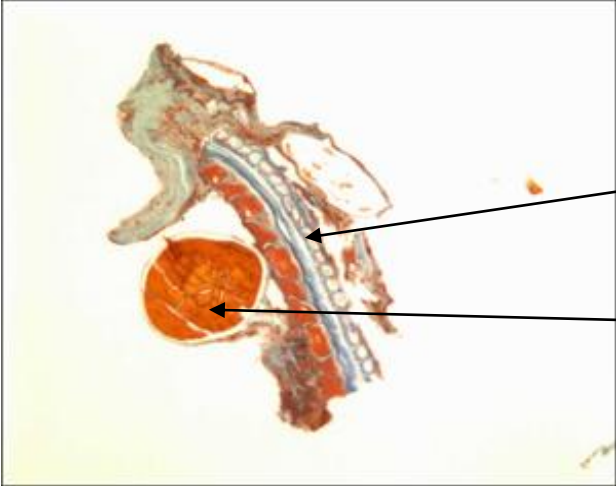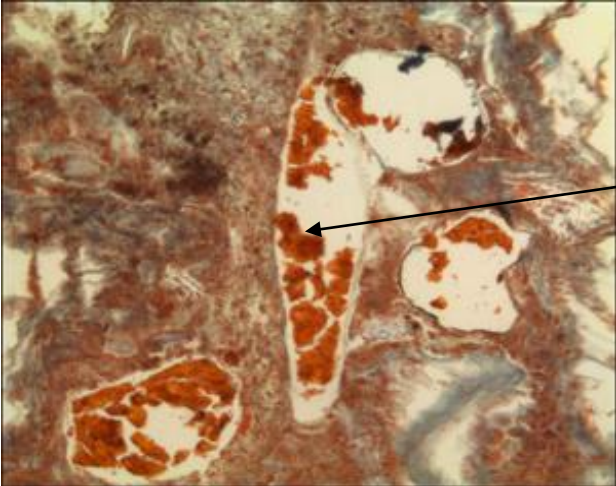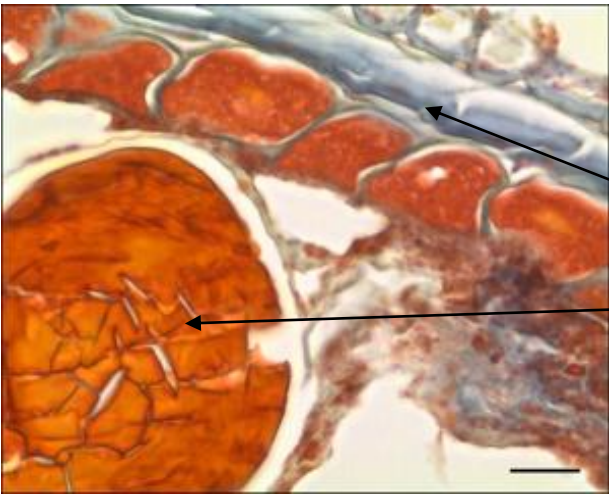
Fig 4.161

Stain – Haematoxylin and Eosin

Magnification – x2.5

Numerous parasite ova

Fig 4.162

Fig 4.163

Stain – MSB

Magnification – x10

Outer part of seed

Parasite ovum with internal structure crystallised

Fig 4.164

Stain – MSB

Magnification – x10

Misshapen parasite ova

Fig 4.165

Stain – MSB

Magnification – x40

Outer pericarp
Seed coat
Aleurone layer

Parasite ovum with crystallised internal structure

Scale bar = 25 microns

Stain – MSB

Magnification – x5
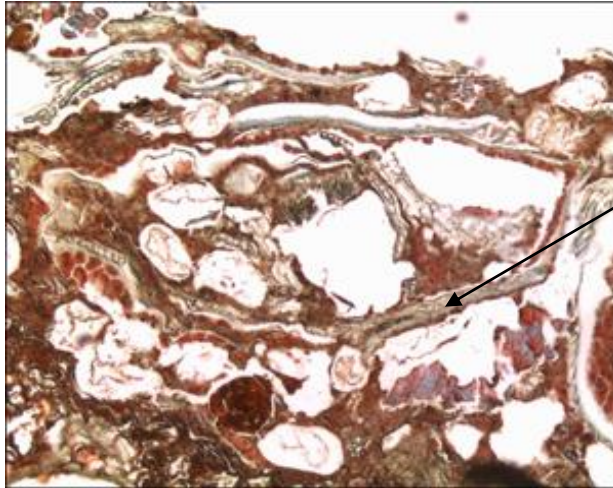
Remains of a seed

Fig 4.166

Stain – MSB

Magnification – x40

Sieve tube

Fig 4.167

Stain – MSB

Magnification – x40

Sieve tubes at a different orientation
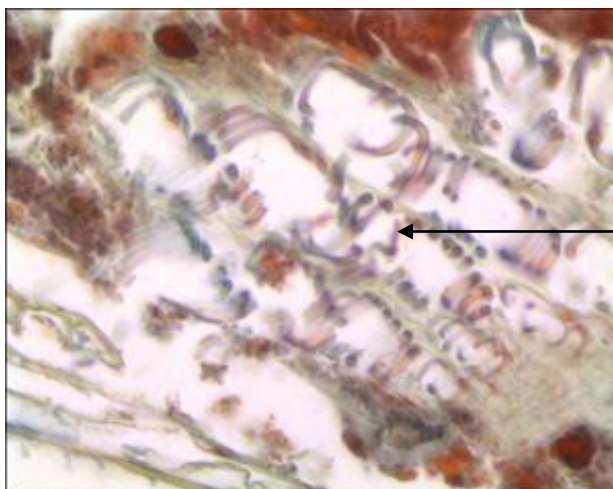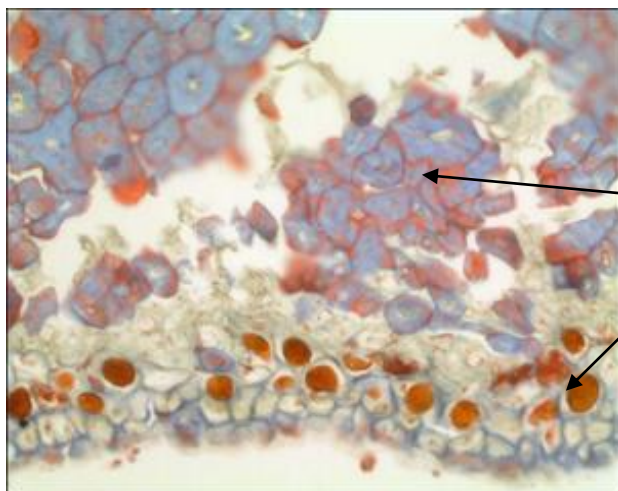
Fig 4.168

Stain – MSB

Magnification – x20

Starch

Outer part of seed

Fig 4.169

Stain – MSB

Magnification – x20

Polarised Light Microscopy

Starch under polarised light
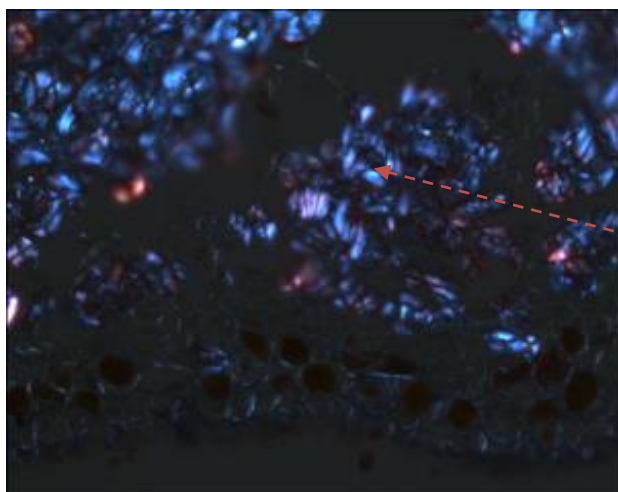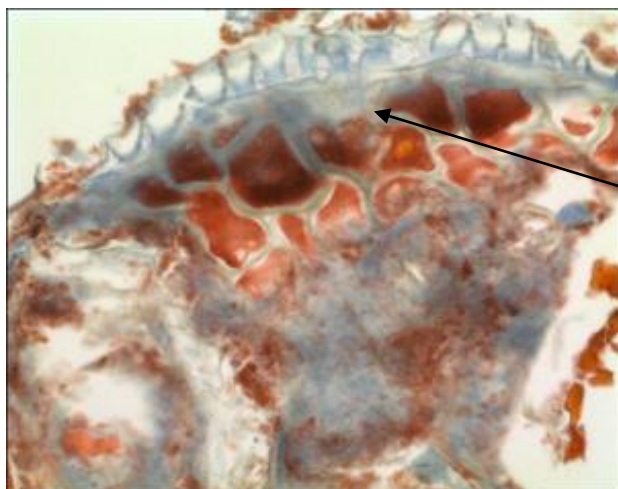
Fig 4.170

Stain – MSB

Magnification – x20

Part of a seed
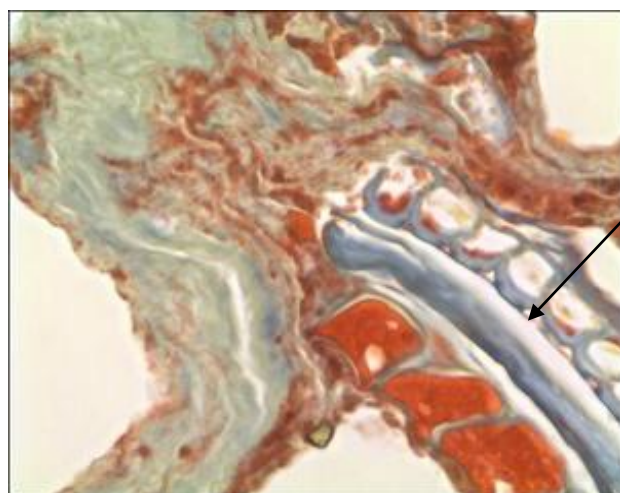
Fig 4.171

Fig 4.172

Stain – MSB

Magnification – x40

Outer part of a seed
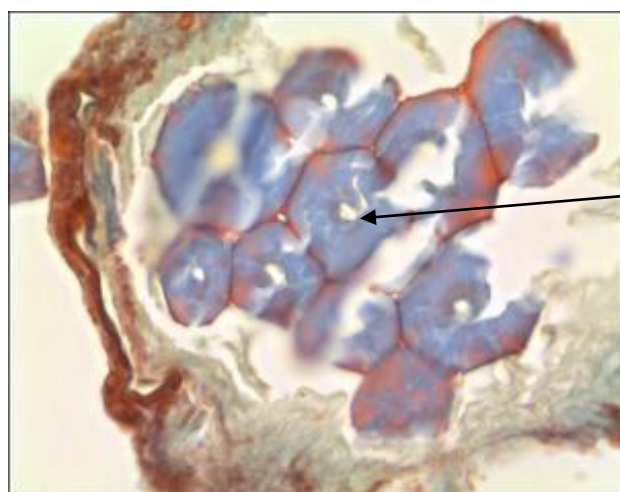
Fig 4.173

Stain – MSB

Magnification – x40

Starch

Fig 4.174

Stain – MSB

Magnification – x40

Plant remains
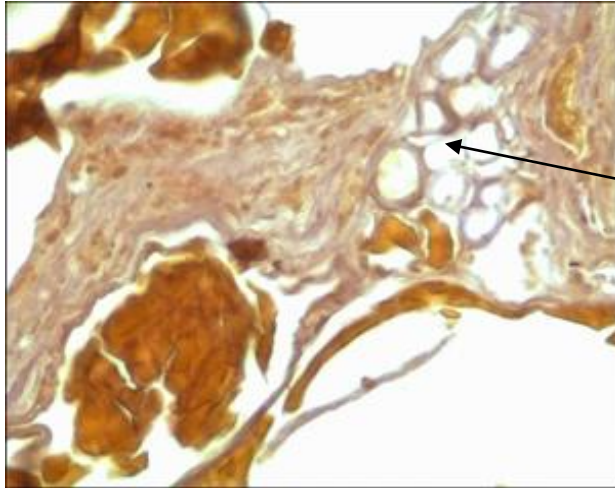
Fig 4.175

Stain – Haematoxylin and Eosin

Magnification – x40
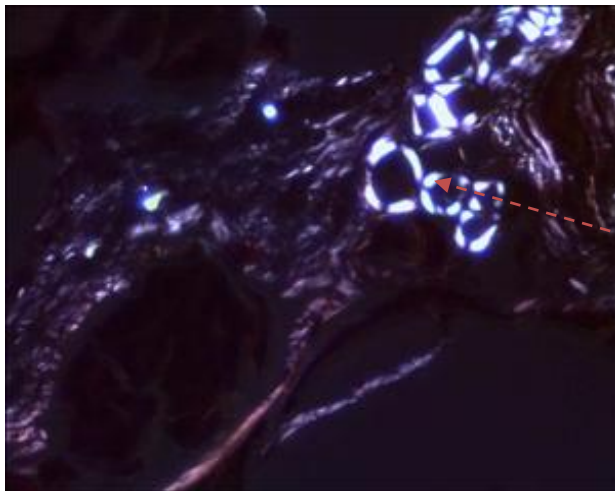
Sieve tubes

Fig 4.176

Stain – Haematoxylin and Eosin

Magnification – x40

Polarised Light Microscopy

Sieve tubes under polarised light
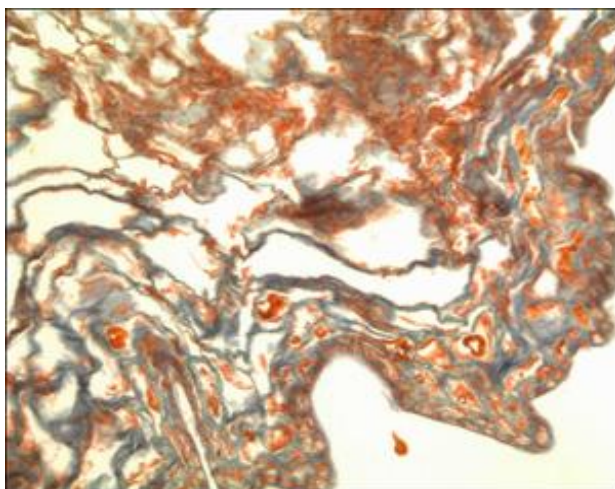
Fig 4.177

Stain – MSB

Magnification – x10

Plant remains

|
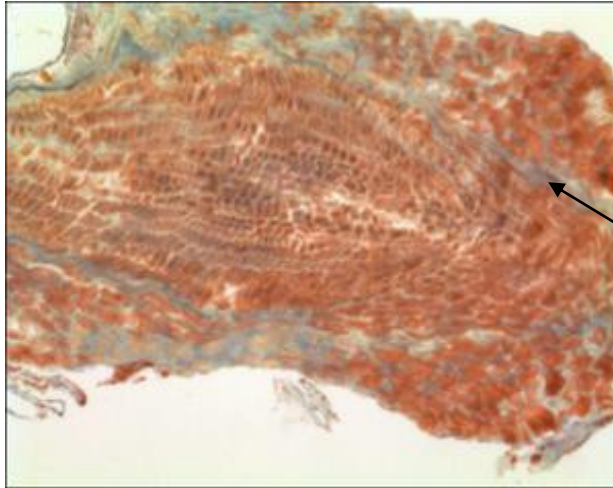
Fig 4.178 | Stain – MSB

Magnification – x20

Plant material with seed coat (stained grey) |
|
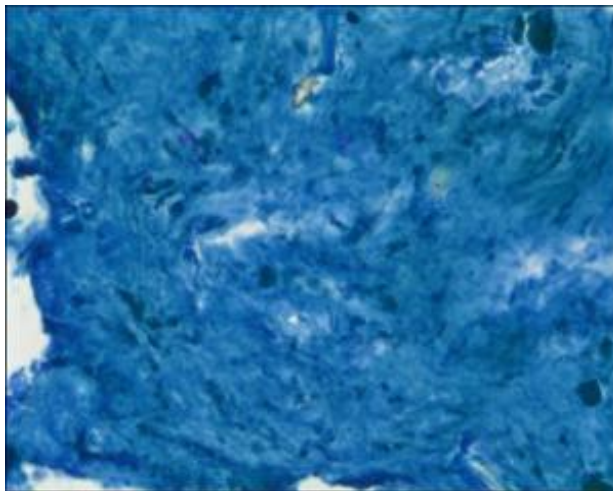
Fig 4.179 | Stain – Toluidine Blue

Magnification – x40

Fibrous connective tissue |
|
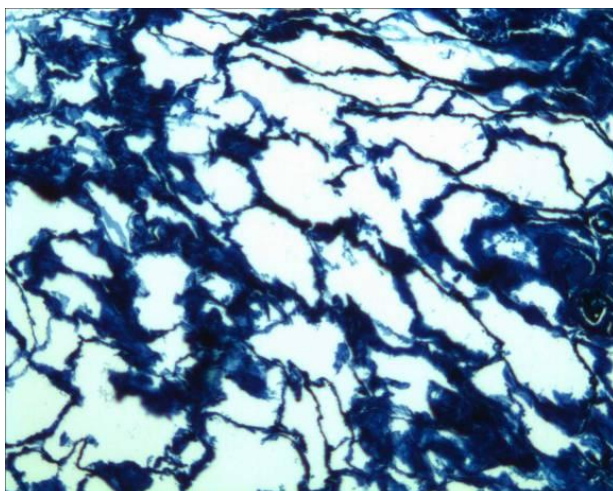
Fig 4.180 | Stain – Toluidine Blue

Magnification – x10
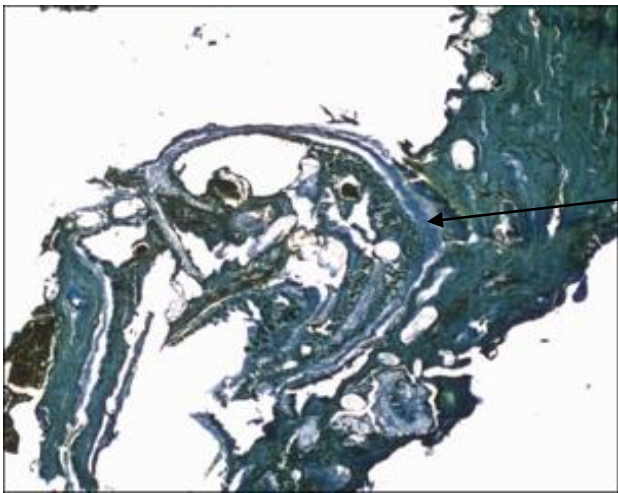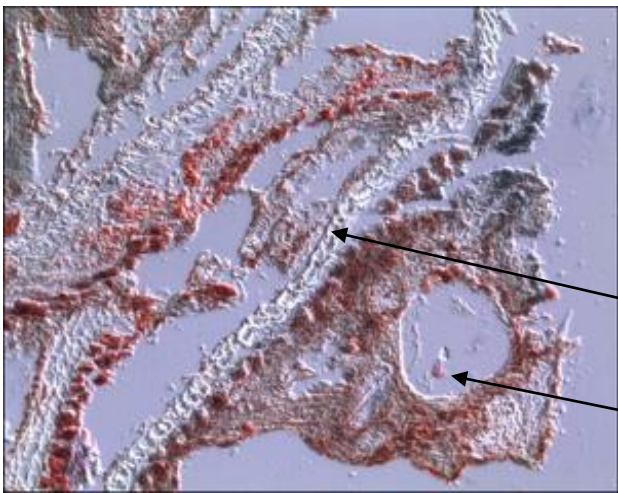
Relatively large empty cell walls characteristic of soft fruit material |

4.12.3 - Liver (Bowel)

The sample identified as liver at the time of autopsy (Cartmell 1998a; 6) contained both plant remains and parasite ova, making it most likely to be another sample of coprolite material. It did not show any characteristic features of liver.

While liver samples tend to be of poor histological preservation, this coprolite sample was well preserved.

The MSB stain displayed the plant material extremely well while the toluidine blue was much better for showing some of the internal structures of the parasite ova.

Fig 4.181	Stain – Toluidine Blue Magnification – x2.5 Outer seed coat
Fig 4.182	Stain – MSB Magnification – x10 Differential Interference Contrast Microscopy Seed coat Empty parasite ovum
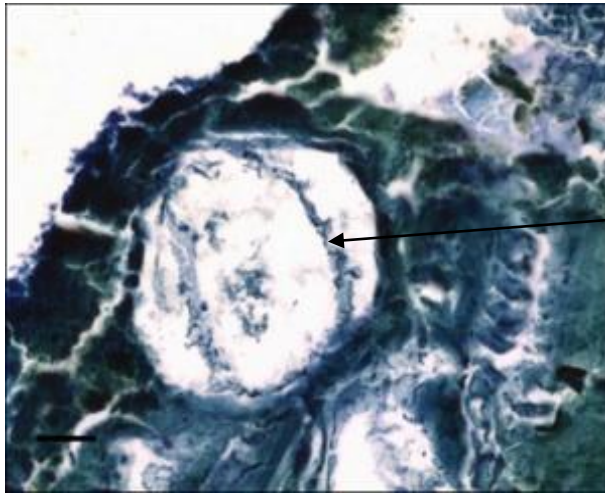
Fig 4.183

Stain – Toluidine Blue

Magnification – x40

Internal structure of parasite ovum coming away from its surrounds

Scale bar = 25 microns
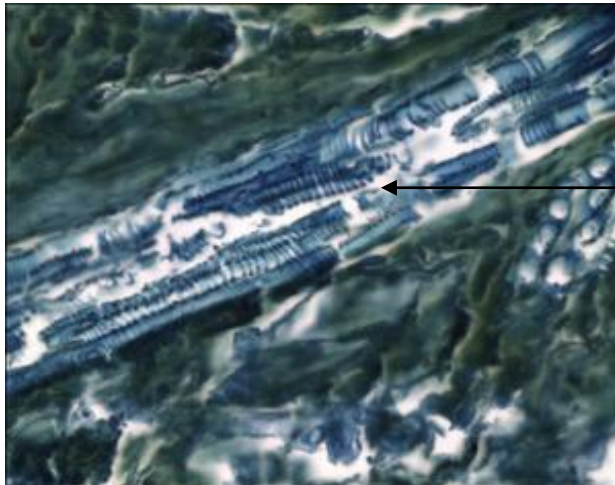
Fig 4.184

Stain – Toluidine Blue

Magnification – x20

Sieve tubes

Fig 4.185

Stain – MSB

Magnification – x20

Fungal body
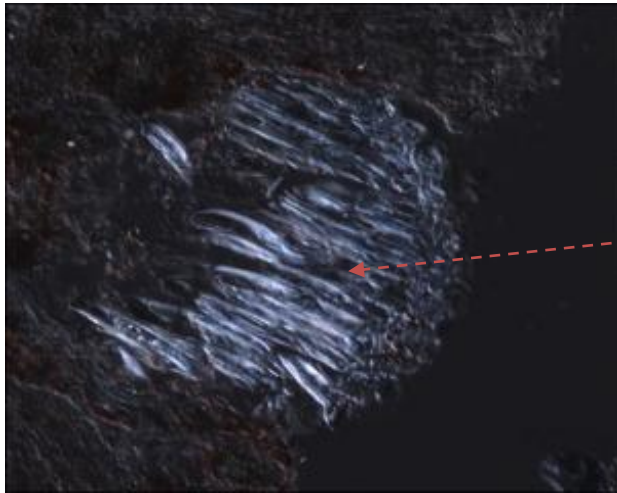
Fig 4.186

Stain – MSB

Magnification – x20

Polarised Light Microscopy

Fungal bundle (birefringent because of the chitin within it)

4.12.4 - Muscle

The muscle sample from Mummy A101 was in an excellent state of preservation.

Once stained, the sample displayed the fascial planes and muscle fibres. Fascial planes are connective tissue that surrounds muscles, muscle groups, blood vessels and nerves binding them together.

Preservation was so good that a distinction could be made between the fast and slow fibres.

No pathologies could be identified.
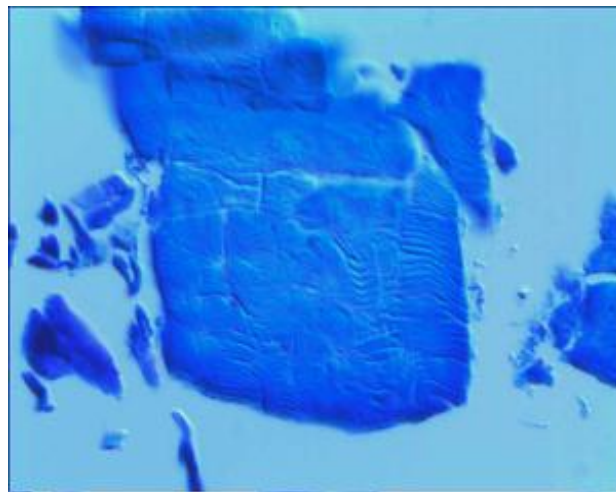
Fig 4.187	Stain – Toluidine Blue Magnification – x40 Muscle striations shown by using Differential Interference Contrast Microscopy
Fig 4.188	Stain – MSB Magnification – x40 Fascial planes, allowing muscle movement (large white lines)
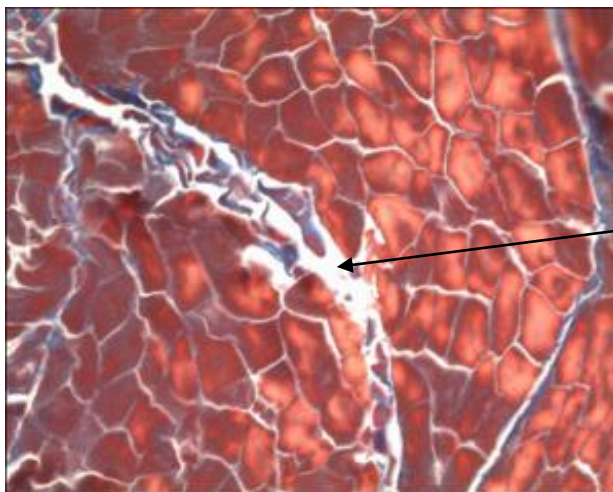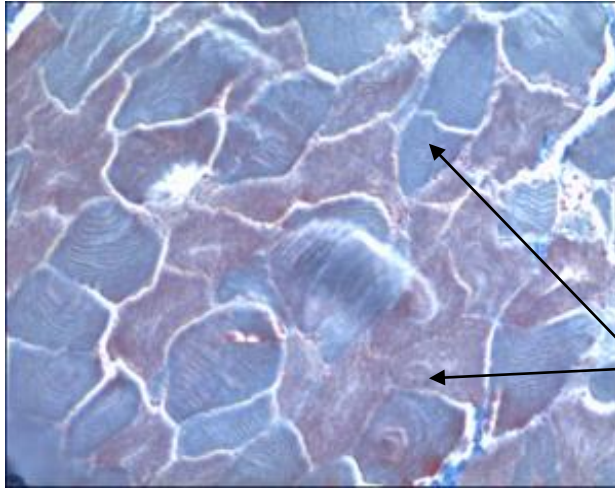
Fig 4.189

Stain – Toluidine Blue

Magnification – x40

Muscle in an excellent state of preservation

Slow and fast muscle fibres (blue and mauve)

4.12.5 - Bone (Rib)

Given the very good preservation levels of the soft tissues of Mummy A101, it is somewhat surprising to find the rib sample in such poor condition.

Something has affected the mineral matrix, leaving the toluidine blue stain unable to bind with any elements of the sample. The sample was blocked out in acrylic resin (LR White), however the relative hardness of this medium does not appear to have had any positive influence on the condition of it.

Using Differential Interference Contrast Microscopy (DIC) enabled the visualisation of some tissue components, such as osteocytes and their related canaliculi, which for some reason were present but too degraded to be stained.

No pathologies could be identified.

 Fig 4.190	<u>Stain – Toluidine Blue</u> <u>Magnification – x20</u> <u>Resin Section</u> Osteocytes

Fig 4.191

Stain – Toluidine Blue

Magnification – x40

Differential Interference Contrast Microscopy

Osteocyte with related canaliculi

4.13 – PRODUCE AND PARASITES – DISCUSSION OF MUMMY A101

The soft tissue samples from Mummy A101 were in a relatively exceptional state of preservation. The muscle sample was close in appearance to fresh tissue with the distinction between fast and slow muscle fibres able to be identified. The skin and cartilage sample from the ear of the mummy had chondrocytes with surviving nuclei within the cartilage and the dermis was still easily recognisable. No epidermis remained, but as the rest of the skin sample was in a good state of preservation as well as evidence that the body had been unwrapped at some point in antiquity, it is likely the epidermis came away at this time.

The coprolite sample was also in a very good state of preservation, demonstrating evidence of both diet and disease. Plant remains, such as seed coatings and starch cells, stained very visibly as did the remains of what appear to be parasite ova. From the amount of (probable) parasite ova within the sample, it would seem that Mummy A101 had a very heavy parasitic load.

The dissector, at the time of autopsy, recorded that the liver was still recognisable albeit very decreased in size, measuring only 5 x 4 x 3 centimetres. Next to the liver were several loops of empty bowel (Cartmell 1998a; 7). However, the liver sample provided was also coprolite, and in a very good state of preservation. No liver components were present. While some parasite ova could be seen in this sample, probably from higher up in the gastro-intestinal tract than the sample labelled coprolite, the load was not as heavy, nor was the amount of plant material as large.

Surprisingly, given how well preserved the soft tissue samples were, the rib sample was poorly preserved. Despite being blocked out in the acrylic resin (LR White), the sample appeared to be too degraded for the stain to take. Very few osteocytes could just be made out, however no canaliculi were visible.

Canaliculi are microscopic canals running between the various lacunae (small spaces containing an osteocyte in bone or chondrocyte in cartilage) of bone and cartilage. The osteocytes, adjacent to blood vessels, collect nutrients, which are then distributed throughout the bone matrix by the canaliculi. Osteocytes and canaliculi often survive quite well in the archaeological

context (see Figure 4.239, Mummy A102 for a good example of canaliculi preservation).

As the rib sample had not taken up the stain but it appeared that some bone elements had survived (osteocyte) the sample was examined using Differential Interference Contrast Microscopy, which gives unstained components a three-dimensional appearance. Once applied, not only the osteocytes became clearer, but also their related canaliculi were visible.

The good state of preservation nearly all the samples examined from Mummy A101 was unusual. It could be due to most of the samples not being from organs metabolically active during life. However, the exception to this is the skeletal muscle, which was not only very well preserved, but during life is metabolically active being critical for the maintenance of body homeostasis. Mummy A101 was spontaneously mummified, so it was not the skill of the embalmers that caused soft tissue preservation. The most likely explanation for it is very little delay between death and burial into the hot dry sands of the tomb. Also, given this level of preservation it was probably summer when A101 died, as in winter temperature fluctuations can hinder rapid desiccation.

The two coprolite samples (one labelled liver) were particularly interesting. Like the skin and muscle samples, they were very well preserved and the contents have the potential to provide information relating to both diet and parasitic infection in Kellis during the early Roman Period.

4.13.1 – Ascaris

Mummy A5 has already provided compelling evidence for the presence of parasites within the population of Kellis (see Chapter 4.7). Mummy A101 offers a different type of evidence, no less compelling.

The coprolite sample from Mummy A101 contains what appear to be a large number of parasite ova. The little internal structure that remains strongly suggests the *Ascaris* species.

4.13.1.1 - *Ascaris sp.*

Today, *Ascaris* sp. occurs throughout the world, transmitted through the ingestion of infective eggs in contaminated water, food or faecal material on

hands (WHO 1987; 14). Under conditions of poor sanitation, virtually 100 percent of the population can harbour the parasite (Markell 1999; 270). In 1989, a Lancet editorial stated that the *Ascaris* burden was so great that if placed head to tails, the worms would encircle the earth fifty times.

Fig 4.192 - Female Ascaris lumbricoides wormcan be up to 30cm in length (http://www.dpd.cdc.gov/dpdx)

The species of *Ascaris* sp. that is most relevant to the findings of the Dakhleh cacheis *A. lumbricoides*. While the numerous ova found in mummy A101were highly crystallised, they displayed the size and characteristics of *A. lumbricoides*. It may be possible, at a future date, to confirm identification using ancient DNA, a technique already successfully utilised for the same result by Loreille et al (2001). There is also a precedent for the Dakhleh identification as previous work by Cockburn et al (1998) and Harter et al (2003) has recognised *A. lumbricoides* eggs in a mummy and embalming rejects respectively.

4.13.1.2 - Transmission and Lifecycle of Ascaris lumbricoides

A female *A. lumbricoides* worm living inside an infected human produces on average approximately 240 000 eggs a day for about a year. These eggs are then passes in the faeces where the eggs develop within three weeks. When the eggs are swallowed, they develop into a larval worm in the small intestine. These larvae migrate through the body via the hepatic portal system to the liver and lungs, where they develop further two weeks. They then return to the small intestine and attain sexual maturity (Markell et al 1999; 270).

A. lumbricoides is specific for man and the infection does not produce a strong immunity. For survival, it is dependent upon a high reservior of infective eggs in an environment, which is why it thrives in areas of poor sanitation, especially

where people defecate around indiscriminately around human settlements. The eggs are able to survive adverse environmental conditions owing to the protective shells, which also explains their identification in ancient remains (WHO 1987; 14).

Fig 4.193 – Life Cycle of the Ascaris sp. (www.dpd.cdc.gov/dpdx/HTML/Ascariasis.htm)

Fig 4.194 - Fertilised egg of A. lumbricoides, showing the thick protective shell (http://www.dpd.cdc.gov/dpdx)

4.13.1.3 - Symptoms of Ascaris lumbricoides in Humans

While the ingestion of a small quantity of infective eggs at any one time would probably not give rise to any recognisable symptoms, ingestion of a large quantity can lead to complications and ill health. As the worm migrates through the body, it releases powerful allergens, which in turn, may induce hypersensitivity.

In the lung phase, *A. lumbricoides* is also known as *A. pneumonitis*. Once in the lung, it causes haemorrhage, inflammation and bacterial infection. Asthma attacks may occur, even in people who have previously never experienced asthma (Markell et al 1999; 272). Pneumonitis is a further lung condition that can occur while the worm is in the lungs. These complications occur six to fifteen days after initial infection (Markell et al 1999; 270).

In the intestinal phase, *A. lumbricoides* can cause malnourishment, intestinal blockages (produced by a mass of worms, or adult worms migrating from the small intestine into the bile and pancreatic ducts, respiratory passages and peritoneum) and verminous intoxication. This occurs six to eight weeks after initial exposure (Markell et al 1999; 273).

Visual difficulties can also be caused by *Ascaris* sp. if ascarid larvae invade the eye producing iritis or other symptoms (Markell et al 1999; 323).

Most of these complications are rare in *A. lumbricoides* infection; however, some such as pneumonitis are possible more common than recorded as they are rarely diagnosed clinically (WHO 1987; 15).

4.13.1.4 - Ancient Ascaris sp. and Modern Findings

The presence, in ancient times, of *Ascaris* sp. in Europe and Africa, as well as in the New World, proves that Ascaris represents an extremely successful human parasite. Ascaris eggs are hard to exterminate, they can remain viable in the soil for up to fifteen years and are common finds in archaeological sites. *Ascaris* sp., like most nematodes, are easily visualised under a microscope (Loreille & Bouchet 2003; 41).

Ascaris sp. eggs were found in coprolites from 30 000 year old caves at Arcy-sur-Cure in France. Both bears and humans inhabited the caves and therefore the zoological origin of the coprolites has not been confirmed. In Europe, the

oldest recorded dates for *Ascaris* sp. in human coprolites are 800 – 350 BCE (Iron Age) from the Hallstatt salt mines (Austria), and from Prussian mummies dated to 600 BCE. *Ascaris* sp. eggs are also extremely abundant in European mediaeval sites, found in faecal material (Bouchet et al 2003; 97).

While the evidence for the *Ascaris* sp. in ancient Egypt and Nubia is not as ubiquitous as it is for European archaeological sites, there is confirmation of its presence there.

There is some evidence of the presence of ascariasis in past populations of Nubia; egg samples were recovered from the inside of two mummies dated to 300 – 1500 CE and 2050 – 1720 BCE respectively. The context of the samples makes it almost certain that they were of the *A. lumbriciodes* species (Loreille & Bouchet 2003; 42).

In a mummy housed in the Philadelphia Art Museum, evidence was found that also suggested an *Ascaris lumbricoides* infection. Although its Egyptian origins are unknown, from the style of the wrappings, PUMII (as it has been named) dates to approximately 200 BCE (Ptolemaic Period). In 1973, PUM11 was autopsied and samples including spleen and intestine were collected and histologically examined. A single parasite egg was found in the intestine tissue, which was identified as *Ascaris lumbricoides* (Cockburn et al 1998; 79). It is probable that had coprolite material been present within the intestinal tract many more *Ascaris* sp. ova would have been observed.

*Fig 4.195 - Ova from Ascaris lumbriciodes found in
PUM II (Cockburn et al 1998; 80)*

Due to the resilience of the ascaris ova, it is not only coprolite samples that have been the source for this parasitic infection.

Twenty jars, found in Saqqara and dated to the Tenty-Fifth Dynasty, formed a deposit of rejects from the embalming process, including bags of natron, straw, linen, papyrus marrows, ointments, oils and fetid human remains, such as decayed liquids. The linen, papyrus marrows and straw (mixed with natron) were examined for evidence of any parasite remains. Two parasitic helminths were identified – *A. lumbricoides* (giant roundworm) and *T. Saginata* (beef tapeworm) (Harter et al 2003; 120).

The researchers of this project noted that the contents of the jars appeared to be contaminated by faecal matter, which contained the parasitic remains (Harter et al 2003; 120). This finding is in line with that of Mummy A4 from the Kellis 1 cache, where the body had been contaminated with faecal material, most probably at the time of burial. Both these results confirm the lack of hygiene even in areas where corpses were treated or buried.

4.13.1.5 – Ascaris sp. and the Medical Papyri

The *A. lumbricoides* adult female worm may exceed 30 centimetres in length, and while it most common for the larvae to be evacuated from the body via the faeces, the adult worms may also be passed this way. It is also possible for the worms to crawl up the throat and attempt to exit through the nose or mouth (Aufderheide & Rodriguez 1998; 238). As the adult worms are so large and therefore quite conspicuous, they would have likely have been known to the ancient Egyptians.

There are numerous prescriptions in the Papyrus Ebers that carry the worm determinative:

Fig 4.196 – Reading right to left, the worm determinative can be seen at the end of the word – Prescription in the Papyrus Ebers

Many of the descriptions of these prescriptions strongly suggest that a parasitic infection is the subject. Unfortunately, the identification of which parasites are being described is not possible. Ebbell, an early over-enthusiastic translator of the Papyrus, identified the hefat worm to be those of *Ascaris lumbricoides*, however, he did so with little basis for his claim.

4.13.2 - Diet

The coprolite samples from Mummy A101 also displayed a wealth of plant material, some of which could be categorised as cereal remains. Plant material is easily recognised in histological sections for many reasons including the cellulose in plants has birefringent qualities very clear when using polarised light microscopy. Starch cells are also identifiable; when staining with the trichrome stain MSB, these cells are coloured a bright light blue, and have a white cross, visible through the middle of the cell.   The most ubiquitous plant parts to be found in coprolite material are sieve tubes.

The main function of the sieve elements is transport of carbohydrates in the plant from the leaves to the fruits and roots. Sieve cells are more primitive than sieve tube sells in phloem, and are found in most seedless vascular plants (e.g., ferns, club mosses, horsetails) and gymnosperms (conifers, *Gingko*, etc.). Sieve cells have relatively narrow, uniformly-sized pores in the sieve areas. Sieve tube cells are the more advanced type of conducting cell, and are the only sieve element found in the phloem of angiosperms (flowering plants). Sieve tubes are elongated ranks of individual cells, arranged end to end, and functioning to conduct food materials throughout the plant. The sieve areas of these cells and are called sieve plates; the pores in sieve plates are generally larger and more variable in size than those in sieve cells (Bowes & Mauseth 2008; 67-68).
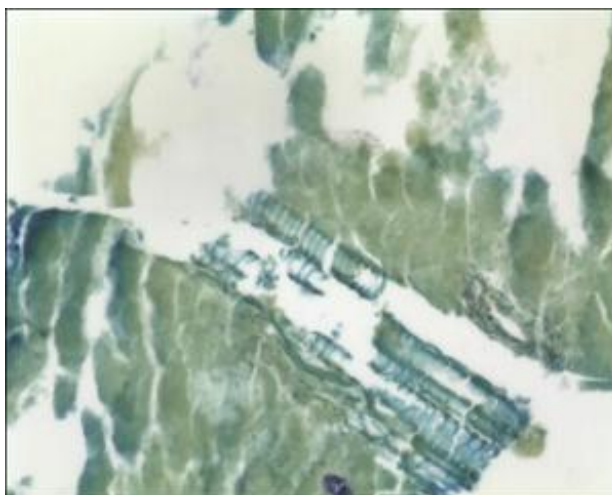
Fig 4.197 –Sieve tubes - coprolite sample from Mummy A106

The identification of sieve tubes in a sample is sometimes the only indication that plant material is present.

4.13.2.1 – Overview of the Ancient Egyptian Diet

There is no doubt of the wealth and variety of the ancient Egyptian diet; the evidence is seen in the offering scenes on the tomb and temple walls and the botanical and faunal remains uncovered by excavations, and it most likely is comparable to the Egyptian diet of today.
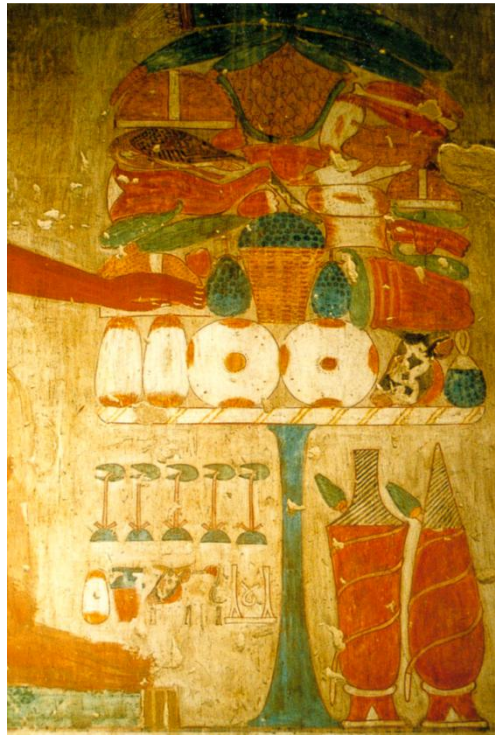
Fig 4.198 – Offering table scene from the tomb of Rekhmire (Donovan & McCorquodale 2004; pl 12.4)

Egyptian agriculture, including the farming of cereal crops and herding of animals, was probably established during the sixth millennium BCE. Domestic crops, most importantly, emmer wheat and barley, were imported from the Levant; the earliest archaeological finds of these plants date to 5300 BCE from sites in the Fayum and Merimda Beni Salama in the Delta (Murray 2000a; 506). Emmer wheat and hulled barley, used for the ancient Egyptian staples of bread and beer as well as animal fodder, continued to be the most important cereals produced until the Graeco-Roman times. At this point, new wheat species (*Triticum durum*, hard wheat and *Triticum aestivum*, bread wheat) were introduced and quickly became more popular. The reason for this is that the new species did not require the laborious processing necessary for emmer, as the grain falls clear of the chaff during the threshing process. Emmer is a hulled wheat, which means after the threshing process breaks up the cereal ear into

spikelets, further processing is needed to separate the chaff still adhered to the grain. Once introduced, Egypt became the prime exported of *T. durum* to the Roman Empire (Murray 2000a; 513). Interestingly, excavations in the Fayum discovered that emmer wheat was still used in the temples, even when hard and bread wheats predominate (Crawford 1979; 144).

Among the cereal crops at Kellis, bread wheat and barley (*Hordeum vulgare)* are dominant in the archaeological assemblage. Hard wheat is also much in evidence, while there have only been minor finds of emmer (perhaps connected to the temple). These cereals were supplemented by the production of two species of millet, which were suited to the arid environment of the Oasis; pearl millet (*Pennisetum americanum*) and broomcorn millet (*Panicum miliaceum*) (Thanheiser & König 2002; 143).

From offering scenes on tomb and temple walls, we know that a variety of fruits and vegetables were available in Egypt. While caution must be taken using these scenes as evidence of the diet of anything more than the elite members of society, the rich and varied archaeological assemblages at many sites has provided direct evidence for the fruits and vegetables that were readily obtainable in ancient Egypt, as well as the additions to the botanical range throughout Pharaonic and post-Pharaonic Periods.

In Kellis, archaeo-botanical finds have shown a vast range of vegetables was grown in gardens. Kellis also benefits from the discovery of the Kellis Agricultural Account Book (KAB), consisting of eight wooden boards tied together, of more than 1700 lines relating to the agricultural production of the town (Bagnall 2002; 115). This combination, as well as, the knowledge of the crops grown in the Oasis today, enables a fairly full record of the botanical diet in Kellis during the Roman Period. Tables 1.1 and 1.2 in Chapter One list the botanical evidence in the KAB and the archaeological finds.

The lack of meat as a regular item in the diet of most ancient Egyptians leads some scholars to believe that pulses, such as lentils, peas, chick peas, and beans, to have been important protein sources for much of the population (Murray 2000a; 637, Bagnall 2002; 117). However, the evidence is lacking. Pulses are generally not found as tomb offerings or depicted in the tomb art, and are generally lacking in the excavated botanical collections. This may be due, in part, to pulses not being recovered as efficiently as other plant remains,

as key morphological features needed for determining species are often obscured or missing in charred material (Murray 2000a; 638). In Kellis, the lack of pulses in the botanical assemblage is confirmed in the KAB, including in the accounts of rent payments by tenants, suggesting that these crops were simply not grown in any quantity in the Kellis area. The combination of wheat and beans produces higher-quality protein than does either eaten separately and this lack of pulses in Kellis may be a major factor in the widespread cribra orbitalia (evidence of anaemia) observed in the skeletal remains (Fairgrieve & Molto 2000; 319-331). It must be noted however that the study was performed on the skeletal remains from the Christian Kellis 2 Cemetery; none of the mummies examined as part of this project displayed any evidence of anaemia, including the three sub-adults.

It also should be noted that large numbers of faunal remains showing evidence of butchery have been recovered from the settlement site suggesting that many of the Kellis inhabitants had access to protein in the form of cattle, pigs and goats (Churcher 2002; 107). The four most common taxa in the faunal remains of Kellis were pig, cow, goat and chicken (77 percent of all taxa). Chicken eggshells have also been found but it is not known if these were used as food. Evidence for fish (catfish and perch) from the Nile was also more frequent than expected for this desert location, attesting that dried fish was a usual item of diet, if not a common one. While not a large amount, remains of dorcas gazelle have been found, showing that hunting was occasionally used as a supplement to the domestic supplies. Rabbits were also kept during Roman times for food, although bone finds are rare, probably because discarded bones were consumed by scavenger animals such as dogs, cats and jackals (all part of the Kellis taxa) (Churcher 2002; 105-107). From the faunal assemblage, it would appear that the population of Kellis had access to protein in the form of meat (pig, cow, goat, gazelle), fish (perch, catfish), milk (cow, goat) and possibly chicken eggs.

4.13.2.2 – Plant Remains in the Gastro-intestinal Tract of Mummy A101

The plant remains in the gastro-intestinal tract of Mummy A101 were well preserved and showed that a variety of plants had been consumed at some point in the days before his death. The large quantity of coprolite material was found in the bowel loops of the cecum and transcending colon (large

intestine) as well as the rectum; the small bowel was empty. While there is a great deal of variation in the time of transit through the human digestive tract (food type, size of meal and the individual), digestion usually takes between 24 to 72 hours. Once bile, pancreatic and other digestive enzymes have broken down the food in the small intestine, it travels to the large intestine, then onto the rectum (Cannon 2008; 753-755). The coprolites were found at the end of this process, suggesting that Mummy A101 had a rather large meal one to three days before he died. The digestion process can be slowed if the person is unwell, a detail not known in this case.

Analysis of the plant material found within human intestinal tracts is useful in determining such wide-ranging matters as what foods were eaten, what part of the plant was eaten and in what season the individual died. This analysis also has the potential to show whether the diet was nutritionally sound and whether or not the individual had ingested any medicinal plants close to death. Only when food plants have been identified in human palaeofaceces can we completely certain that they were actually consumed as food (Hillman et al 1993; 111).

The usual method for analysing gut contents is sieving, however, this can lose or damage some of the fragile plant material. Histological analysis of coprolites keeps the plant remains in context and the blocking out process protects their structure. However, the main problem with this technique is the very little work that has been done in the area of ancient plant histology, and until this work has been done, most of the plants found in the A101 sample cannot be identified.

It would appear there were two types of plant material present in the A101 sample; firstly, probably being that of a fleshy soft fruit characterised by relatively large empty cell walls where the once-present sugars had broken down (see Figure 4.180). Secondly, a cereal seed could be identified with parts of its outer wall; the pericarp, aleurone layer and starch cells undigested and beautifully preserved (see Figure 4.165). During autopsy, the dissector recorded a large number of small black seeds were present within the coprolite, similar to those of apples, which may be the source of the empty cells in Figure 4.180 as apples are present within the archaeological botanical assemblage from Kellis. The starch cells were clearly swollen, suggesting that the form of which the

cereal was ingested was a liquid, such as porridge or beer. There were many other plant remnants that could not be identified.

Coprolite samples were also examined from other sources as part of this project, including those from:

- Mummy A106 (Kellis 1) (Figures 4.199 to 4.201, pg 343)

- Asru – Late Period mummy from Thebes (Figures 4.202 to 4.204, pg 344)

- The Christian cemetery of Kulab Narti (Nubia) (Figures 4.205 to 4.207, pg 345)

- A Peruvian mummy (Figures 4.208 to 4.210, pg 346)

- York (United Kingdom) (see Figures 4.211 to 4.213, pg 347).

The coprolite sample from Mummy A106, another mummy from the Kellis 1 cemetery, unsurprisingly, had much of the same type of plant material as Mummy A101. However the samples from the other sources showed a marked variety in plant remains. The samples from Peru, Kulab Natri and York were much more degraded than those from Kellis 1. The Roman Period York sample had fossilised, not mummified and needed to be blocked out in acrylic resin, which was of a more comparable hardness to the sample than that of paraffin wax.

The coprolite sample from Mummy A106 was in a wonderful state of preservation, similar to that of A101. The outer coating of some type of cereal seed was identifiable. The intestinal contents of the Late Period mummy Asru (Manchester Museum) when blocked out in wax were impossible to analyse due to degradation. However, when blocked out in acrylic resin, the plant remains became very clear, including some material that is quite woody and is probably stem and part of a cereal seed. There was also an area showing what could be undigested meat (see Figure 4.204). If so, it is unique within the sample examined in this project. As a chantress of Amun, Asru was a member of the nobility and would have had access to meat though her work in the Karnak Temple. Unfortunately, with only two coprolite samples examined from the Kellis 1 Cemetery and little known about the individuals the samples came

from, no conclusions on the relationship of status and meat ingestion at Kellis can be drawn.

The Kulab Natri sample was extremely degraded and the only confirmation of plant material came from the presence of sieve tubes. A lot of plant material had been preserved in the coprolite sample from the Peruvian mummy and it is clear to see it is very different from that of the Kellis mummies, as is the conglomerate samples from York (United Kingdom).

The coprolite samples examined as part of this project came as somewhat as a surprise. Not only were they in good states of preservation, especially the mummified material; however they were also extremely revealing in terms of both diet and parasitic infection. The plant remains were varied and many of the components, such as seed coats, starch cells, were, if not complete, in a condition that species identification should be possible. That this was not achieved highlighted the fact that there has been very little work done in the area of ancient plant histology and there is a wonderful opportunity in the future for this to be rectified.

Evidence for parasitic infection within the population of Kellis has already been seen in Mummy A5, where the liver was extremely fibrotic most likely due to the disease schistosomiasis, as well as possible *Trichinella* sp. ovum in the muscle sample. The coprolite sample from Mummy A101 has a large number of parasite ova within it, the shape and internal structure of which suggest the nematode *Ascaris* sp. (roundworms). Despite the large number of these ova being present, A101 may not have suffered any adverse effects, as most roundworm infections are asymptomatic.

Despite the excellent preservation level of the soft tissue samples from Mummy A101, no pathologies could be identified other than the large number of parasite ova within the coprolite, which is highly unlikely to be cause of death. These ova, and the variety of plant material, found within the coprolite are worthy of further investigation.

As stated above, coprolite samples are usually examined using the sieving technique. This method for recovering plant and parasite remnants from coprolite material (for microscopic analysis) invariably targets only the most easily identifiable coarse components (Hillman et al 1993; 112). The samples

examined as part of this project demonstrate that histology potentially has a lot to offer in this field, whatever elements survive the digestion process to which they have been subjected are secured within the blocking out medium (paraffin wax or acrylic resin) and can be utilised as part of the identification process. The samples can also be further used in other techniques, such as ancient DNA retrieval.

Mummy Identification Number	A101
Individual Age	20 – 30 years
Sex	Male
Current Examination Methods	Histology
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	100
Samples Used	Colon, Coprolite, Liver, Muscle, Skin (ear), Rib
Previous Palaeopathological Findings	Some Dental Caries
Current Palaeopathological Findings	**Parasitic infection, Probably *Ascaris* sp.**
Cause of Death	Not Known
Mummification Type	Four

Table 4.7 – Revised Minimum Standards Case Report – Mummy A101
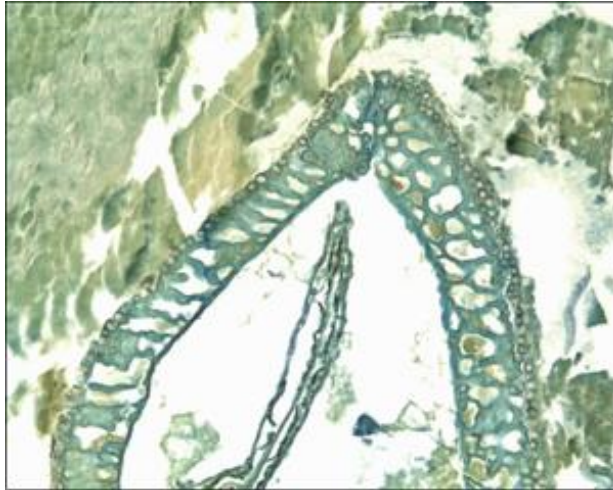
Fig 4.199

Stain – Toluidine Blue

Magnification – x10

Seed coat from the coprolite sample of Mummy A106
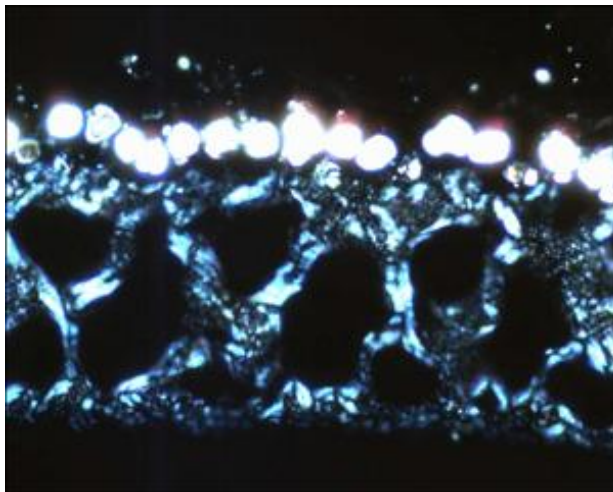
Fig 4.200

Stain – Toluidine Blue

Magnification – x40

Polarised Light Microscopy

Cellulose in plant material is extremely birefringent

Seed coat
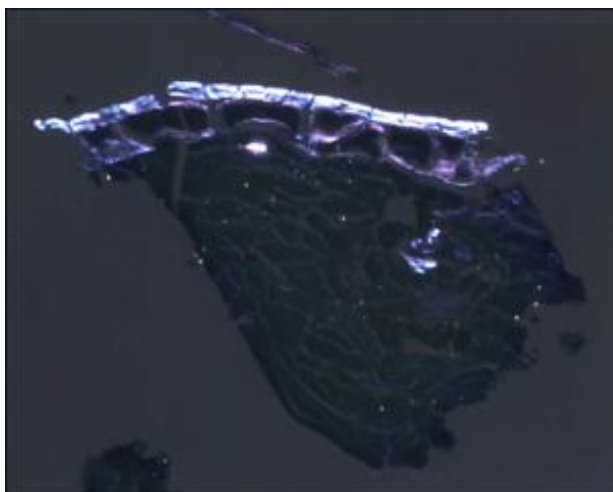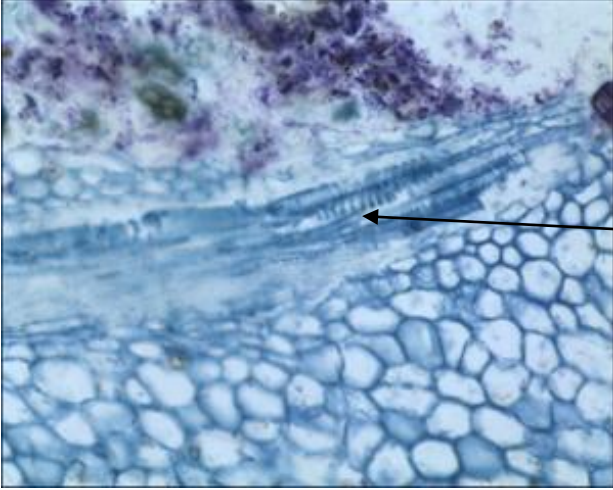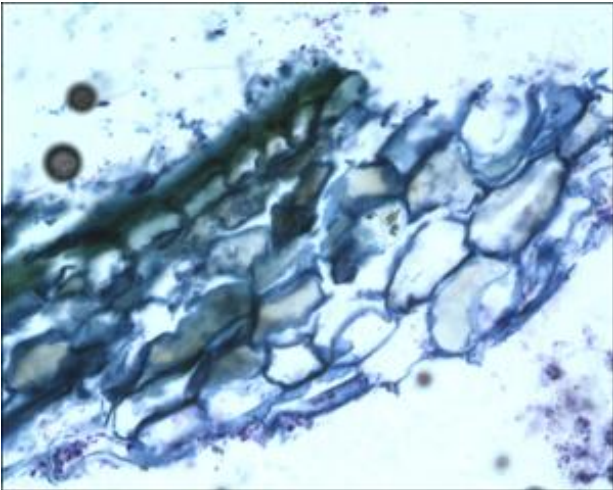
Fig 4.201
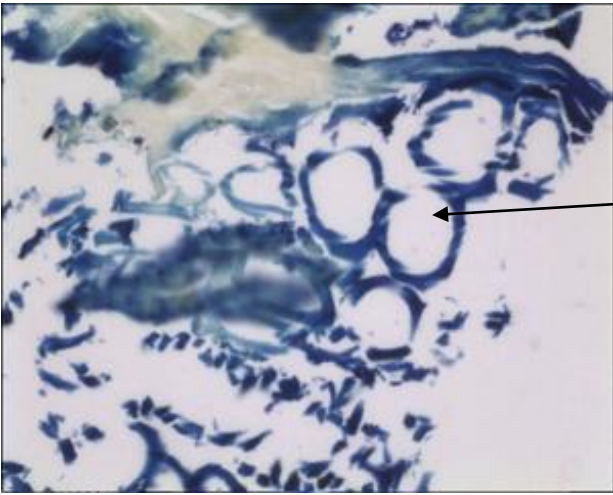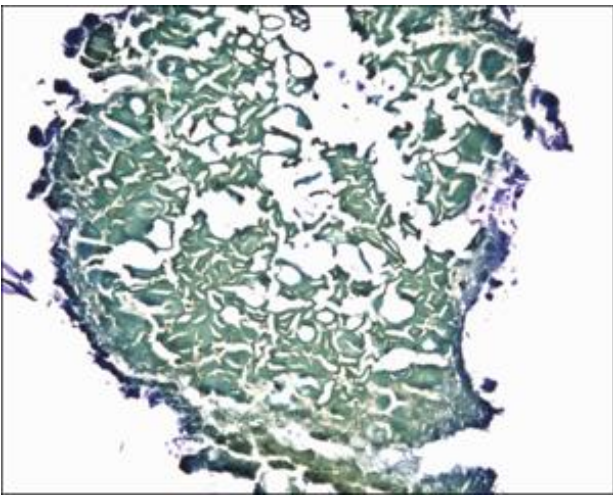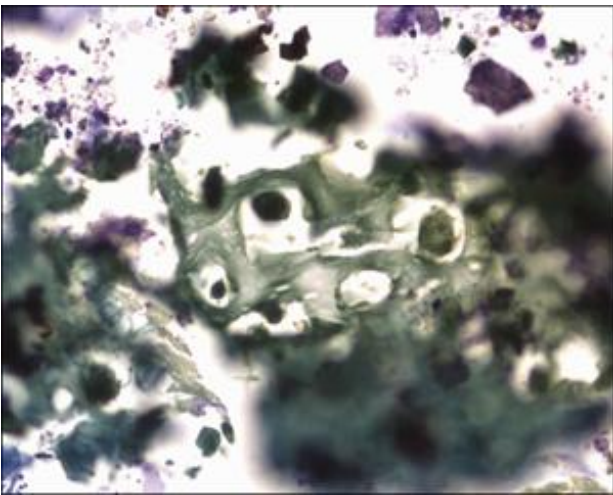
Stain – Toluidine Blue
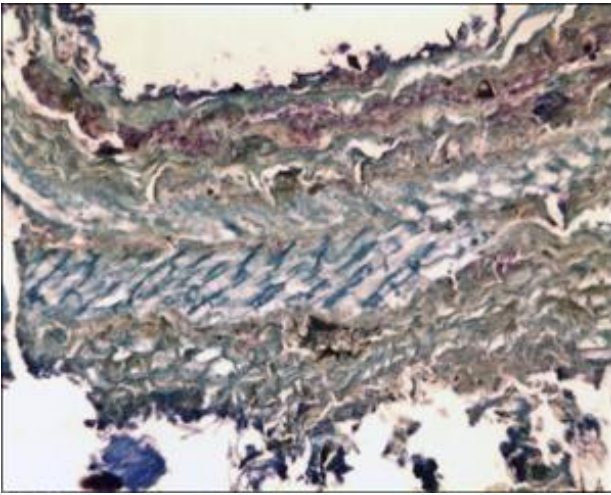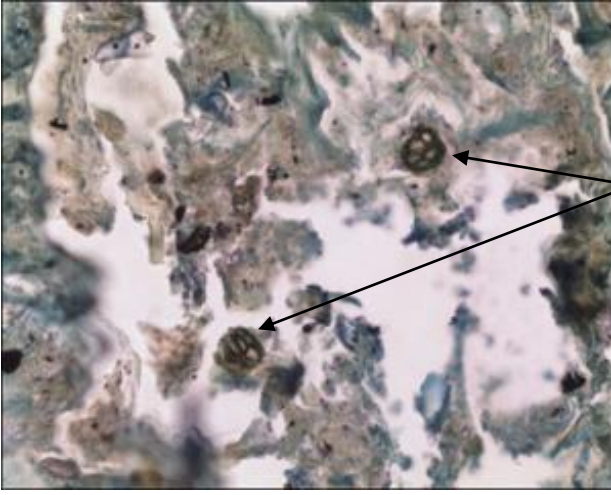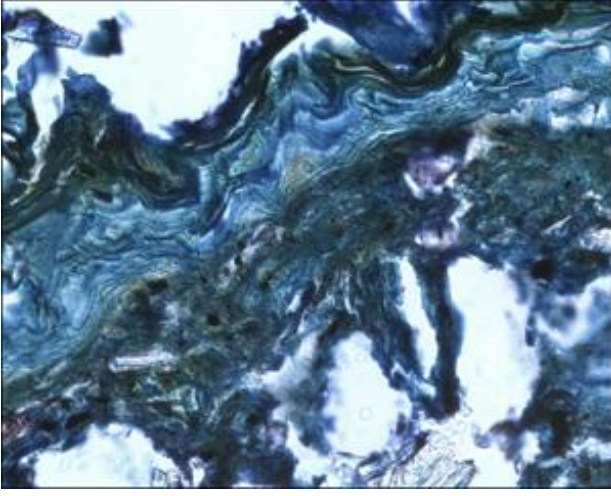
Magnification – x20

Unidentified plant material from coprolite sample of Mummy A106
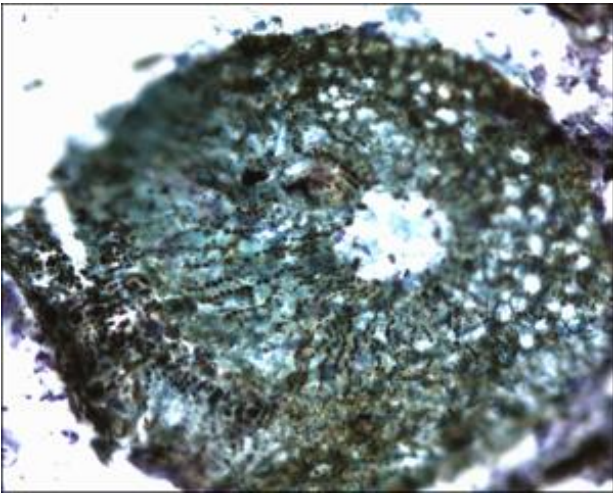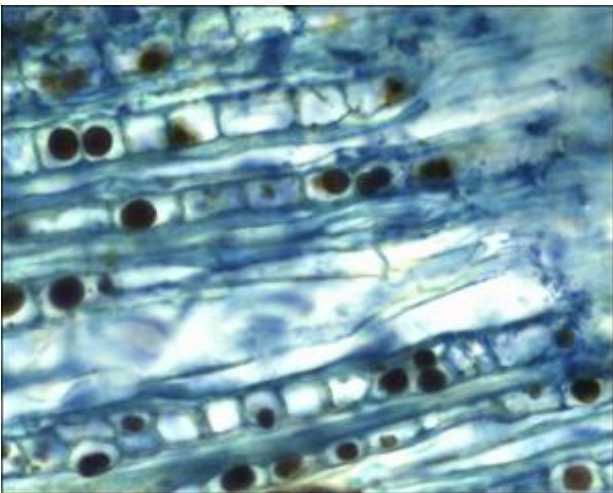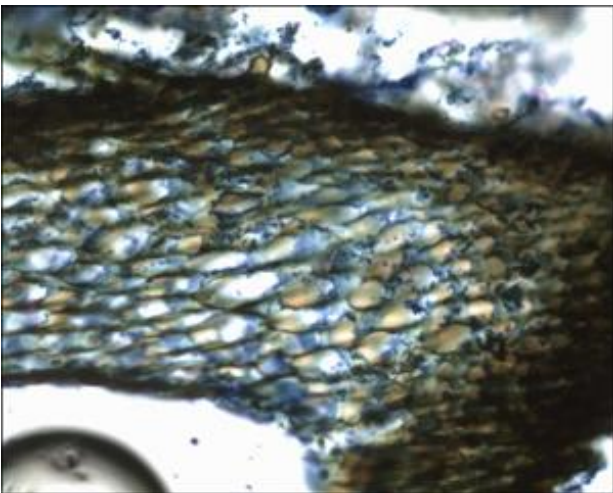
Fig 4.202

Stain – Toluidine Blue

Magnification – x20

Resin section

Sieve tubes

Plant remains in intestinal contents of Asru, probably stem.

Fig 4.203

Stain – Toluidine Blue

Magnification – x20

Resin section

Part of a cereal seed

Intestinal contents - Asru

Fig 4.204

Stain – Toluidine Blue

Magnification – x20

Undigested meat(?)

Intestinal contents - Asru

Fig 4.205

<u>Stain – Toluidine Blue</u>

<u>Magnification – x20</u>

Sieve tubes from Kulab Narti sample

Fig 4.206

<u>Stain – Toluidine Blue</u>

<u>Magnification – x5</u>

Unidentified plant material

Coprolite sample from Kulab Narti

Fig 4.207

<u>Stain – Toludine Blue</u>

<u>Magnification – x20</u>

Unidentified plant material

Coprolite sample from Kulab Narti

Fig 4.208

<u>Stain – MSB</u>

<u>Magnification – x10</u>

Plant material from Peru mummy coprolite sample

Fig 4.209

<u>Stain – MSB</u>

<u>Magnification – x20</u>

Pollen in Peru mummy sample

Fig 4.210

<u>Stain – Toluidine Blue</u>

<u>Magnification – x20</u>

Plant material in Peru mummy sample

Fig 4.211

Stain – Toluidine Blue

Magnification – x10

Resin Section

Plant material from York

conglomerate sample

Fig 4.212

Stain – Toluidine Blue

Magnification – x40

Resin Section

Plant cells

Conglomerate sample from York

Fig 4.213

Stain – Toluidine Blue

Magnification – x10

Resin Section

Plant material

Conglomerate sample from York
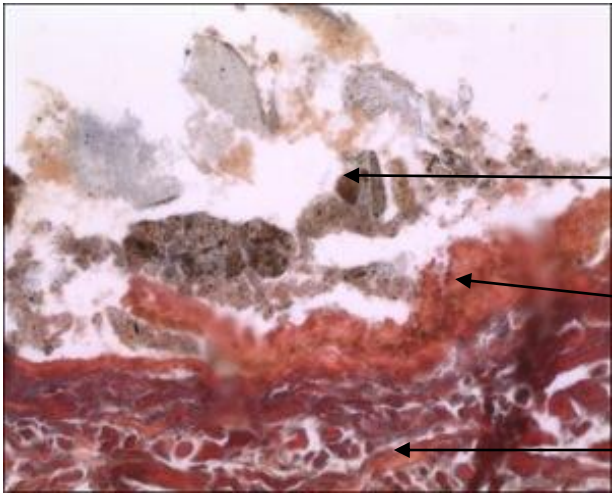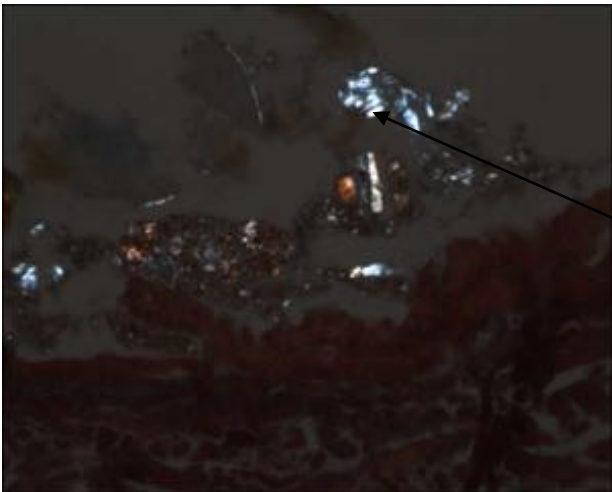
4.14 - RESULTS - MUMMY A102
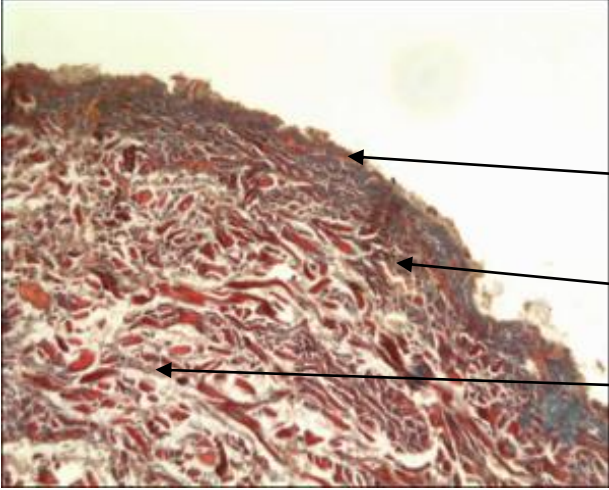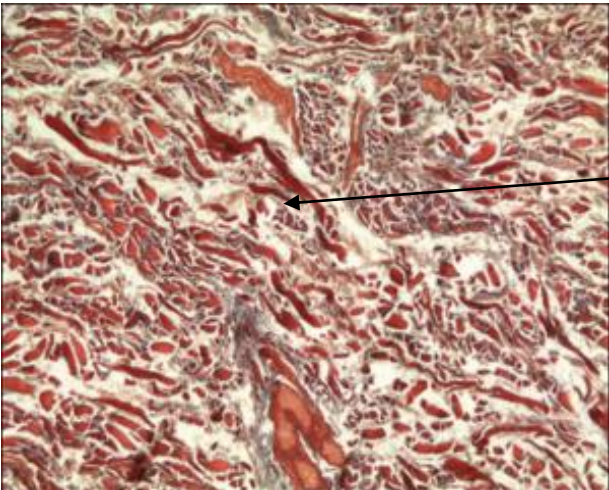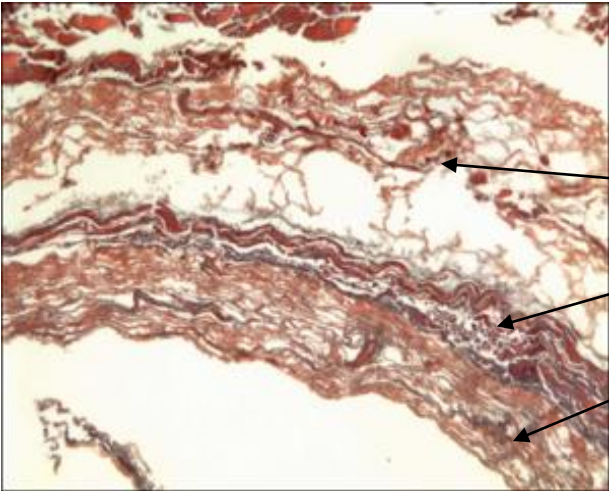
4.14.1 - Skin (Thigh)

The skin sample taken from the thigh of Mummy A102 displayed an excellent state of preservation, to the point that it was possible to visualise a small section of epidermis, sloughing off in sheets.

Hair follicles and their associated glands could be identified, although no remaining hairs could be seen.

The fat cells appeared to be extremely limited (only ten cells thick), suggesting this individual was emaciated at the time of death.

Stain – MSB

Magnification – x20

Sand and debris - external layer

Remains of epidermis sloughing off

Dermis

Fig 4.214

Stain – MSB

Magnification – x20

Polarised Light Microscopy

Silica – external layer

Fig 4.215

Fig 4.216

Stain – MSB

Magnification – x10

External layer of sand and debris

Dermis

Deep Dermis

Fig 4.217

Stain – MSB

Magnification – x20

Deep Dermis

Fig 4.218

Stain – MSB

Magnification – x10

Thin layer of fat cells

Facia

Fat

369
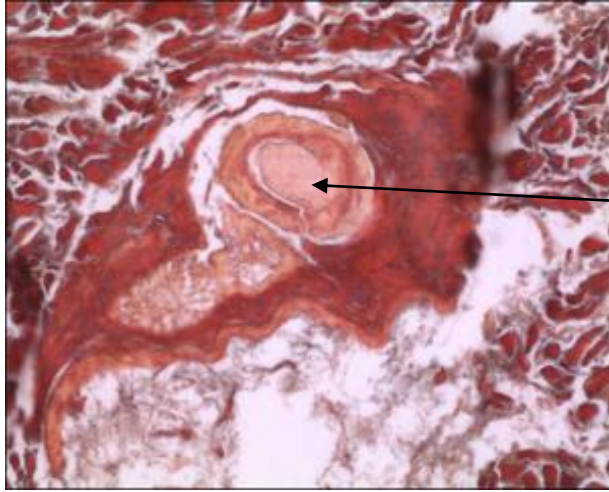
Fig 4.219

Stain – MSB

Magnification – x20

Hair follicle and associated sebaceous gland
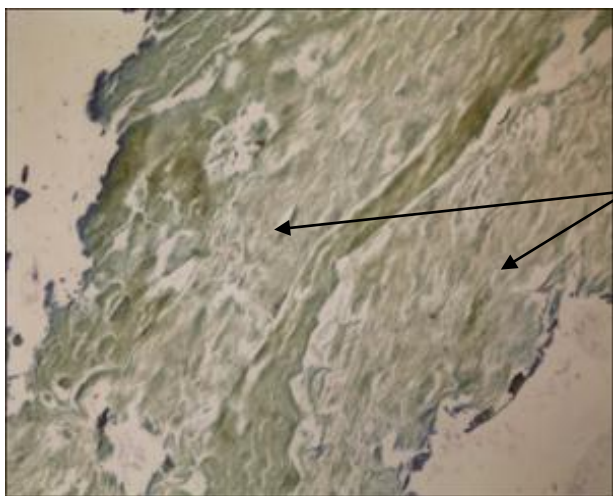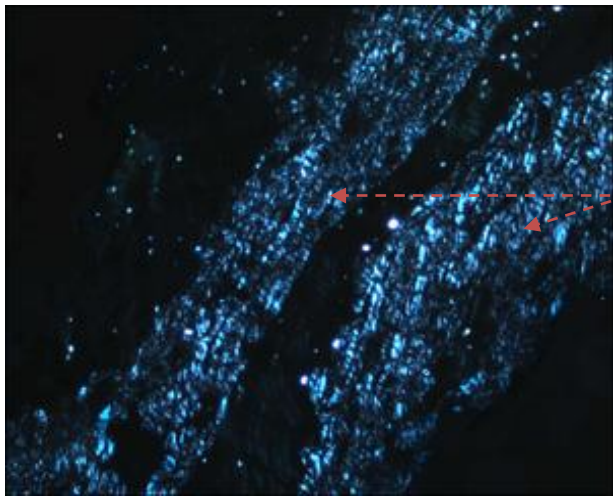
4.14.2 - Colon

The sample of colon from Mummy A102 is not easily identifiable as such. It is possible that the identification is correct as there it demonstrates a thick collagenous wall, consistent with that of the bowel. This is confirmed by the polarised light image in which the collagen is birefringent.

Bowel samples, unless they are actually the intestinal contents, do not preserve well.

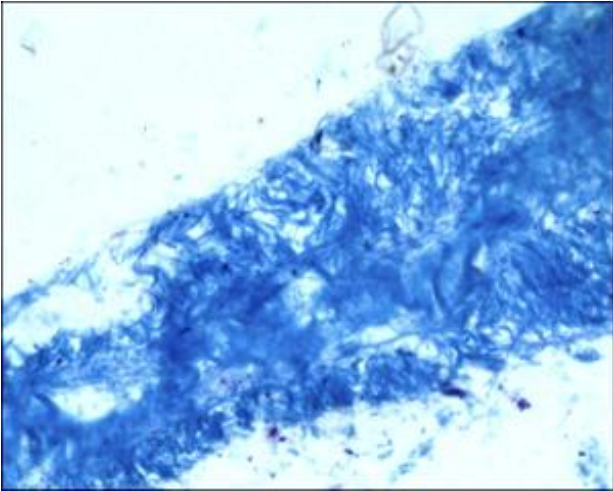Due to the poor state of the tissue, no pathologies could be identified.
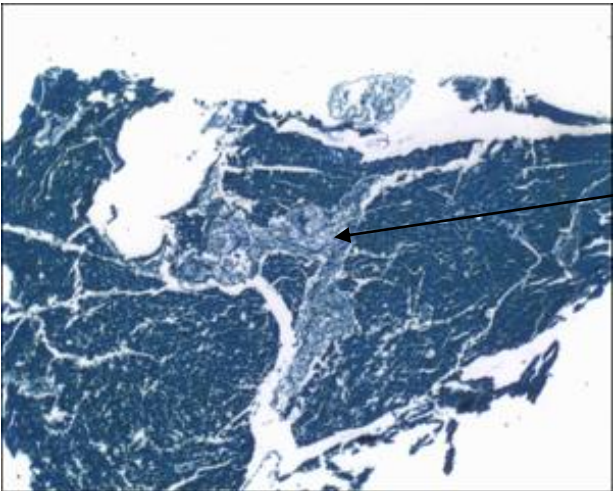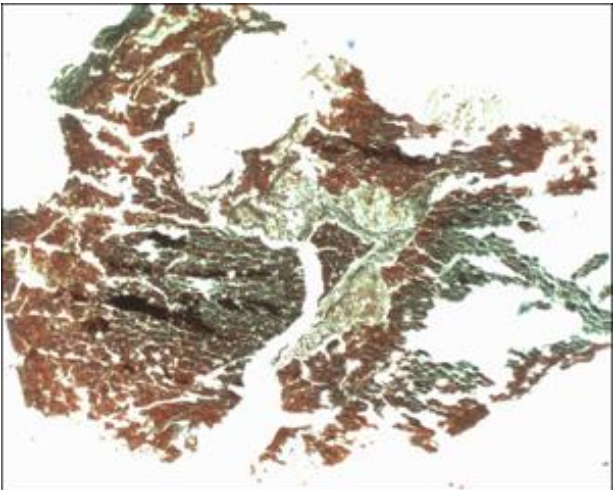
Fig 4.220	<u>Stain – Toluidine Blue</u> <u>Magnification – x5</u> Bowel wall
Fig 4.221	<u>Stain – Toluidine Blue</u> <u>Magnification –x5</u> Collagenous bowel wall (birefringent)

4.14.3 - Liver

The liver sample from Mummy A102 is not well preserved, as is the case with many liver samples examined. The sections stained with MSB make identification difficult, although a collagenous sinusoidal space (where blood passes through the liver) can just be recognised. The sections stained with toluidine blue are of a much better quality. In this case, toluidine blue has acted like a fixative and held the elements of the tissue together. It does this by its staining action, which irreversibly binds to all components (MSB is a pore filling stain). The toluidine blue sections are identifiable as liver.

No ante-mortem pathologies were identifiable; however a post-mortem fungal body was visible.

 Fig 4.222	Stain – Toluidine Blue Magnification – x2.5 Hepatic portal vein
 Fig 4.223	Stain – MSB Magnification – x2.5 Degraded liver sample
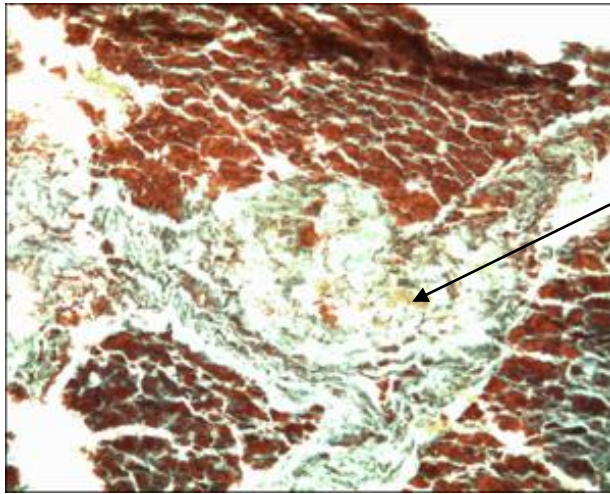
Fig 4.224

Stain – MSB

Magnification – x10

Outline of hepatic portal vein
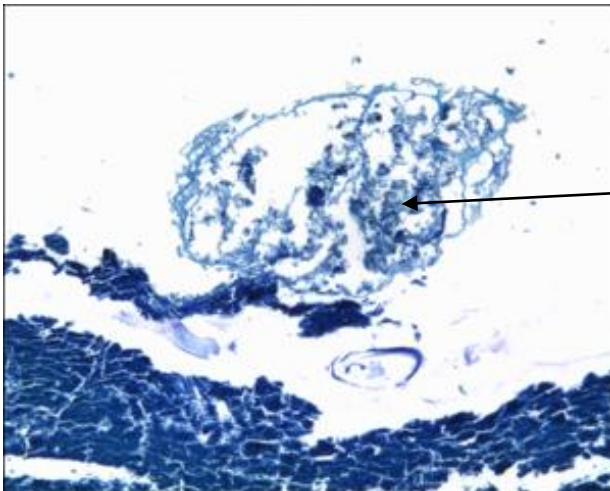
Fig 4.225

Stain – Toluidine Blue

Magnification – x10

Fungal body

4.14.4 - Lung

The lung sample from Mummy A102 was in a good state of preservation, although the sample had putrefied in places.

The lung was quite fibrotic and the destruction of the air sac walls and the bullae filled with anthracotic material suggest that Mummy A102 suffered emphysema during his lifetime.

A few sections show the bronchioles filled with sputum, possible evidence of a case of pneumonia.

There was also evidence for some type of worm and, due to its position within the lung; it is probably that this was an ante-mortem pathology.

From all the identifiable pathologies, this was the lung of a very unhealthy individual.
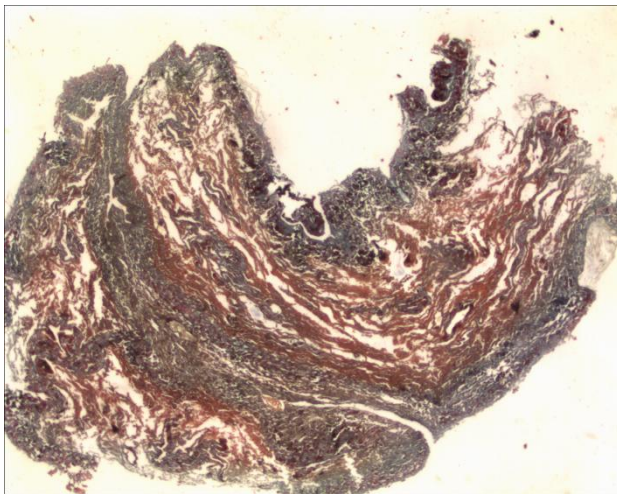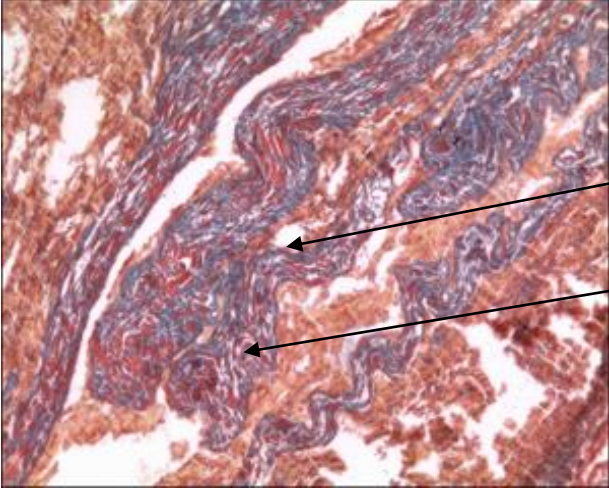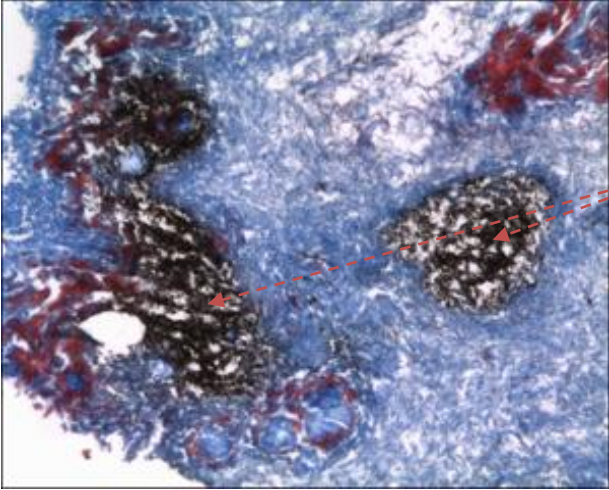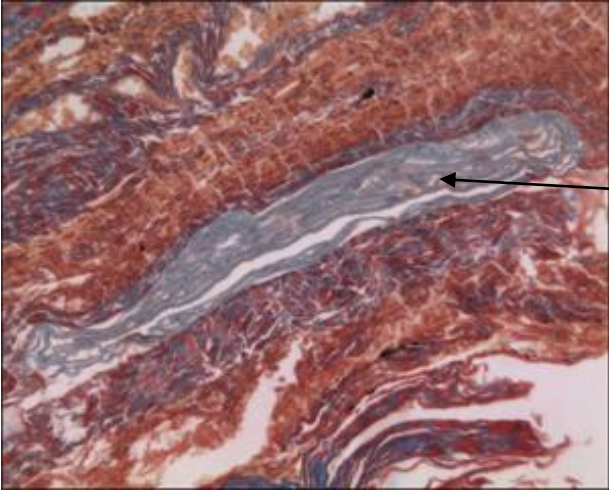
Fig 4.226	Stain – MSB Magnification – x1.6 Overview of lung sample

Stain – MSB

Magnification – x10

Collapsed bronchiole

Collagenous walls of bronchioles

Fig 4.227

Stain – MSB

Magnification – x10

Bullae filled with anthracotic pigment

Fig 4.228

Stain – MSB

Magnification – x10

Possible post-mortem worm

Fig 4.229
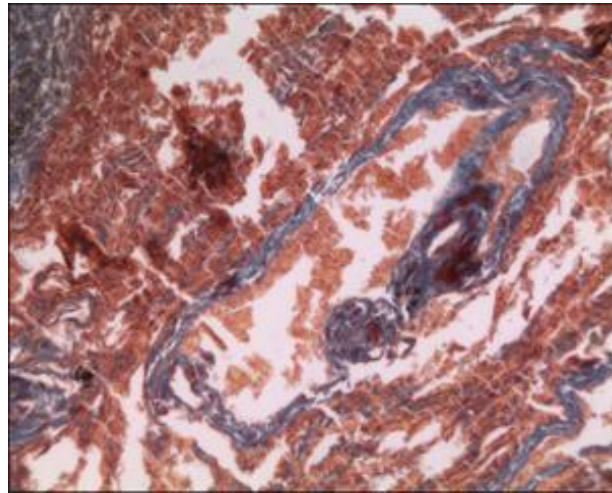
Fig 4.230

<u>Stain – MSB</u>

<u>Magnification – x10</u>

Vein (if it was an artery, a much thicker internal elastic lamina would be visible)
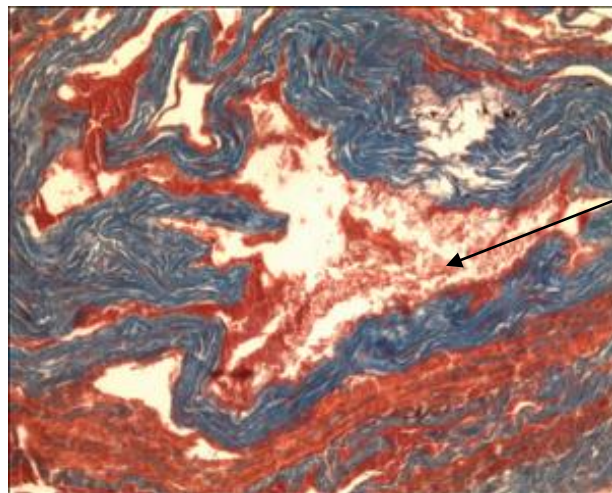
Fig 4.231

<u>Stain – MSB</u>

<u>Magnification – x10</u>

Digestive contents with bronchiole
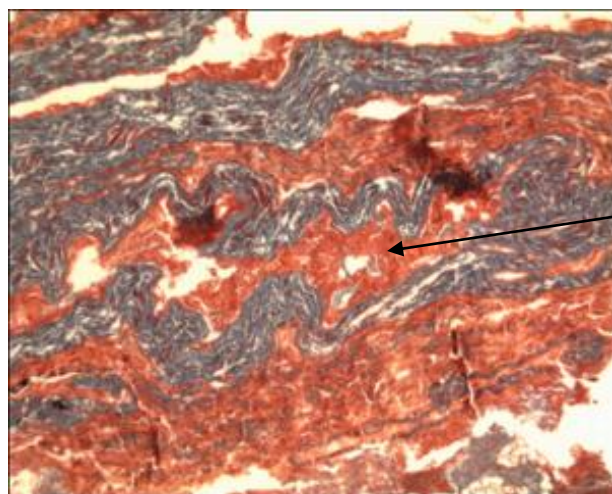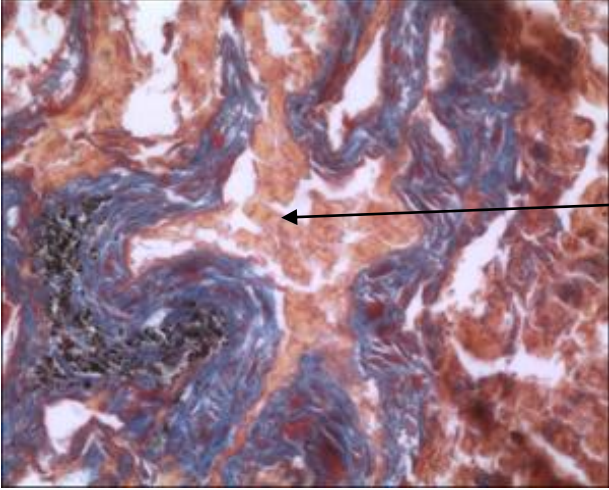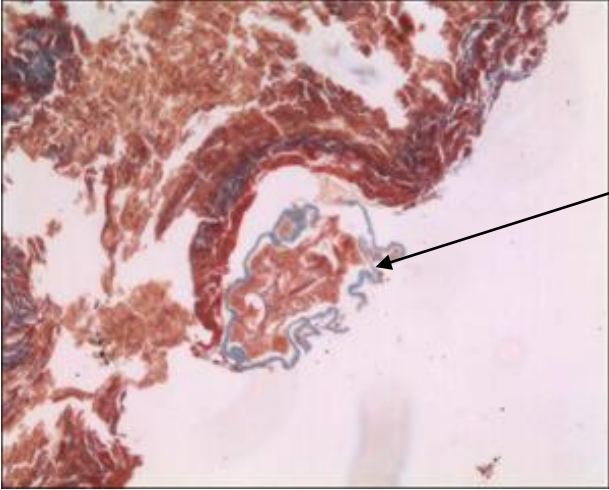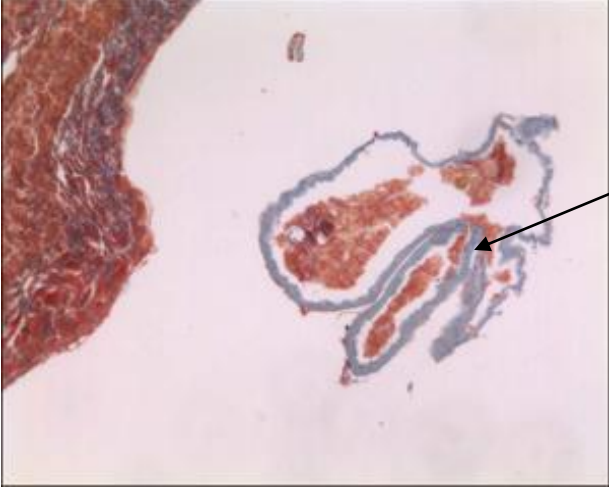
Fig 4.232
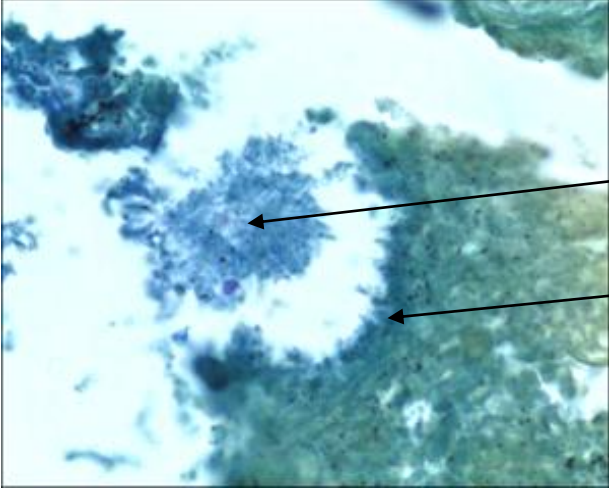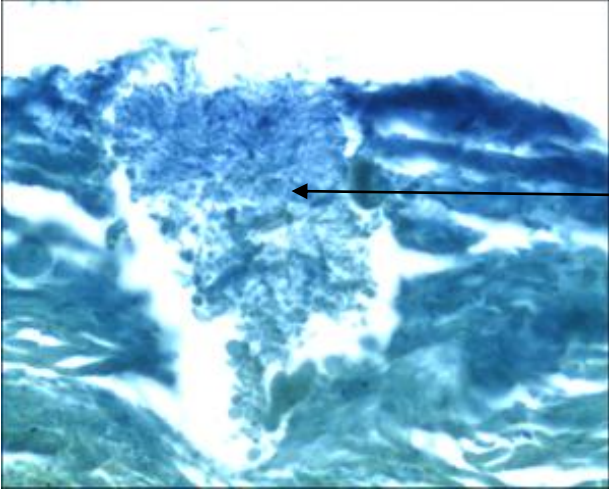
<u>Stain – MSB</u>

<u>Magnification – x10</u>

Digestive contents within bronchiole

Fig 4.233

Stain – MSB

Magnification – x20

Digestive contents within bronchiole

Fig 4.234

Stain – MSB

Magnification – x10

Possible post-mortem worm

Fig 4.235

Stain – MSB

Magnification – x10

Possible post-mortem worm

Fig 4.236

Stain – Toluidine Blue

Magnification – x40

Fungal body

Area digested by fungi

Fig 4.237

Stain – Toluidine Blue

Magnification – x40

High magnification of fungal body that has eroded the tissue
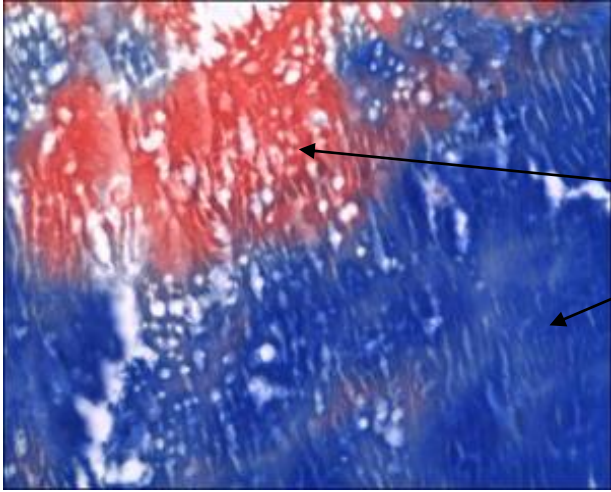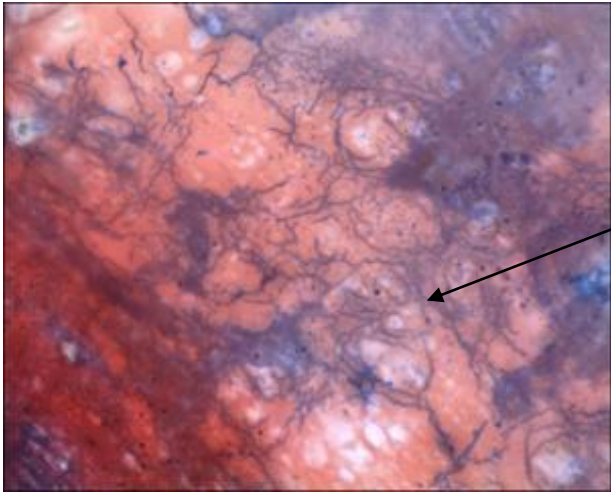
4.14.5 - Bone (Rib)

While the decalcified rib sample from Mummy A102 displayed an excellent state of preservation in some areas, other parts of the sample had been digested by bacteria.

In areas of excellent preservation, canaliculi joining up the osteocytes were clearly visible.

The areas of end stage putrefaction (red) can be seen travelling into the unaffected areas (blue).

No pathologies could be identified.

Fig 4.238	<u>Stain – MSB</u> <u>Magnification – x40</u> Undecalcified bone Decalcified bone
Fig 4.239	<u>Stain – MSB</u> <u>Magnification – x40</u> High magnification of clearly visible canaliculi
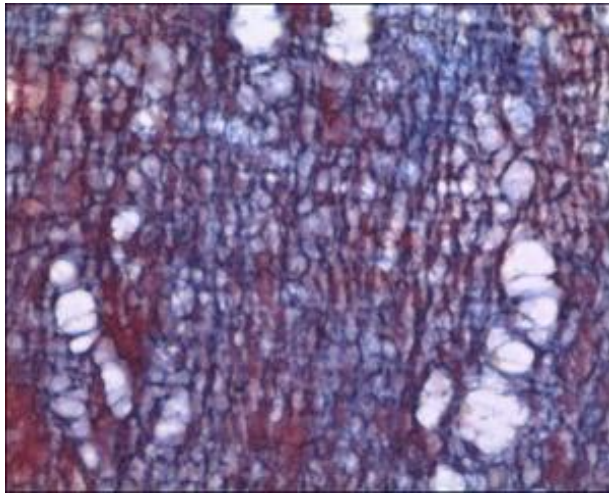
Fig 4.240

Stain – MSB

Magnification – x40

Fungal degradation

4.15 – RESPIRE AND EXPIRE: LUNG DISEASE IN ANCIENT EGYPT – DISCUSSION OF MUMMY A102

Evidence that the body of Mummy A102 had obviously at some point after death been invaded by fungi is visible in the samples of liver, lung and bone. Despite this, the lung remained in a fairly good state of preservation; however, as has been displayed in the liver of Mummy A5, the diseased state of A102's lung could be the reason for this. Some of the fungi are still present within this sample. The rib sample has areas that remain unaffected by fungal bodies and in which the canaliculi are clearly visible. The liver sample is poorly preserved, although the sections stained with toluidine blue were much more successful than those using MSB. The toluidine blue has, in this case, acted like a fixative assisting the tissue elements to remain bound together.

The skin sample is a very good state of preservation; the epidermis can be seen, albeit sloughing away from the dermis in some areas. Affixed to the epidermis, is a layer of sand and debris, which most likely adhered to the skin when the body was placed in the tomb. Mummy A102 was found with irregular fragmented wrappings over most of the body (except for the head); as the epidermis remains mostly in situ, it is possible that A102 was wrapped after the body had completely desiccated, as the epidermal layer did not adhere to the bandages.

As with many gastrointestinal tract samples, the colon sample is very poorly preserved, with only the collagenous portion of the bowel wall remaining identifiable.

Histologically speaking, the most interesting tissue from Mummy A102 is lung. It is very clear from this sample that during life, A102, was a very ill individual. As would be expected in such a young person (Mummy A102 was aged between eight and eleven years at the time of death), there is little evidence of silica-type particles or anthracotic-type pigment. However, there is evidence that A102 suffered from aspiration pneumonia. Aspiration pneumonia is an inflammation of the lungs and airways to the lungs (bronchial tubes) from breathing in foreign material, usually food, liquids, vomit, or fluids from the mouth.

Of all the visceral organs, lungs are often the best preserved in mummified

remains. Much of this has to do with their structure, only a small fraction of which is composed of epithelial cells. Epithelium is rich in lysosomes filled with hydrolases, and enzyme that the autolytic decay process leading to the decomposition of those organs that have larger quantities of these cells. The rate of desiccation is also augmented because of the large surface area of the pulmonary capillary bed and the relative lack of chest wall tissues (Aufderheide & Rodriguez-Martin 1998; 262). Despite this positive assessment, of the 49 Kellis 1 mummies, only thirteen had lungs in evidence. Many of the mummies lacking lung tissue had been spontaneously mummified so the absence of lungs is hard to understand. Of the thirteen that had lung tissue remaining, three had been artificially mummified and therefore the lungs should have been removed.

A variety of lung diseases have been recorded in many human remains from ancient cultures.

4.15.1 – Lung Disease in Ancient Egypt

During the process of artificial mummification, the lungs were removed from the body, treated and placed into canopic jars or back into the body. It was important for the stomach, intestines, liver and lungs to be protected so they could go on functioning for their owner in the Afterlife. Contents of the canopic equipment have proven favourable for histological study, and many of the diseases that plagued the ancient Egyptians have been discovered. By the Roman Period, however, this long-standing tradition of canopic equipment seems to have ended and the eviscerated organs, more often than not, cannot be located (Ikram & Dodson 1998; 292). This is certainly the case for the artificially mummified bodies of the Kellis 1 Cemetery.

In spontaneously, or naturally, mummified bodies, all visceral organs are left in place and desiccation is dependent on the environmental conditions. In a desert region, such is the town of Kellis, mummification would have taken place quite quickly once the bodies were placed in the hot, dry sand of the tombs. In conditions like this, the lungs are usually preserved to some degree allowing diagnosis of ailments such as pneumonia, bronchitis, anthracosis and silicosis.

Mummy A102 was a sub-adult, estimated to be no older than thirteen at time of death, possibly as young as eight. Therefore, a discussion regarding the lung pathologies of anthracosis and silicosis are not relevant in this section. These

conditions will be covered in Chapter 4.19 (Mummy A126). Discussed below will be lung diseases found in Egyptian lung samples other than anthracosis and silicosis, and focussing on pneumonia, which is the most likely diagnosis for the lungs of Mummy A102.

4.15.1.1. – Tuberculosis

Tuberculosis is one of the important, and frequent, mycobacterial diseases attested in ancient Egyptian human remains.

Previous research has identified the presence of a variety of microbes in the ancient world, although this research usually focused on an individual or small series of sample; research into larger series of sample have only been performed to a limited extent. Research employing on molecular techniques tend to focus on identification of *Mycobacterium tuberculosis* because the bacteria are assumed to be better preserved than other microbes due to their lipid-rich, acid-resistant cell wall (Zink et al 2003; 239).

Human tuberculosis is an acute infection of the soft tissue or skeletal system by either *Mycobacterium tuberculosis* or *Mycobacterium bovis*. Infection by M. tuberculosis is contagious and acquired by inhaling bacilli-laden moisture droplets coughed into the air by a lung-infected individual; this disease therefore usually manifests first as a respiratory infection. The host reservoir for *M. bovis* is animals, especially cattle, and infection usually comes about with the consumption of contaminated food products (especially milk) (Aufderheide & Rodriguez-Martin 1998; 118).

Tuberculosis is a biphasic disease, which means it has a primary infection phase and a reinfection, or reactivation, phase. It derives its name from the Latin word *tubercle*, meaning *little lump*; small nodules of diseased tissue are often found on the lungs of infected individuals. Poverty, unsanitary conditions, overcrowding, poor nutrition and ill health provide the best conditions for tuberculosis to thrive. It is still prevalent today in developing countries, such as parts of Africa, Asia and Oceania. Individuals with lung conditions such as silicosis (see Chapter 4.19) are at a much higher risk of developing tuberculosis than healthy individuals, who often show no symptoms of the disease when infected. The symptoms of active tuberculosis of the lung are coughing,

sometimes with sputum or blood, chest pains, weakness, weight loss, fever and night sweats (/www.who.int/topics/tuberculosis/en/).

In 1910, M A Ruffer reported on the spinal column in the Twenty First Dynasty Mummy, Nesparehan, which displayed typical features of Pott's disease (collapse of the thoracic vertebrae, producing an angular kyphosis or hump back). A complication of Pott's disease is the tuberculosis suppuration (pus), which in Nesparehan's case had formed a large abscess under the psoas major muscle (Ruffer 1910a; 1-5).

Zimmerman (1979; 604-608) examined a mummy of a five-year old child from the looted tomb of Nebwenenef at Dra Abu el-Naga. Unfortunately, due to the intrusive burials within this tomb, a date for the mummy could be anywhere between 1000 BCE to 400 CE. On gross examination of the body skeletal pathologies (scoliosis, fresh blood in trachea) suggested a diagnosis of tuberculosis, which was then confirmed by microscopic analysis as tubercle bacilli were present in the vertebral bone. This is a rare example of a diagnosis being made by microscopic examination, usually histology and microscopy have not been useful in confirming (or denying) the presence of tuberculosis.

Tuberculosis has been detected by examination of the skeleton and its presence confirmed by ancient DNA (Donoghue et al 2004; 584-592, Zink et al 2003; 239-249). In order to study the molecular evidence for human tuberculosis from different populations in ancient Egypt, Zink et al (2003) took bone samples from 50 mummies from three groups of dates and locations:
Abydos – Predynastic to Early Dynastic
Thebes-West – Middle Kingdom to Second Intermediate Period
Theban Necropolis – New Kingdom to Late Period.

Eighteen cases tested positive for ancient DNA of the M. tuberculosis complex, suggesting that tuberculosis was not only present in ancient Egypt but prevalent from the very earliest recorded period of human civilisation (Zink et al 2003; 239).

The initial examinations of the ten Kellis 1 mummies recorded no skeletal abnormalities suggestive of Pott's disease or any other tuberculosis-related pathology; therefore, no tubercle bacilli specific stain was employed in this thesis.

4.15.1.2 – *Emphysema*

While certainly not as frequent a finding as tuberculosis, diagnoses of emphysema in Egyptian mummies have been made (Walker et al 1987, Shaw 1938).

Emphysema is a long-term, progressive lung disease, in which damage to the air sacs (alveoli) of the lungs, the primary symptom of which is shortness of breath but can lead to respiratory or heart failure. Emphysema damages the structure of the alveoli causing the walls of the lung to break down. When this happens the alveoli are no longer able to hold the bronchioles open, making it hard for the lungs to empty air. As time and damage to the alveoli progresses, lung elasticity decreases. Emphysema often occurs with bronchitis, termed chronic obstructive pulmonary disease (Aufderheide & Rodriguez-Martin 1998; 263-265).

Some types of the disease are due to aging; new alveoli tissue stops developing when a person is approximately twenty. As people age, alveoli die, the number of lung capillaries decline, the elastin of the lungs will break down, chest muscles will weaken and posture may change; these symptoms together may cause the development of emphysema (Slezak 2008; 876-877).

The main cause of emphysema is chronic smoke inhalation; today, cigarette smoking, any other causes lead to secondary emphysema. It is possible that the smoky indoor hearths were to blame for the few-recorded cases from ancient Egypt.

During Shaw's (1938; 118-119) examination of the much damaged mummy of the Eighteenth Dynasty singer, Harmose, he reported that the margins of the middle lobe of the right lung were white with very little carbon and that the air sacs were emphysematous; a case of centrilobular emphysema. Harmose was quite elderly at the time of death.

Another case of centrilobular emphysema was found during Walker et al's (1987; 46-47) examination of six lung specimens; the lung sample, obtained from a Canopic jar housed at the British Museum (BM 51813), dated to the Twentieth Dynasty, displayed loss of alveolar septae consistent with this condition.

In emphysema in the absence of substantial carbon accumulation suggests a deficiency of alpha-1-antitrypsin, which is a protein produced by the liver - its main role is to protect the lungs from destruction by other enzymes. A deficiency can be caused when the protein is still formed by the liver but not released into the blood stream. This deficiency may be confirmed by the histological appearance of the liver; liver cells become engorged with the retained alpha-1-antitrypsin, which would be demonstrable with specific stains (Aufderheide & Rodriguez-Martin 1998; 264). It is unlikely that A102 suffered from emphysema due to his age. However, an area of his lung tissue show large bullae as is known to develop as the disease progresses (see Figure 4.228), unfortunately, the liver sample of A102 was far too degraded for such staining to occur.

One fact is clear; A102 was certainly suffering from some form of respiratory distress.

4.15.1.3 – Pneumonia

A more likely diagnosis for A102 is pneumonia.

Pneumonia is an acute condition characterised by an infection of the lower respiratory tract due to any infectious agent; over 75 germs can cause pneumonia, mostly bacteria and viruses, fungi and parasites are less common. Just as the causes can vary so can the disease take different forms; most usually an infected person will have inflamed lungs and the alveoli (air sacs) fill with mucus and other matter, making it difficult for oxygen to be transferred. Breathing becomes difficult because the lungs have to work harder to inhale oxygen and exhale carbon dioxide, which may build up in the body (Aufderhiede & Rodriguez-Martin 1998; 181).

Anyone can be infected; however, it tends to strike people whose natural defences against infection are weak, such as the elderly, infants or young children. Symptoms vary depending on the original health of the person with the infection. Bacterial pneumonia can manifest with high fever, chills, headaches, tiredness, loss of appetite, nausea, vomiting, rapid breathing, deep cough which brings up greenish mucus (sometimes mixed with blood) and severe chest pain with breathing and coughing. Viral pneumonia produces

symptoms similar to those of influenza – fever, muscle aches, breathlessness and dry cough (Cannon 2008; 2178).

Two cases of pneumonia in ancient Egyptian mummies have been cited by Ruffer (1910a; 1-5) and another by Shaw, who examined Harmose, the elderly singer from the Eighteenth Dynasty (1938; 122). Of the six samples examined by Walker et al (1987; 44), two displayed alveolar spaces that were partially or completely filled with a proteinaceous exudate (any fluid that filters from the circulatory system into lesions or areas of inflammation), one of these also showed what appeared to be an intra-alveolar cellular infiltrate consistent with a pneumonic process. The extent of this suggested respiratory compromise as the immediate cause of death.

Respiratory distress as cause of death is also a possibility for A102. Figures 4.231 to 4.233 suggest A102 was suffering from aspiration pneumonia, which is the accidental inhalation of food or vomited material into the lungs. The amount of material in the bronchioles in conjunction with what appears to be thickening of the intima (innermost layer) of these vessels points towards A102 having been ill for some time.   A102 was also emaciated at the time of death; the skin sample demonstrates only a very thin layer of fat cells indicating that A102 had been undernourished for some time. Whether or not the respiratory distress due to pneumonia was the cause of the emaciation, or was part of a secondary condition cannot be confirmed with the samples available for histological examination.

At the time of gross anatomical examination, only one ante-mortem pathology could be recorded for Mummy A102, that of a dental abscess. After histological examination, we now know that A102 was a frail sickly child, suffering from a chronic form of respiratory compromise, most likely pneumonia.

Mummy Identification Number	A102
Individual Age	8-11 years
Sex	Male
Current Examination Methods	Histology
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	72
Samples Used	Skin, Rib, Lung, Bowel, Liver
Previous Palaeopathological Findings	Dental Abscess
Current Palaeopathological Findings	**Pneumonia,** **Possible Emphysema,** **Anthracotic-type and Silica-type particle presence in lung (very mild),** **Emaciation**
Cause of Death	**Possible Aspiration Pneumonia**
Mummification Type	Four

Table 4.8 – Revised Minimum Standards Case Report – Mummy 102

4.16 - RESULTS - MUMMY A108

4.16.1 - Bowel

The bowel sample from Mummy A108 is in a fair state of preservation, unlike most of bowel samples examined for this project. The reason for this is that the sample is mainly the collagenous bowel wall; no other structures could be identified. There was no evidence of intestinal contents (plant material, parasite ova) in the sample, which corresponds to the autopsy report that stated the stomach, large and small intestines were empty (Aufderheide 1998b; 7).

No pathologies could be recognised within this sample.
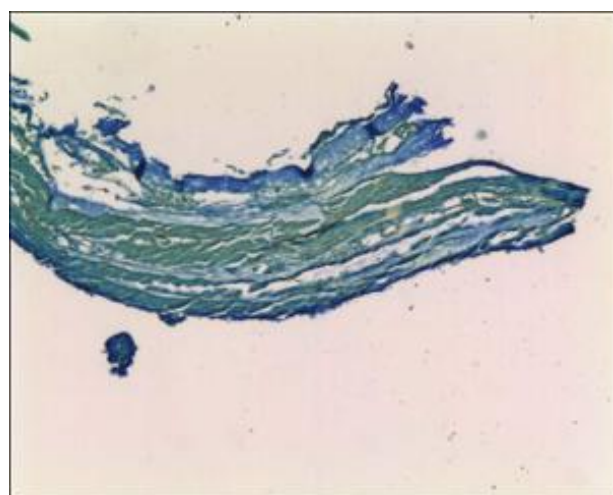
 Fig 4.241	<u>Stain – Toluidine Blue</u> <u>Magnification – x5</u> Low magnification of bowel sample
 Fig 4.242	<u>Stain – MSB</u> <u>Magnification – x10</u> Collagenous wall of the bowel sample
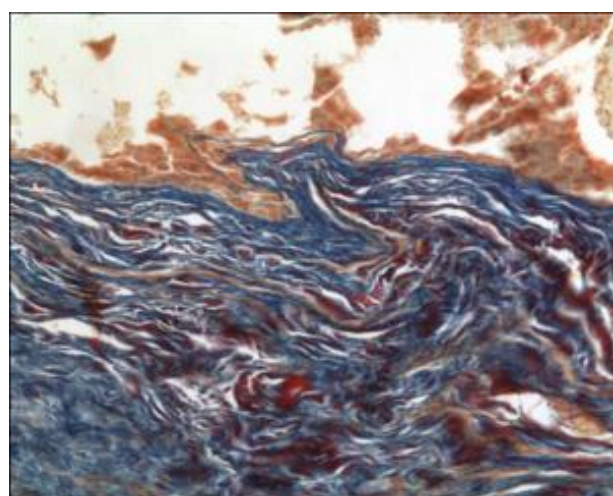
4.16.2 - Heart
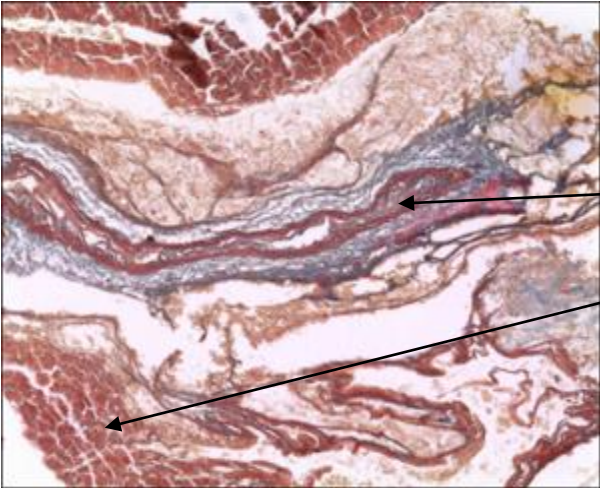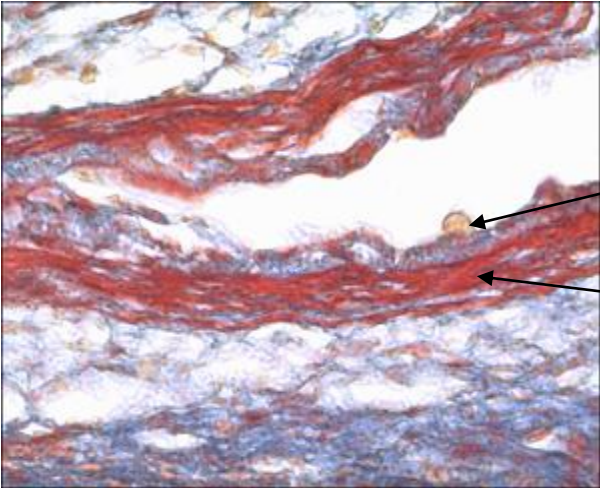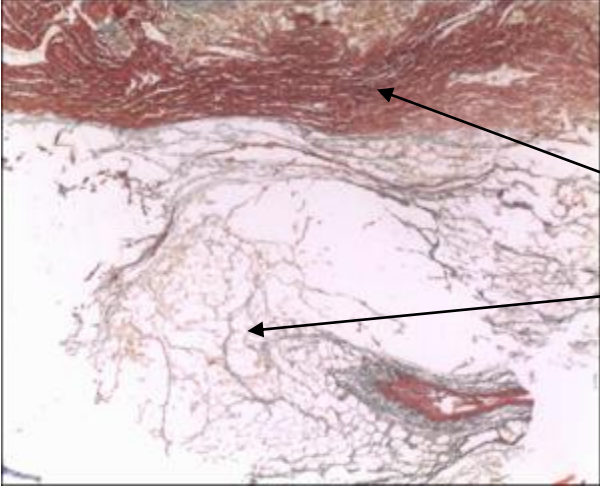
The heart sample from Mummy A108 is in a good state of preservation and enables a diagnosis the presence of some type of heart disease.

The sample from A108 was blocked out using both paraffin wax and acrylic resin. The paraffin wax sections show coronary vessels and a fair amount of fat surrounding and within the heart muscle. These fatty changes alone indicate the presence of heart disease. The resin sections show a good degree of fibrosis in some areas of the heart. There were still viable interstitial cells in between the fibrosis but they would not have functioned well due to the large amount of fibrotic scarring.
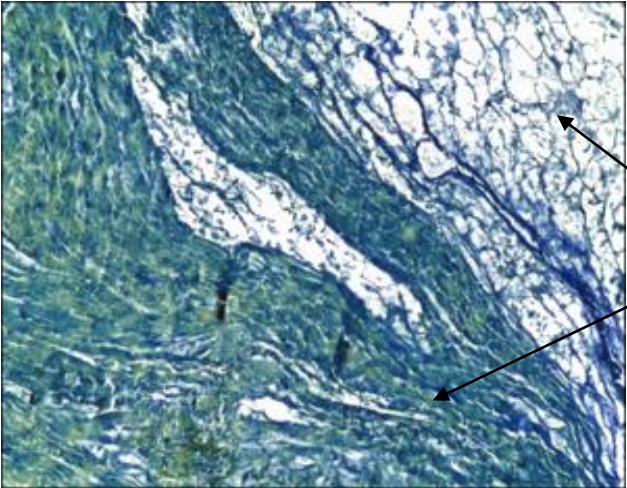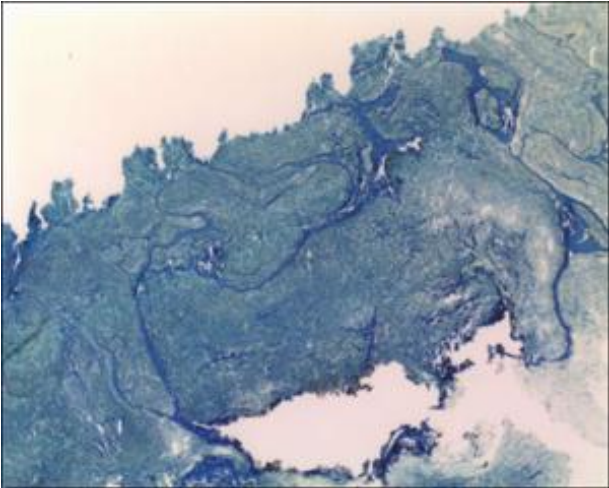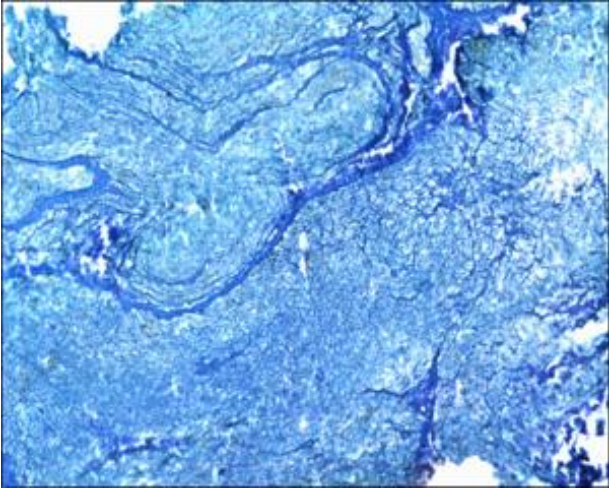
While the sample is well preserved, some bacteria are visible within an arterial wall.

This sample suggests that Mummy A108 was extremely ill and it is possible that this damage to the heart was the cause of death.

Stain – MSB

Magnification – x1.6

Cardiac muscle

Collapsed artery

Fat cells
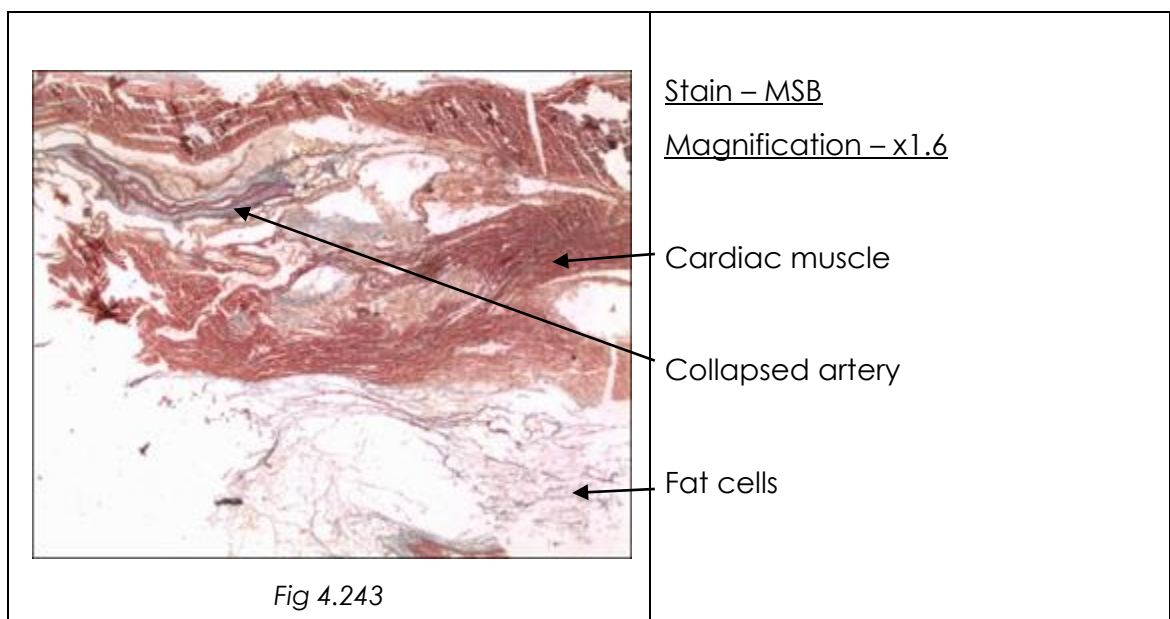
Fig 4.243

Fig 4.244

Stain – MSB

Magnification – x5

Collapsed artery

Cardiac muscle

Fig 4.245

Stain – MSB

Magnification – x40

Possible red blood cell

Arterial wall

Fig 4.246

Stain – MSB

Magnification – x2.5

Cardiac muscle

Fatty cell layers surrounding the heart muscle

Fig 4.247

Stain – Toluidine Blue

Magnification – x5

Fat cells

Cardiac muscle

Fig 4.248

Stain – Toluidine Blue

Magnification – x1.6

Resin Section

Low magnification of heart sample

Fig 4.249

Stain – Toluidine Blue

Magnification – x5

Resin Section

Section of heart displaying a excessive fibrosis
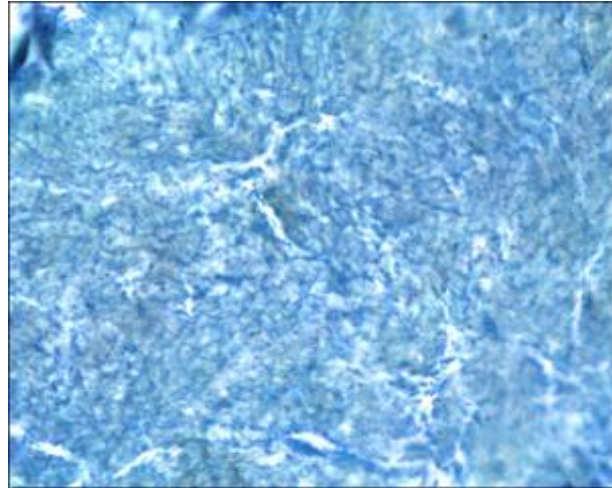
Fig 4.250

Stain – Toluidine Blue

Magnification – x20

Resin Section

Section of heart with no evidence of fibrosis
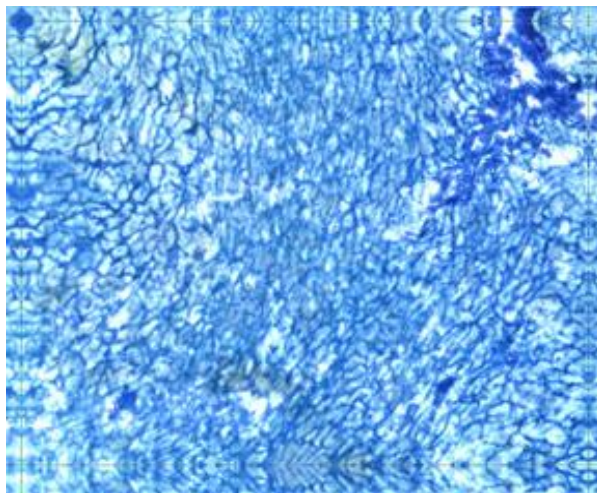
Fig 4.251

Stain – Toluidine Blue

Magnification – x20

Resin Section

Interstitial cells between fibrosis (dark blue lines = fibrosis)
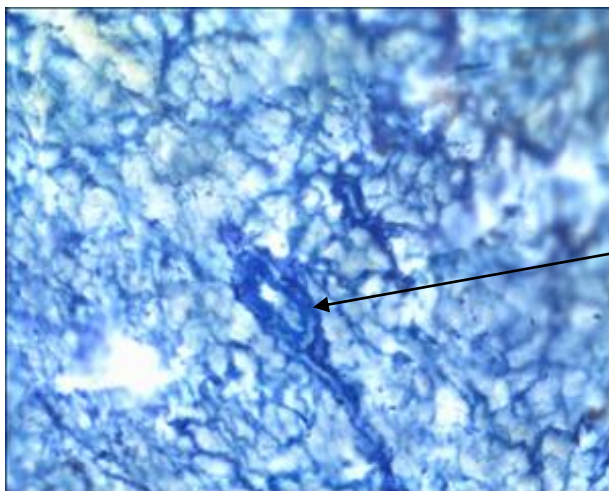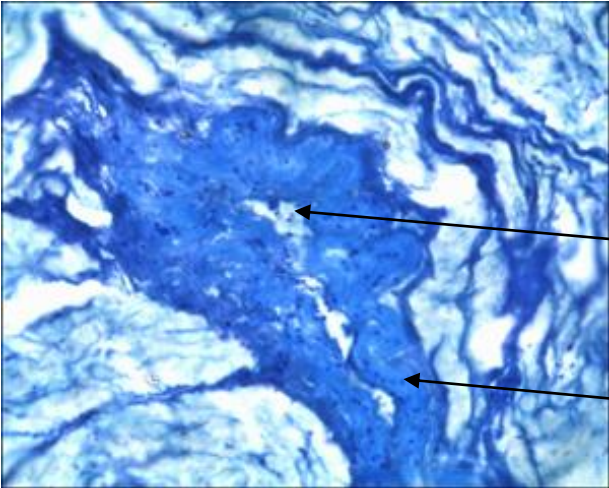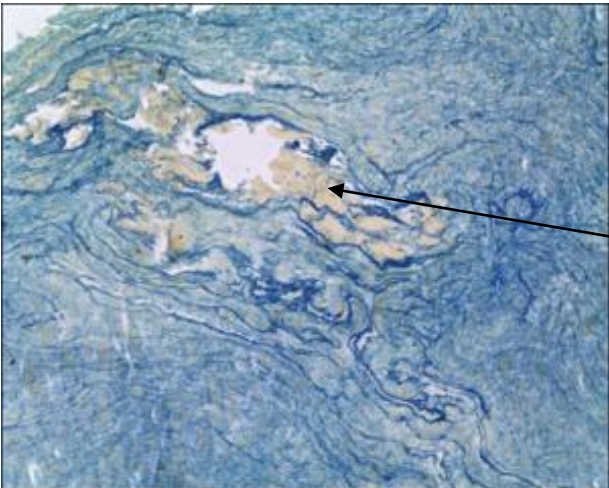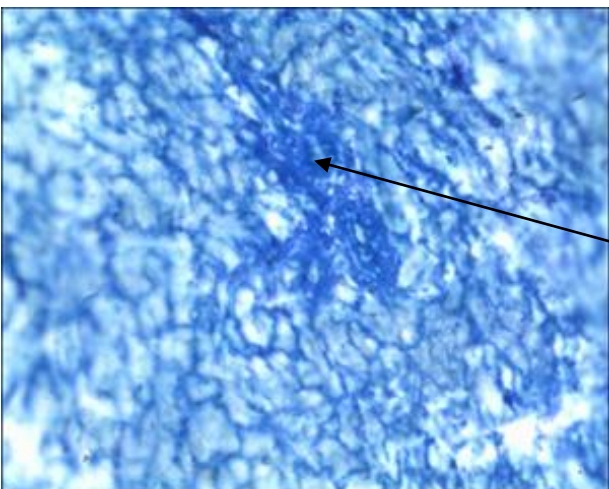
Fig 4.252

Stain – Toluidine Blue

Magnification – x40

Resin Section

Arteriole

Fig 4.253

Stain – Toluidine Blue

Magnification – x 40

Resin Section

Internal elastic lamina of artery wall

Bacteria (dark blue dots)

Fig 4.254

Stain – Toluidine Blue

Magnification – x5

Resin Section

Fatty inclusion surrounded by fibrosis

Fig 4.255

Stain – Toluidine Blue

Magnification – x40

Resin Section

Fungi

4.16.3 - Liver

The liver sample from Mummy A108 was in an extremely poor state of preservation. It was blocked out in paraffin wax and acrylic resin, neither medium able to provide support for the already badly degraded sample.

In the paraffin wax sections, the stain did not take to any part of the sample, leaving any structures remaining invisible. The resin sections proved to be slightly more successful, displaying s small area of fibrosis and the presence of fungi that had digested the sample (post-mortem).

 While fibrosis can be seen, it is impossible to state how widespread this may have been and what other pathologies might be present.
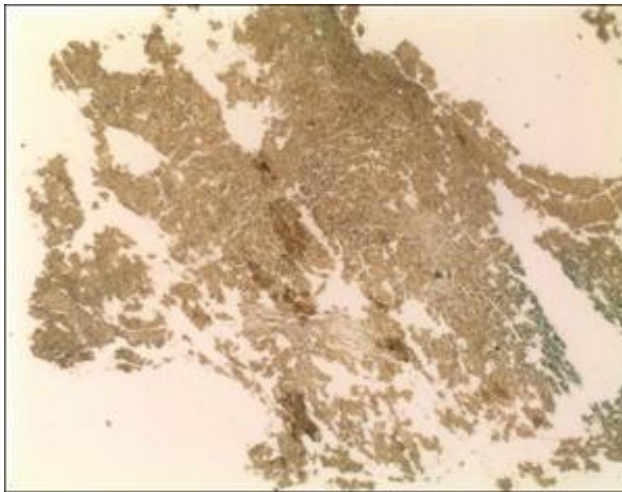
Fig 4.256	Stain – MSB Magnification – x2.5 Very poorly preserved liver sample, which was so degenerated that no staining was possible
Fig 4.257	Stain – MSB Magnification – x20 As Figure 4.256 at a higher magnification
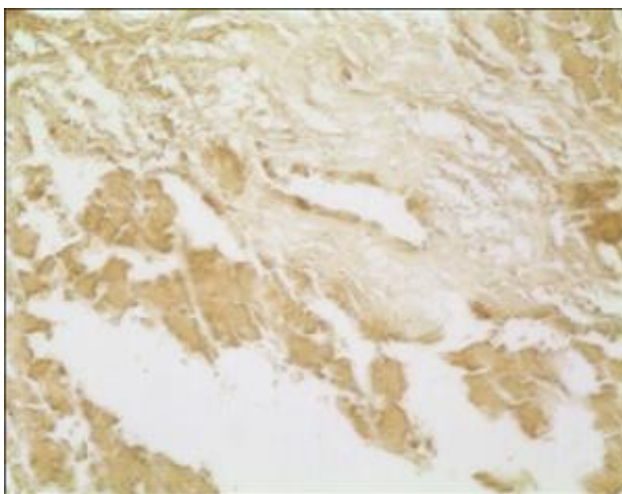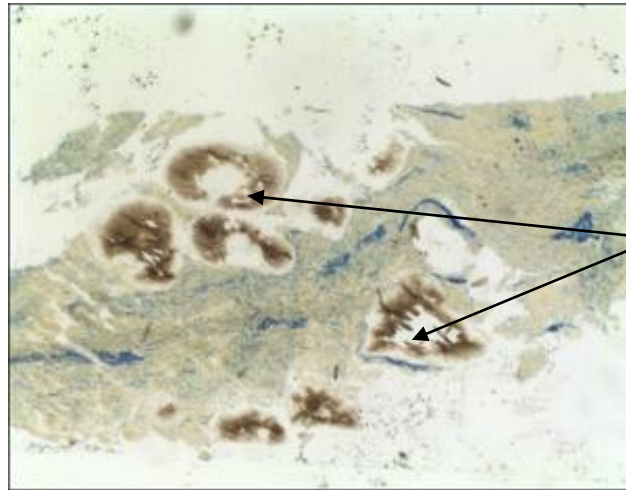
Stain – Toluidine Blue

Magnification – x2.5

Resin Section

Fungal bodies
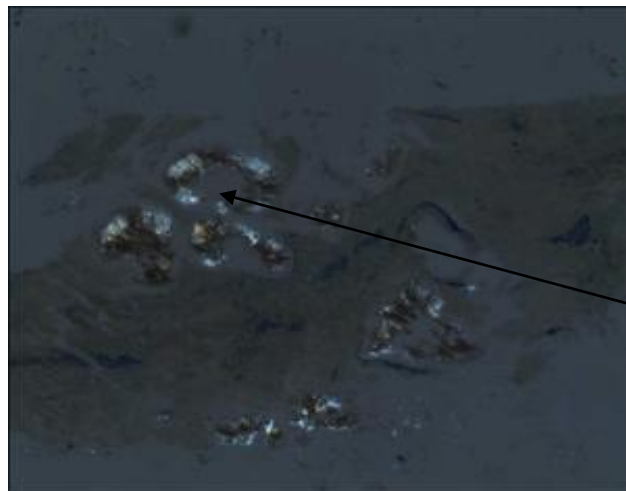
Fig 4.258

Stain – Toluidine Blue

Magnification – x2.5

Resin Section

Polarised Light Microscopy

Chitin in fungal bodies
(birefringent)

Fig 4.259
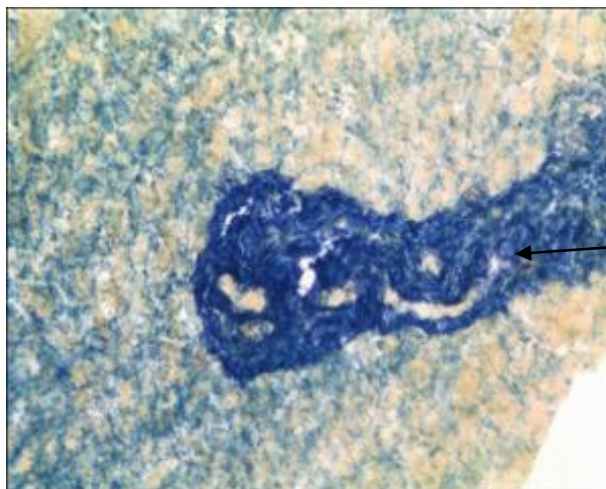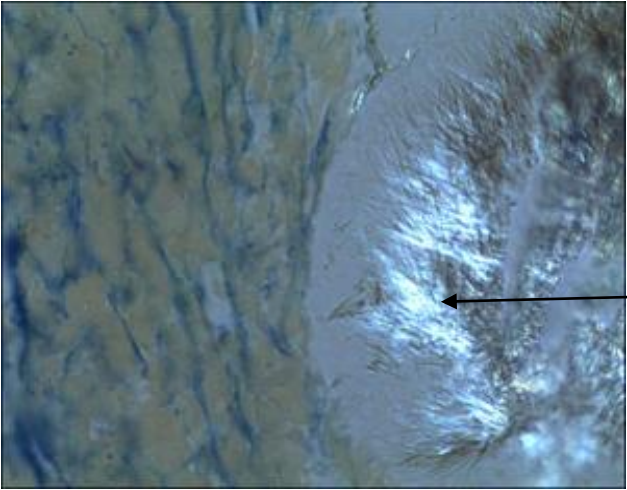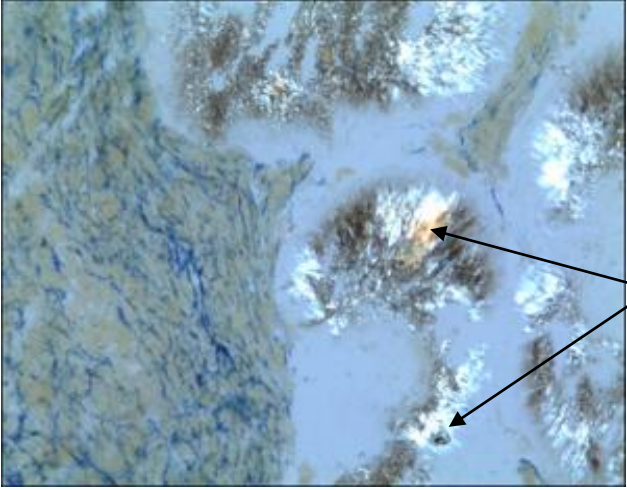
Stain – Toluidine Blue

Magnification – x10

Resin Section
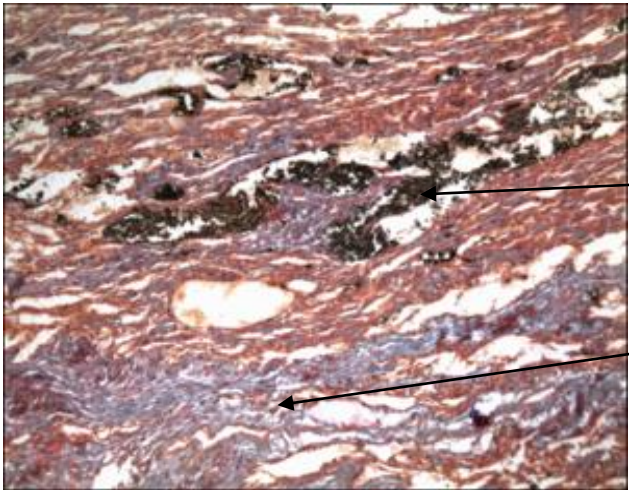
Fibrosis

Fig 4.260

Fig 4.261

Stain – Toluidine Blue

Magnification – x40

Resin Section

Polarised Light Microscopy

Fungal metabolites, possibly calcium oxalate (birefringent)

Fig 4.262

Stain – Toluidine Blue

Magnification – x10

Resin Section

Polarised Light Microscopy

Fungal metabolites, possibly calcium oxalate (birefringent)

4.16.4 - Lung

The lung sample from Mummy A108 was easily recognisable as lung due to the fair amount of carbon- and silica-type particles present within it. Some bronchioles were visible as they have been coloured blue in sections stained with MSB.

An accumulation of silica- and anthracotic-type particles were the identifiable pathologies within this sample.

Fig 4.263	Stain – MSB Magnification – x5 Carbon-type pigments Collagenous walls of collapsed bronchioles
Fig 4.264	Stain – MSB Magnification – x5 Polarised Light Microscopy Silica-type particles (birefringent)
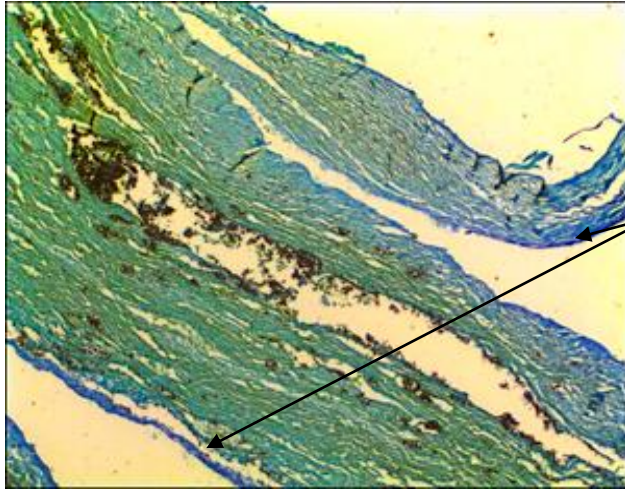
Fig 4.265

Stain – Toluidine Blue

Magnification – x2.5

Tissue change from
bacteria/fungi or oxidation
(darker blue)

4.16.5 - Muscle

The muscle sample from Mummy A108 is very well preserved, displaying anatomical features that would be seen in sample of fresh tissue. The spaces between the muscle bundles, facial planes and striations can easily be recognised.

No pathologies could be identified.

<table>
<tr>
<td>

Fig 4.266

</td>
<td>

Stain – Toluidine Blue

Magnification – x2.5

Space between muscle bundles (fascia)

</td>
</tr>
<tr>
<td>

Fig 4.267

</td>
<td>

Stain – Toluidine Blue

Magnification – x10

Fascial plane

</td>
</tr>
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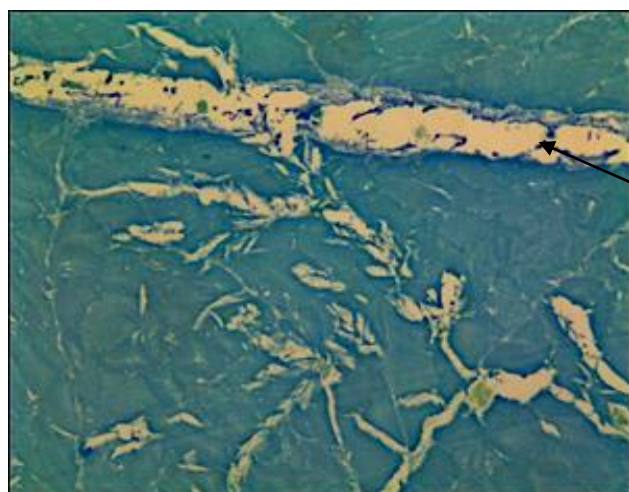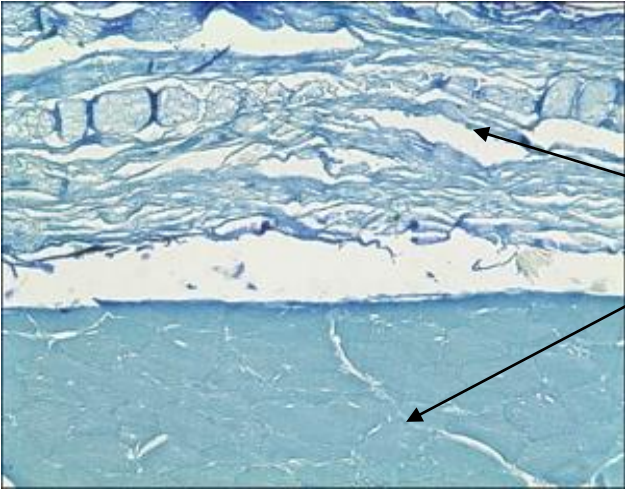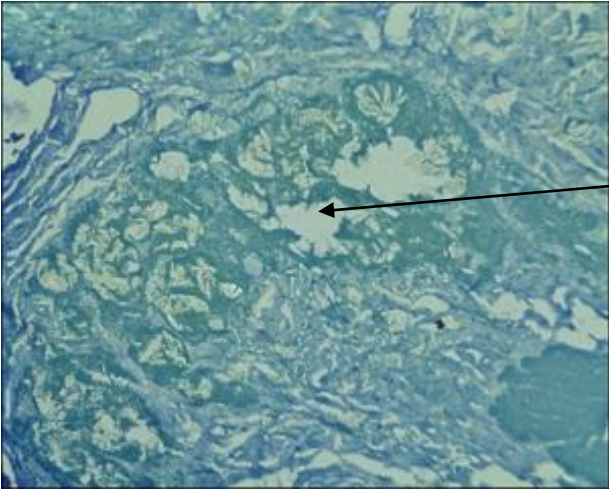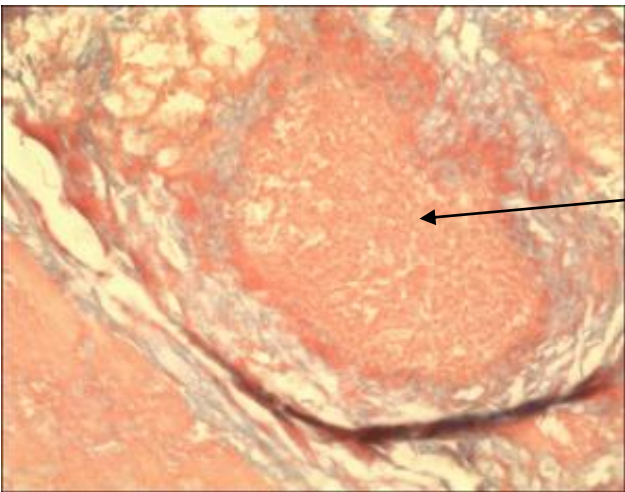
Stain – Toluidine Blue

Magnification – x10

Skin

Muscle tissue

Fig 4.268

Stain – Toluidine Blue

Magnification – x10

Fungal Inclusion

Fig 4.269

Stain – MSB

Magnification – x20

Fungal inclusion
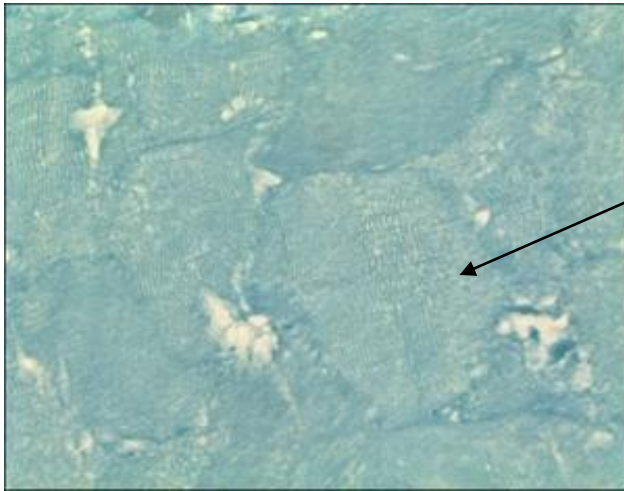
Fig 4.270

Fig 4.271

Stain – Toluidine Blue

Magnification – x20

Skeletal muscle striations
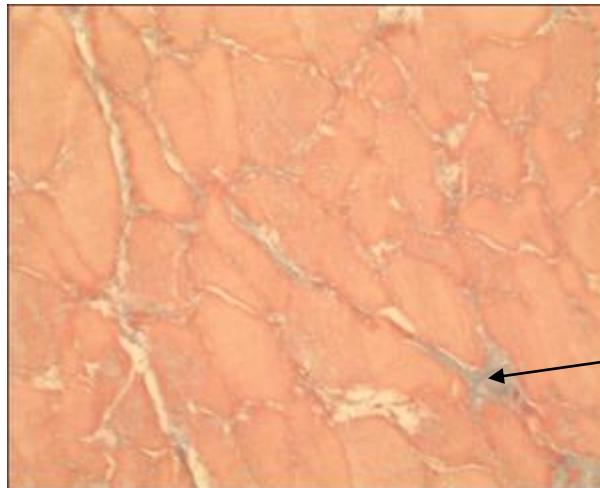
Fig 4.272

Stain – MSB

Magnification – x20

Spaces between muscle bundles

Fascial planes

4.16.6 - Bone (Rib)

The rib sample from Mummy A108 was extremely degraded and could not be confirmed as rib. In raw form, the sample appeared to be very brittle so it was decided to block out using acrylic resin (LR White). The sample sectioned well, however, it was so degraded that it did not take up the toluidine blue stain and no elements can be recognised with certainty.
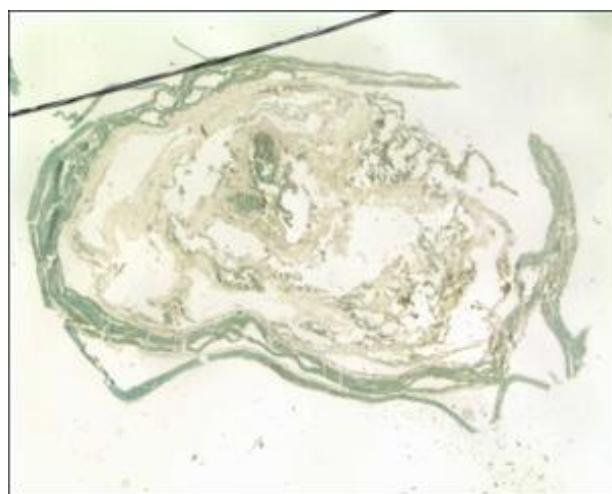
 Fig 4.273	Stain – Toluidine Blue Magnification – x1.6 Resin section Unidentifiable sample
 Fig 4.274	Stain – Toluidine Blue Magnification – x10 Resin section Unidentifiable sample
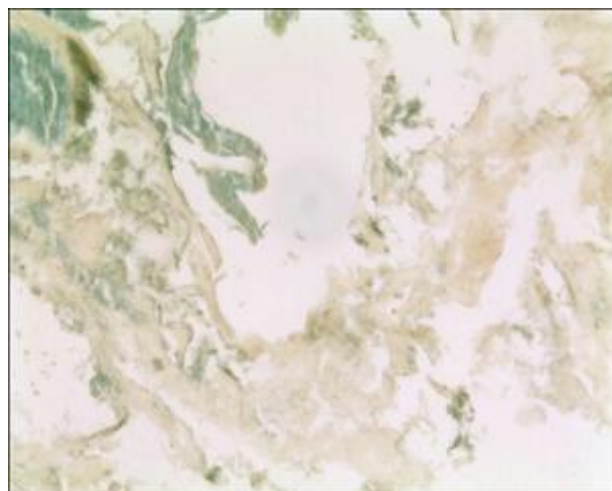
4.17 - HEARTACHE IN ANCIENT EGYPT – DISCUSSION OF MUMMY A108

The bowel, heart, lung and muscle samples from Mummy A108 all displayed a good level of preservation. The liver sample was not well preserved, and the rib sample could not be confirmed as such. The degradation of the liver sample is not surprising; as stated above the liver is highly metabolically active during live, which leaves it, after death, highly susceptible to autolysis and putrefaction (see Chapter 3.3.4). In addition, the presence of fungal bodies that have digested the sample are still clearly visible.

The very bad state of preservation of the rib sample is less easily understood; bone usually survives quite well in the archaeological context but is highly dependent on its surrounding environment. Soils that retain water and/or acidic soils are able to dissolve the mineral matrix of hydroxyapatite. However in this case, it degradation was most likely caused by microorganisms, mainly bacteria and fungi, which are capable of invading bone tissue and leeching the minerals into the surrounding environment, causing a disturbance in the bone structure (see Chapter 3.4.8). Alternatively, due to the poor quality of the sample, it may not be rib bone but a fragment of another element that was either on or near the rib cage at the time of autopsy.

Histologically, the most interesting sample was that of the heart. It appeared in a good state of preservation, but like the liver sample of A5 (see Chapter 4.6.3), it may a diseased state that is holding components of the sample together. While the paraffin wax sections stained with MSB show some elements of interest, mainly the fatty inclusions around the heart muscle, it is the resin sections stained with toluidine blue that show the highly fibrotic nature of the sample. Some areas are so fibrotic that it suggests the heart was struggling to work effectively and could very well be a cause of death or, at the very least, a contributing factor.

4.17.1 – The Heart in Ancient Egypt

The ancient Egyptians believed it was the heart, not the brain that controlled human wisdom, memory and emotions.

The heart's connection to memory, intelligence and emotion made it the most important of the internal organs. It also recorded the deeds and behaviour of its owner during life and therefore could testify for or against its owner after

death, and for this reason, it was left in the body during mummification. If it were to be accidently removed, it would be sewn back into place. From the First Intermediate Period, stone scarabs were often wrapped between with the bandages in close proximity to the heart. Spell 30b from the Book of the Dead (or as the Egyptians knew it - Book of Coming Forth by Day) was usually inscribed on the flat surface of the scarab, which begged that it should not betray its owner in the weighing of the heart ceremony, part of the final judgement before the deceased enter the realm of Osiris. It allowed even the most reprehensible of individuals to enter the Afterlife (Andrews 1994; 76).

O my heart, which I had from my mother! O my heart, which I had from my mother! O my heart of my different ages! Do not stand up as a witness against me, do not be opposed to me in the tribunal, do not be hostile to me in the presence of the Keeper of the Balance, for you are my ka which was in my body, the protector that made my members hale. Go forth to the happy place where to we speed; do not make my name stink to the Entourage who make men. Do not tell lies about me in the presence of the god; it is indeed well that you should hear! (Faulkner 1972; 28).
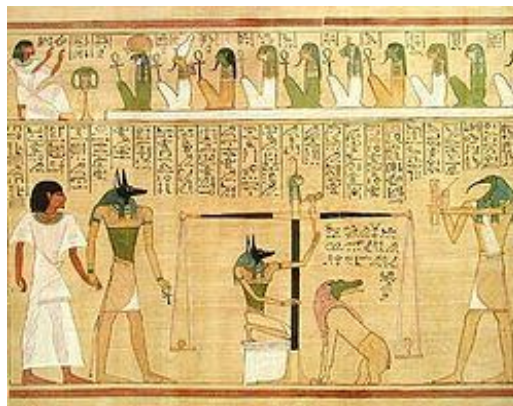
Fig 4.275 – Vignette of Chapter 125 (Book of the Dead) -
Weighing of the heart ceremony for Hunnefer (Taylor 2001; 36)

The importance of the heart to the ancient Egyptians can clearly be found in the Book of the Dead, which contains four chapters concerned with the heart remaining with its owner in the Afterlife. From the New Kingdom onwards, heart-shaped amulets were introduced into the funerary equipment, which very quickly became the most important of all amulets and set on mummies until the end of the Pharaonic Period (Andrews 1994; 72). No amulets of any kind were discovered in the tombs of the Kellis 1 Cemetery so it impossible to ascertain whether this powerful belief in the need for the heart in the Afterlife

continued here. Some of the bodies were mummified using the traditional technique, which suggests it was. Many of the Kellis 1 mummies were missing their hearts at the time of autopsy; however, this was mainly due to decomposition rather than any deliberate removal (Aufderheide et al 2003; 139).

Fig 4.276 – Heart-shaped amulets (www.metmuseum.org)

4.17.2 – Cardiovascular Disease in Ancient Egypt (The Texts)

While the heart's function in blood circulation was not understood, the opening words of the Edwin Smith Surgical Papyrus and Prescription 854a in the Ebers demonstrate the ancient Egyptian's knowledge of the direct correlation between the pulse and the heart (Saba et al 2006; 417).

There are vessels in him to all his limbs. As to these if any doctor, any wab priest of Sekhmet or any magician places his two hands or his fingers on the head, on the back of the head, on the hands, on the place of the heart, on the two arms or on each of the two legs, he measures the heart because of its vessels to all his limbs. It speaks from the vessels of all the limbs (Bryan 1974; 125).

No mean feat when considering the Pharaonic Period was 2000 years before the discovery of blood circulation in the seventeenth century CE.

Proving that the efficient functioning of the heart was as important during life as it was in the Afterlife, Prescriptions 854 to 856 in the Papyrus Ebers concentrate on the cardiovascular system. Each of the Prescriptions is divided into many sub- paragraphs, describing the connections of the *met.w*. The word *met.w* (singular *met*) has no equivalent in English; it includes blood vessels, tendons, muscles and nerves, which transport all bodily fluids (blood, urine, faeces, etc), as well as air and malign or benign spirits. According to Ebers 856b:

Man has twelve heart-vessels. It is they, which give to all his members/limbs (parallel text in Berlin Medical Papyrus 163) (Bryan 1974; 130).

The conditions, which these Prescriptions describe, can be categorised into four types of heart complaints:

1) Failing heart

2) Possible congenital heart failure

3) Displacement or enlargement of the heart

4) Miscellaneous (Nunn 1996; 86).

4.17.3 – Cardiovascular Disease in Ancient Egypt (The Human Remains)

In modern times, heart disease is often caused by certain lifestyle factors, such as obesity, smoking, lack of exercise, large alcohol consumption, however, in ancient Egypt, it is unlikely these sources were to blame and when investigating the possible case of heart disease in Mummy A108, other causes must be looked into.

The heart is a large muscle with a single purpose – to keep blood in motion so oxygen and nutrients can be passed throughout the body and metabolic waste products can be transported to excretory organs (lungs, kidneys, gastrointestinal tract). Today, heart disease is a major cause of death.
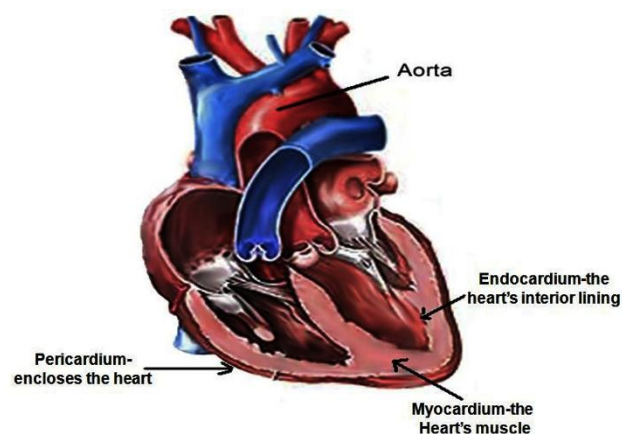
Fig 4.277 – Simple structure of the heart muscle (www.nhlbi.nih.gov/health/health-topics/images/heart_interior.gif)

While examination of the heart in desiccated mummies is difficult due to the brittle nature of the tissue, heart disease in ancient Egyptian mummies is not an uncommon finding, especially of those bodies whose owners made it to relative old age. Pharaoh Ramesses the Great and his son and successor, Merenptah,

both suffered atherosclerosis (hardening of the arteries). In the collection of his papers published in 1921, Ruffer described calcification of the aorta and atheroma of the carotid and iliac arteries that he had found in his examination of Egyptian mummies (Sandison 1962: 77-78). Veins and arteries, being made up mainly of connective tissue, are often the only part of the heart available for examination (see Chapter 3.4.3), post-mortem autolysis and/or putrefaction frequently obliterates much of the myocardium (Aufderheide 2003; 435). This means that while many diseases, such as atherosclerosis, had been diagnosed in many mummies (Shaw 1938; 115, Sandison 1962; 79, Long 1931; 92, Zimmerman 1977; 33-36), it is much less common that conditions such as myocardium infarction can be diagnosed. The heart sample examined from Mummy A108 appears to be that of myocardium.
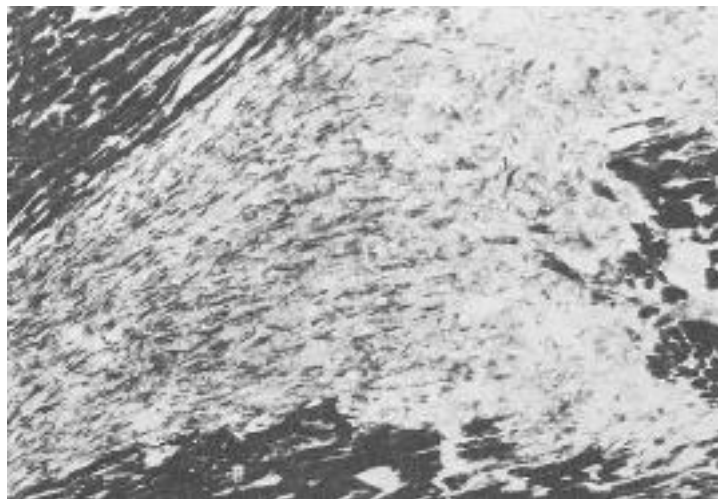
Fig 4.278 – Mummified healed myocardial infarct showing
excellent preservation of reparative fibres (light area)
(Zimmerman 1978; 752)

In 1931, Long examined the heart of a female mummy from Deir el-Bahri dated to the Twenty-First Dynasty. Lady Teye was estimated to be approximately 50 years at the time of death and displayed signs of calcification of the coronary arteries as well as myocardium fibrosis (Long 1931; 92-96). In a study of 37 hearts by Zimmerman (1978; 750-753), he concluded that myocardial interstitial fibrosis would still be recognisable in mummified remains. It is this pattern of disease that Mummy A108 is demonstrating and would be the result of a healing myocardial infarction (heart attack). Zimmerman deemed it unlikely that evidence of an acute myocardial infarction as a cause of death could be found in mummified remains as necrosis of the heart muscle in such an event is,

in essence, a process of in-situ autolysis and a diagnosis of acute infarction would have to be based on finding the remains of a neutrophilic infiltrate, highly unlikely in either a spontaneously or artificially mummified body (Zimmerman 1978; 752).

However, preliminary studies by Miller et al (2000; 831-832) of a Twentieth Dynasty Priest of Amun and Foreman of Craftsmen at Deir el-Medina, Horemkenesi, have proved positive for diagnosing acute myocardial infarction as cause of death. They tested a sample of Horemkenesi's abdominal tissue using a sensitive and specific cardiac troponin assay - cardiac troponinI (cTnI), in order to detect molecular evidence of sudden cardiac death. The results proved that cTnI was preserved over the thousands of years since Horemkenesi's death and the higher levels of this in the abdominal sample was evidence of acute myocardial infarction, or simply put, death by heart attack.

The diseased state of the heart of Mummy A108 is striking due to the age of the individual, A108 was estimated to be no older than 25 at the time of death (Aufderheide 1998b; 1). A similar case was reported during the study of a mummy from the Pennsylvania University Museum (PUMII) dated to the late Ptolemaic Period, which found that the heart displayed intimal fibrosis of the large and small arterioles and arteries. PUMII was estimated between 35 and 45 years of age (Cockburn et al 1998; 69-90). While etiological influences (such as obesity) cannot be ruled out, other reasons for Mummy A108's condition must be explored.

Today, the reasons for heart disease leading that can lead to myocardial infarctions in young people have been given as:

1) Cardiomyopathies – abnormalities of the heart muscle and usually hereditary
2) Congenital Heart Disease - abnormalities of the structure of the heart which have been present since birth
3) Myocarditis – inflammation of the heart's muscle, usually due to a viral infection
4) Genetic Connective Tissue Disease - inheritable conditions affecting the structures that give support, strength and elasticity to the walls of

the major blood vessels and, to a lesser extent, the heart muscle - for example Marfan's Syndrome (Cannon 2008; 1243-1247).

It is not possible to ascertain whether A108 suffered from any of these conditions – none can be ruled out. Further work would need to be carried out on the remains of A108 as well as on heart samples from many other mummies from the Kellis 1 Cemetery. The latter being made particularly difficult as only six of the 49 mummies had hearts remaining to sample.

One Prescription in the Papyrus Ebers appears to be describing an acute myocardial infarction:

If you examine a man because of suffering in his stomach, and he suffers in his arm, his breast and the side of his stomach. One says concerning him/it: it is the wadj-disease. Then you shall say concerning it: something has entered his mouth. Death is approaching. (Ebers 191=194) (Nunn 1996; 87).

In both angina and myocardial infarction, pain is concentrated on the left side of the chest and may radiate down the left arm. Unfortunately, the Ebers' passage does not state on which side the patient is suffering. Nunn (1996; 87) goes as far to suggest that the 'wadj' (without the pustule determinative, wadj translates as 'green') disease could refer to the colour of the patient experiencing cardiogenic shock. However, this Prescription is in the section of the Papyrus dealing with stomach complaints so one must be careful reading too much into the passage.

What can be said is that Mummy A108 had an extremely fibrotic, diseased heart, likely caused by a myocardial infarction, the reasons for which are unknown. He survived and what can now be histologically examined are the preserved pathologic changes this event caused. It is worth noting that radiography and CT Scanning would not have picked up fibrosis such as this.

Mummy Identification Number	A108
Individual Age	21-23 years
Sex	Male
Current Examination Methods	Histology
Previous Examination Methods	Gross Anatomical Examination/Autopsy
Soft Tissue Preservation % (autopsy)	90
Samples Used	Bowel, Heart, Liver, Lung, Muscle, Rib,
Previous Palaeopathological Findings	None Found
Current Palaeopathological Findings	**Probable healed Myocardial Infarction**
Cause of Death	None Found
Mummification Type	Four

Table 4.9 – Revised Minimum Standards Case Report – Mummy A108
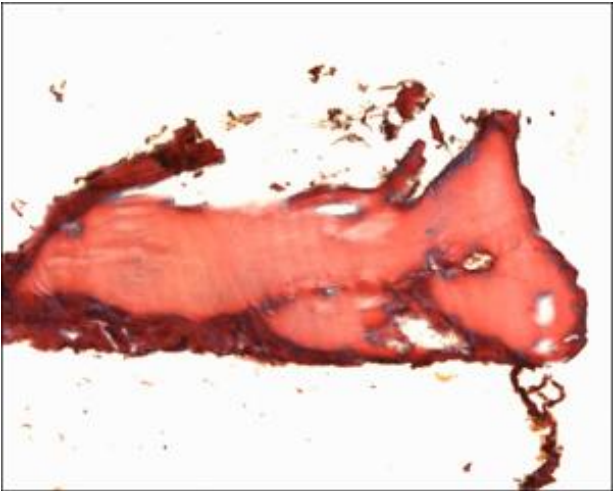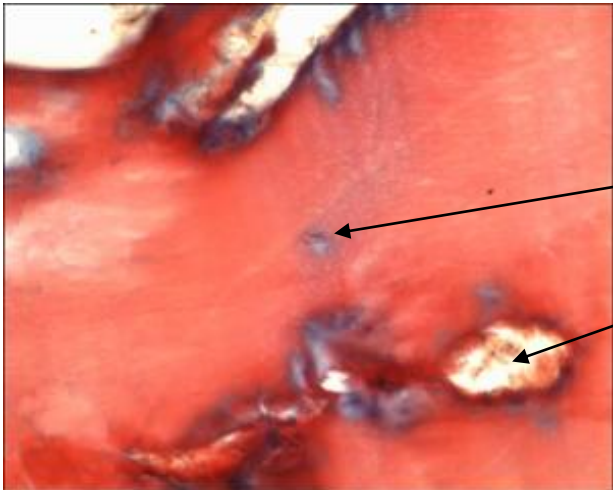
4.18 - RESULTS - MUMMY A126

4.18.1 - Skin (Bone)

The skin sample from Mummy A126 proved to be bone. It was obtained from the upper leg area, during the autopsy in 1998. The mummy was missing both legs below the knees and it is possible than some bone fragments from the break, or the missing legs, made their way to skin's surface.

The sample is that of lamella bone, which is set down in plates. A Volkmann's canal is still visible as are some osteocytes; fungi or bacteria have eroded other areas during the process of putrefaction.

No ante-mortem pathologies could be identified within this sample.

 Fig 4.279	<u>Stain – MSB</u> <u>Magnification – x5</u> Overview of bone sample which had been incorrectly labelled skin at the time of autopsy
 Fig 4.280	<u>Stain – MSB</u> <u>Magnification – x20</u> Osteocyte Area eroded by either fungi or bacteria
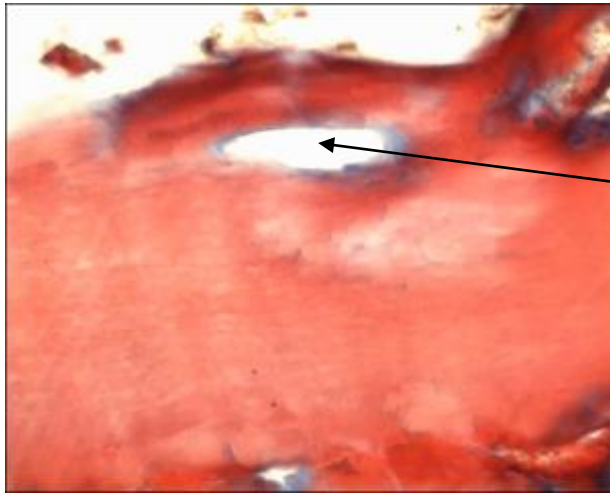
Fig 4.281

Stain – MSB

Magnification – x20

Volkmann's canal

4.18.2 - Lung

The lung sample from Mummy A126 is fairly well preserved, with bronchioles still identifiable.

There is quite a large amount of anthracotic-type pigment, which is not unexpected in a male of this age (30 to 40 years) from ancient Egypt. The anthracotic pigment is sometimes seen in discreet highly localised areas where during life it would have been within macrophages after being phagocytised.

In one area of the sample, the outline of a putrefied worm can be seen. This is most probably a post-mortem artefact, as there does not appear to be any tissue reaction. The large quantities of anthracotic- and silica-type particles appear also not to have caused a tissue reaction.
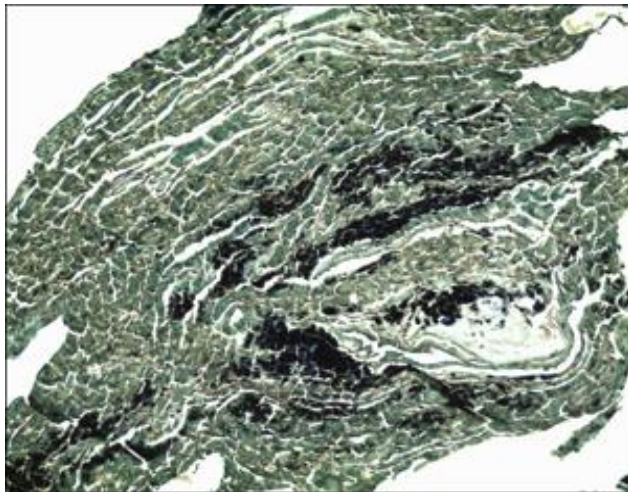
Fig 4.282

Stain – Toluidine Blue
Magnification – x5

General overview of the lung sample
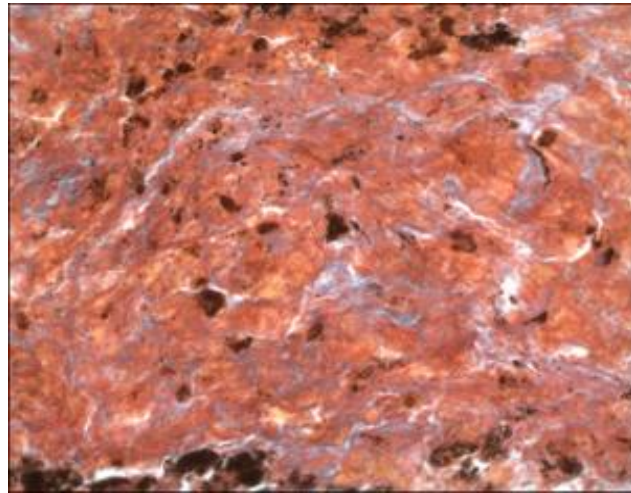
 Fig 4.283	<u>Stain – MSB</u> <u>Magnification – x20</u> Collapsed small bronchioles (stained blue) Very little anthracotic-type pigment – indicating lung tissue from high up in the respiratory system
 Fig 4.284	<u>Stain – Haematoxylin and Eosin</u> <u>Magnification – x40</u> Carbon-type (anthracotic) pigments
 Fig 4.285	<u>Stain – Haematoxylin and Eosin</u> <u>Magnification – x40</u> <u>Polarised Light Microscopy</u> Silica-type particles shown as highly birefringent (white) particles against a dark background
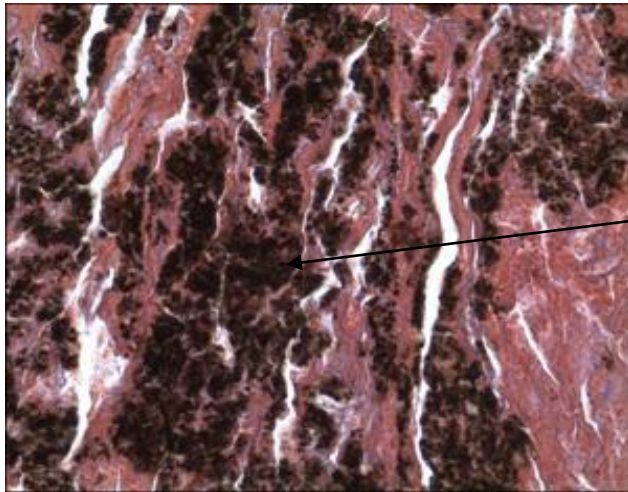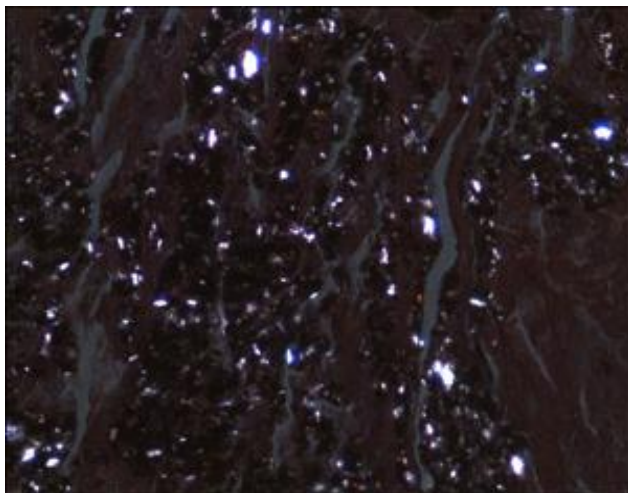
Fig 4.286

<u>Stain – Toluidine Blue</u>

<u>Magnification – x20</u>

Intracellular anthracotic-type pigment
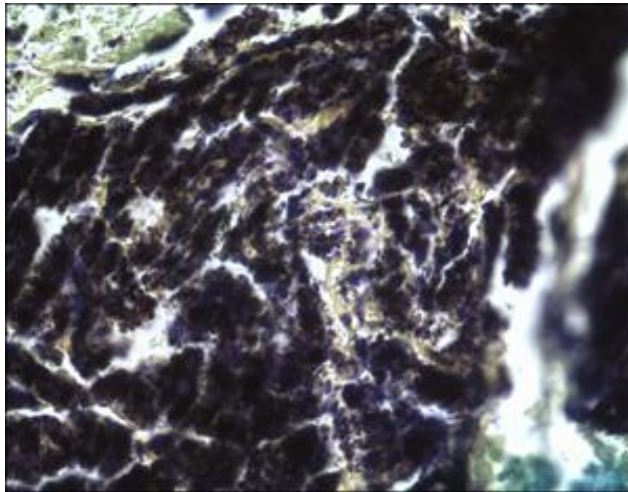
Fig 4.287

<u>Stain – Toluidine Blue</u>

<u>Magnification – x40</u>

<u>Polarised Light Microscopy</u>

Heavy deposition of anthracotic-type pigment
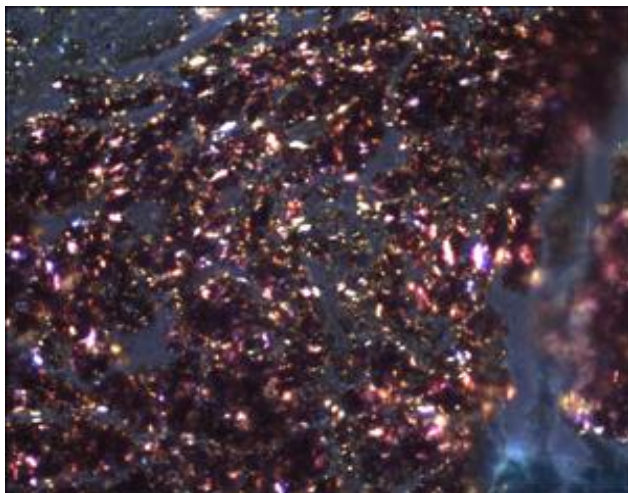
Fig 4.288

<u>Stain – Toluidine Blue</u>

<u>Magnification – x40</u>

<u>Polarised Light Microscopy</u>

When the same area as Figure 4.287, the anthracotic-type pigment is shown to coexist with birefringent silica-type particles
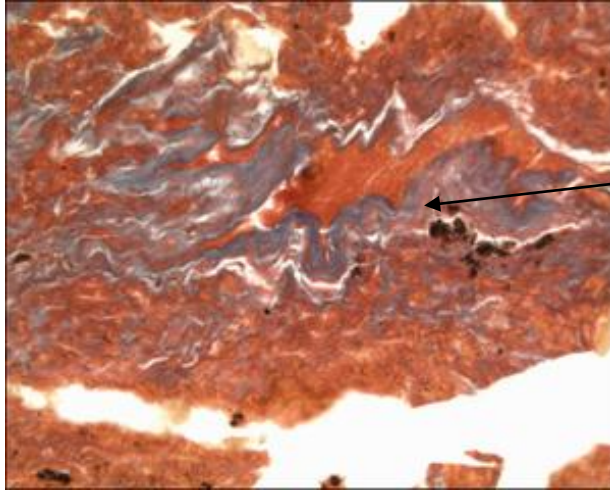
Stain – MSB

Magnification – x20

Collapsed bronchiole

Fig 4.289
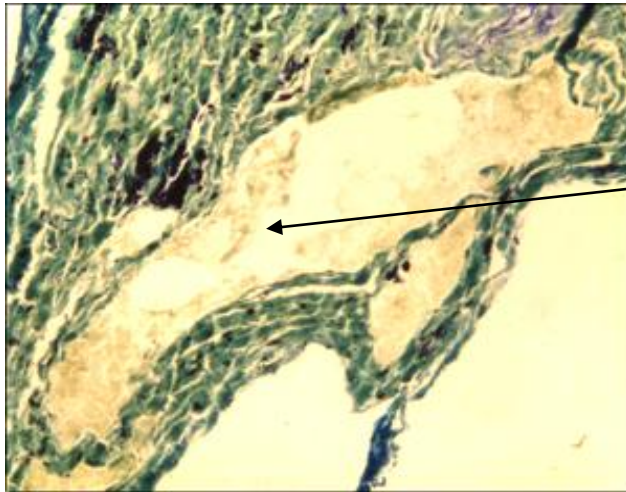
Stain – Toluidine Blue

Magnification – x10

Outline of putrefied worm
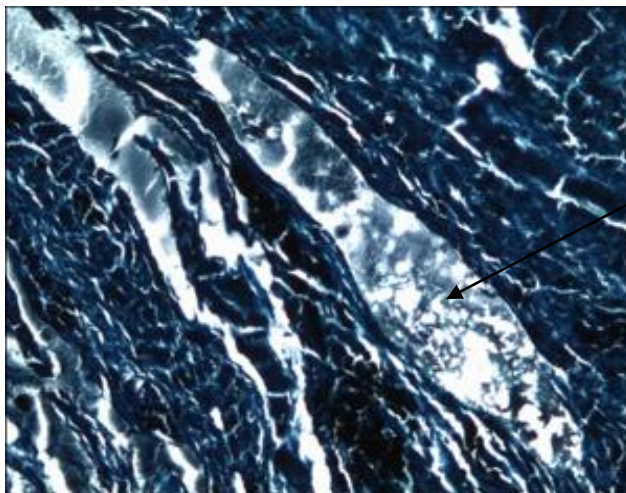
Fig 4.290

Stain – Geimsa

Magnification – x10

Outline of a putrefied worm

Fig 4.291

4.18.3 - Muscle

The muscle sample from Mummy A126 is in a poor state of preservation. It is impossible to recognise it microscopically as such, and identification must rely on the labelling done at autopsy.

Due to the state of degradation, no pathologies could be identified.
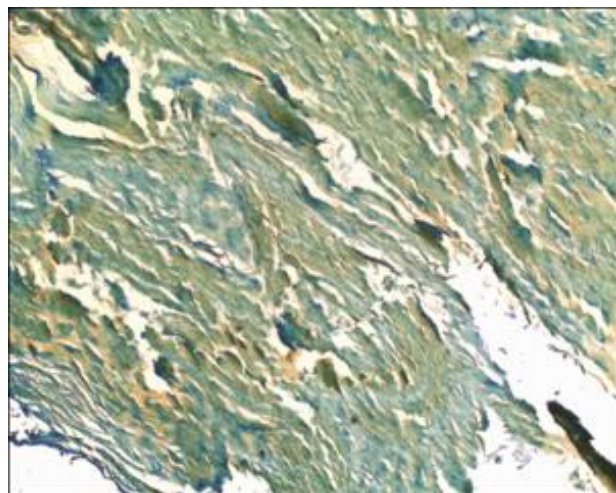
Fig 4.292	<u>Stain – Toluidine Blue</u> <u>Magnification - x2.5</u> Some collagen remaining (stained blue) but unrecognisable as muscle
Fig 4.293	<u>Stain – MSB</u> <u>Magnification – x5</u> Degraded muscle (?)
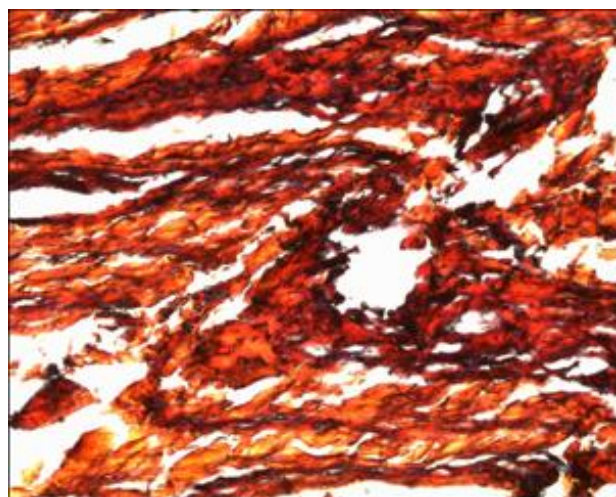
4.18.4 - Bone (Rib)

The rib sample from Mummy A126 is in a relatively good state of preservation, despite staining not being entirely successful. Many elements are still visible, such as osteocytes with some remaining nuclei.

The light blue area in Figure 4.296 is calcifying cartilage. This develops when the bone is just forming, after it is damaged by disease, such as osteoarthritis or is repairing after a fracture. A126 was between 30 and 40 years old so it most likely a case of repair after a fracture. Osteoarthritis is less likely because of the location of the bone (rib).

The bone is lamellar, which is the normal type of adult bone and is organised in layers or plates (lamellae). These layers can be parallel (cancellous bone) or concentrically arranged (compact bone).
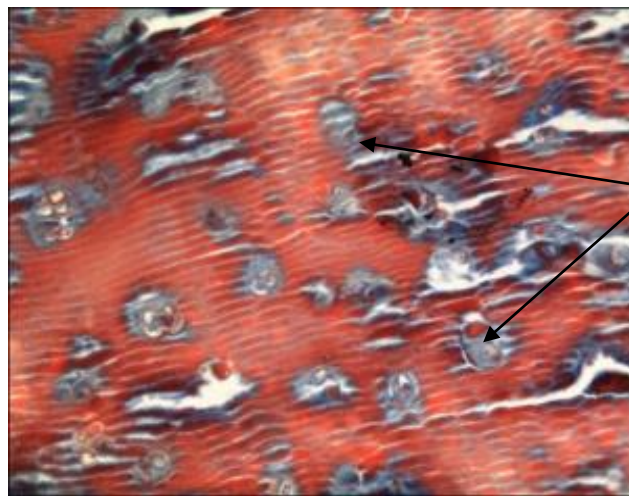
Stain – MSB

Magnification – x10

Osteocytes
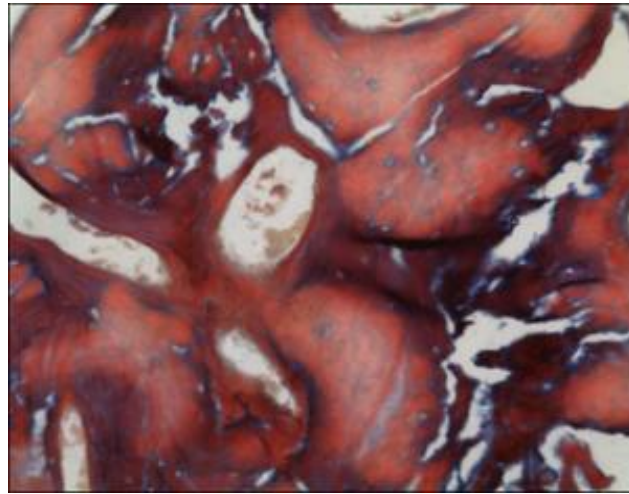
Fig 4.294

Fig 4.295

Stain – MSB
Magnification – x10
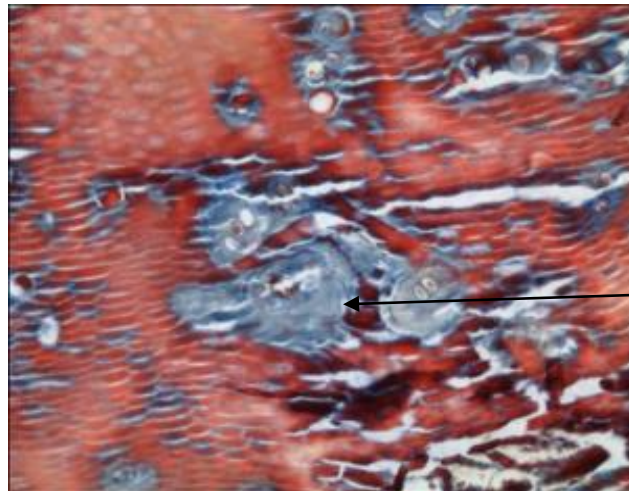
Bone

Fig 4.296

Stain – MSB
Magnification – x10

Bone (red)

Calcifying cartilage (blue)

4.19 – SHORT OF BREATH – DISCUSSION OF MUMMY A126

The samples from Mummy A126 were not well preserved. The sample, which had been labelled 'skin' at the time of autopsy, proved to be bone. While identification errors are easily understood by the homogeneous appearance of desiccated tissue, as well as organs collapsing and having their anatomical position within the body cavities changed, mistaking bone for skin is surprising. The muscle was unrecognisable as such and the liver sample turned to dust at the time of sectioning (see Chapter 3.5.2.5).

The two bone samples (one of which was labelled skin) were in a fair state of preservation and both macroscopic and microscopic structures could still be identified. The rib sample had evidence of a fracture; however, it had healed to a great degree by the time of death.

The lung sample was the least degraded, although this is mainly because of the air sacs and bronchioles that consist mainly of resilient connective tissue. A126 was a male aged approximately 30 to 40 years at the time of death and the quantity of silica-type and carbon-type particles in his lungs confirm this. Mummy A126 was recorded as being artificially mummified, which means the lungs should have been removed. When extracting the viscera, the embalmers first removed those in the abdominal cavity, after which an incision was made in the diaphragm from within the abdomen and, in theory, the lungs were then removed without disturbing the heart and its vessels. In practice, this was an extremely difficult task and, not only was the heart often mistakenly removed, but many artificially mummified bodies show adherent lung tissue within the chest (Thompson-Rowling 1961; 409). Histological studies of such material have shown the widespread presence of lung disease an ancient Egypt.

4.19.1 – Anthracosis and Silicosis

Two of the most common findings in any study of ancient Egyptian lung tissue are anthracosis (carbon or carbon-type pigments) and silicosis (silica or silica-type particles). Nearly every examined ancient Egyptian adult human mummy has evidence of these conditions. It is not only Egyptian mummies that display anthracosis, evidence; carbon pigments have been discovered in Alaskan and Aleutian mummies and bog bodies from Ireland, like the Egyptians, the cause is attributed to method of indoor cooking, lighting and heating (Zimmerman 1998;

151, Fischer 1998; 257). Severe anthracosis was also discovered in a sixteenth century Italian mummy (Ascenzi et al 1998; 280).

In modern industrial society, man is exposed to a number of chemical and physical irritants that can adversely affect the respiratory system, causing pathological changes in the lung. The ancient Egyptians had their own version of these pollutants. Firstly, the population, especially those in the Dakhleh Oasis, which is situated in the Western Desert, would have been subject to the sand storms that still blow up today, made up of small silica particles. Secondly, lamps using animal and plant fats were used for lighting, many of which are notoriously smoky, leading to the inhalation of soot particles (Serpico & White 2000; 392-422). Both silica and carbon inhalation lead to conditions known as pneumoconiosis.

Fig 4.297 – Sand storm in the Western Desert (http://ppg.mysite.com/images/sandstorm2.jpg)

Fig 4.298 – Egyptian lamp (www.libraries.mercer.edu)

Pneumoconiosis, from the Greek *pneumon* (lung) and *konis* (dust), refers to a group of diseases of the lung caused by long-term accumulation of dust particles in the lungs, as well as the reaction of the tissue to its presence. Some types of dust may simply collect in the lung tissue without further significant alterations of the lung morphology or function. However, fibrogenic minerals cause proliferation of connective tissue in the lungs (scarring); examples of these include silicosis, asbestosis and coal worker's pneumoconiosis (David 1991 14).

Silicosis is a pneumoconiosis (pulmonary fibrosis, scars of the lungs) caused by

the inhalation of crystalline free silica, the main forms being quartz, tridymite and cristobalite (all silica minerals). Dust particles of five to fifteen microns diameter deposited in the airways are cleared by mucociliary movement, however, particles of the diameter half to five microns landing in the terminal airways, or further, may be retained. Particles less than half a micron remain suspended in the air and are breathed out. Dust particles retained by the lungs are taken up by macrophages and transported either to the airways where they are cleared, or to the lung parenchyma. When these dust-containing cells die, other cells take up the released particles, and these also are killed, which creates a continuous low-grade reaction to the formation of scars. These scars mostly occur around the terminal airways and in advanced stages, scars increase in size and merge to become large fibrous masses (David 1991; 47-48).

The early stages of silicosis are usually not accompanied by any symptoms or signs of respiratory distress. In the more advance stages, when fibrotic masses are present, impaired respiratory function, including rapidly progressive breathlessness, occurs. Bronchitic symptoms, such as cough and phlegm due to the deposition of larger particulates in the airways, may not be debilitating, however, are sometimes irreversible. The rate of progression of the disease is slow; it usually slows down after exposure has ceased but in extreme cases, the disease can continue to progress, leading to respiratory or heart failure (David 1991; 49).

Anthracosis, or the deposit of carbon in the lungs, is a pneumoconiosis caused by exposure to mixed dust, or soot, in which silica is not the dominant fibrogenic component. Frequent smoke inhalation introduces so many particles (mostly carbon-containing compounds) that some of them adhere to the lung walls; the body has no effective means for disposing of these smoke particles. Continued smoke inhalation may eventually discolour the lungs. The quantity of accumulated smoke particles is a measure of past smoke enclosure. The effects are very similar to those of silicosis. The term 'anthracosis' is limited to the deposition of carbon-containing pigment in the lungs, which does not necessary indicate any limitation of respiratory function (Aufderheide & Rodriguez-Martin 1998; 265).

Even seemingly degraded ancient lung tissue can be examined for evidence of pneumoconioses. The canopic equipment of the Twelfth Dynasty mummy,

Nekht-Ankh (housed at the Manchester Museum, United Kingdom) was found to contain lung, as well as some of the dried soft tissue still attached to his rib bones. Under histological and microscopic examination, the lung was found to be extremely fibrotic, during to scarring. The blood vessels were surrounded by fine black particles. The particles were examined by electron microscope and found to consist of stone with very high silica content. The lesions these caused have been in modern times on the lungs of people living in desert areas, who are constantly breathing in the fine sand particles; it is a condition known as sand pneumoconiosis (Tapp 1992; 97).

Studies have been carried out on these particles and they have to consist of mixtures of granite, silica, aluminum, titanium and iron (Millet et al 1998; 99, Walker et al 1987; 44, Tapp 1992).

Walker et al's study (1987; 47)) of six lung specimens from a range of dates within the Pharaonic Period demonstrated the commonality of the pneumoconioses in ancient Egyptian human remains, with all six samples displaying significant anthracosis, which was attributed to the use of indoor open hearths in rooms with poor ventilation. In association with the anthracosis were found small birefringent particles (silica, iron and aluminium). However, the authors went to pains to emphasise that these silicate particles could not be equated to the presence of the disease silicosis, which refers specifically to interstitial fibrosis and that only half of the samples demonstrated such.

This may also be the case with Mummy A126. While there is what appears to be a large quantity of carbon and silica particles, there is little evidence of tissue reaction that would suggest a diagnosis of silicosis. Unfortunately, the surrounding tissue if quite degraded and any interstitial fibrosis is lost so confirmation either way is not possible.

Whether or not the particulates within A126's lungs caused him respiratory distress, he did have a large accumulation of such. This can be explained in some way by his age. A126 was a male aged 30 to 40 years at the time of death, this means he was well within the average life expectancy of a person at this time and place in history (although if child mortality is added in, the average age in the Dakhleh Oasis would be much decreased). While no personal history is available for the Kellis 1 mummies and therefore details of A126's employment are unknown, at his age he would have suffered through a

number of desert storms and been exposed to cooking, lighting and heating using indoor open hearths. These elements would certainly be a factor in the condition of the A126's lungs when he died.
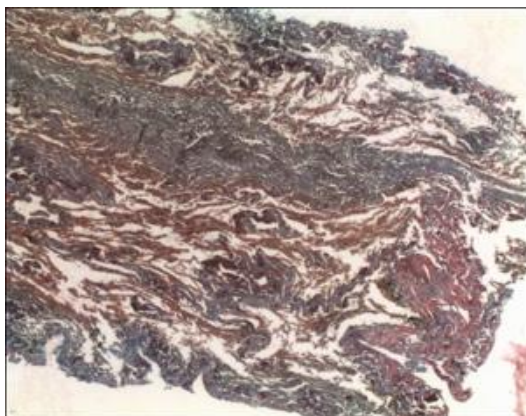
Fig 4.299 – A107- Overview
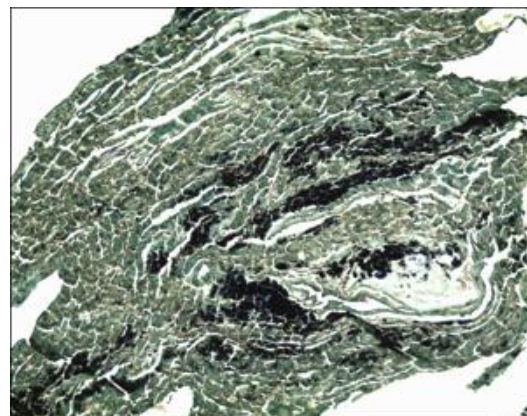
Fig 4.302 – A126 - Overview
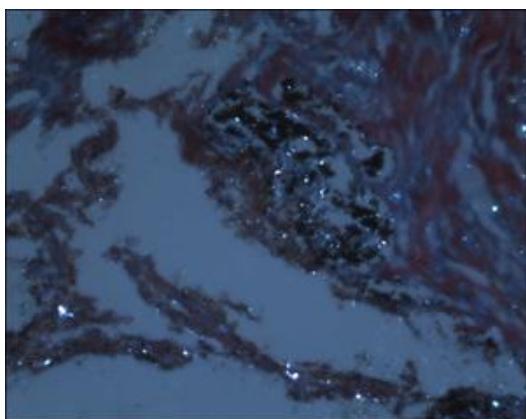
Fig 4.300 – A107 - Silicosis
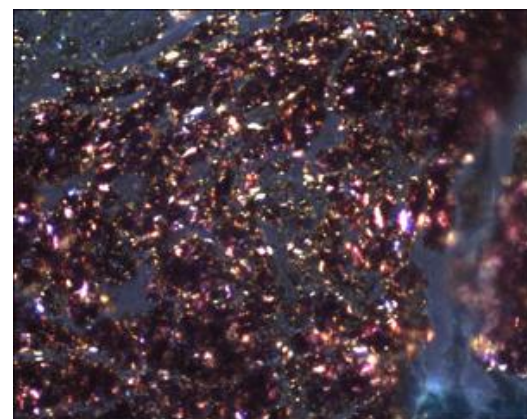
Fig 4.303 – A126 - Silicosis
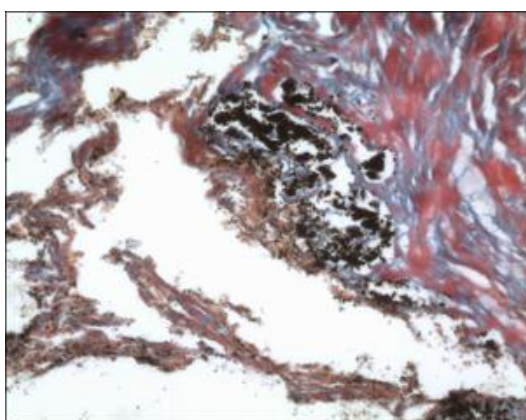
Fig 4.301 – A107 - Anthracosis
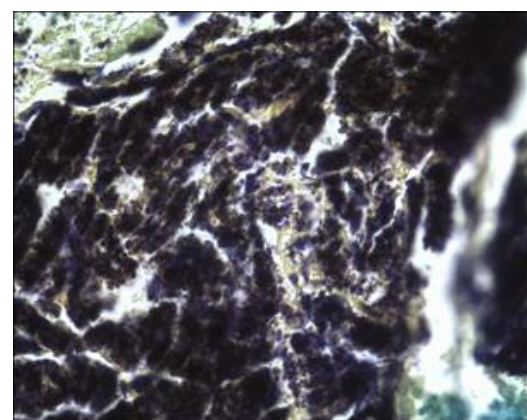
Fig 4.304 – A126 - Anthracosis

Figures 4.299 to 4.304 demonstrate the difference in particle accumulation related to age. Mummy A107 was a sub-adult and consequently, his lungs show little sign of pneumoconioses. There is some anthracosis visible, which suggests time indoors, in proximity to an open hearth, however, when under polarized light microscopy, the sample shows little evidence of silica particles. In contrast, A126's lungs are laden with both silica-type and carbon-type particulates, measuring his past exposure to sand storms and smoke.

The cause of death for Mummy A126 remains unknown. While the lung samples displayed large quantities of carbon- and silica-type elements, the lack of evidence for tissue reaction to these means that no conclusions about the presence of respiratory fibrotic disease could be made. A126 may not have had any symptoms from this accumulation of particulates. However, the finding of such reflects all previous studies of ancient Egyptian lung samples.

Mummy Identification Number	A126
Individual Age	30-40 years
Sex	Male
Current Examination Methods	Histology
Previous Examination Methods	Gross Anatomical Examination/Autopsy
Soft Tissue Preservation % (autopsy)	52
Samples Used	Skin, Muscle, Lung, Rib, Liver
Previous Palaeopathological Findings	None Found
Current Palaeopathological Findings	**Pneumoconioses, Healed Fracture**
Cause of Death	Not Known
Mummification Type	Five

Table 4.10 – Revised Minimum Standards Case Report – Mummy A126

4.20 - RESULTS – MUMMY A129

4.20.1 - Skin (Ear and Leg)

The skin sample from the ear of Mummy A129 is not well preserved although certain elements can be easily recognised, such as fat cells with some remains of adipocere (coloured green in the samples stained with toluidine blue). Hair follicles are visible and intact.

The skin sample from the leg of Mummy A129 is s a much greater state of degradation that the ear sample. The reason for this is the time needed for the desiccation of the areas. Ears desiccate very quickly as they are relatively thin and the desiccating medium (hot, dry sand or natron) can surround them. Legs are made up of many layers of skin, muscle and fat and take much longer to dehydrate.

No pathologies could be identified in either sample.
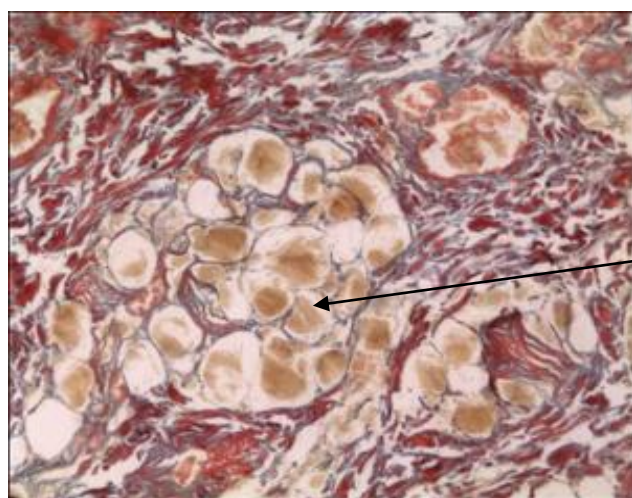
Fig 4.305

Stain – MSB

Magnification – x10

Sample from ear

Fat cells with the remains of adipocere
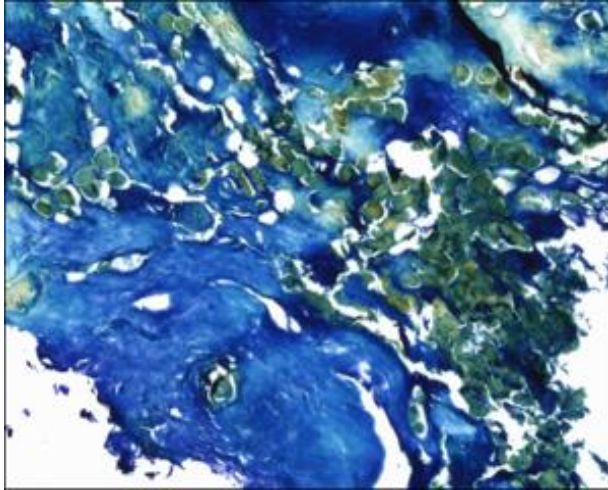
Fig 4.306	<u>Stain – Toluidine Blue</u> <u>Magnification – x5</u> <u>Sample from ear</u> Fat cells with remaining adipocere (coloured green)
Fig 4.307	<u>Stain – Toluidine Blue</u> <u>Magnification – x20</u> <u>Sample from ear</u> Fat cells with remaining adipocere Hair follicle
Fig 4.308	<u>Stain – MSB</u> <u>Magnification – 1.6</u> <u>Sample from Leg</u> Poorly preserved skin sample from the leg
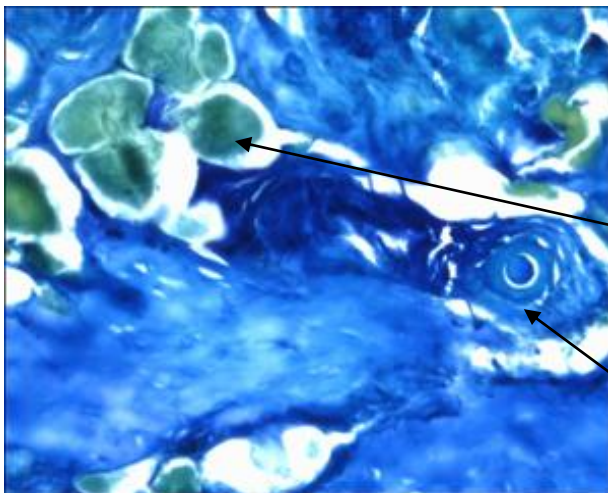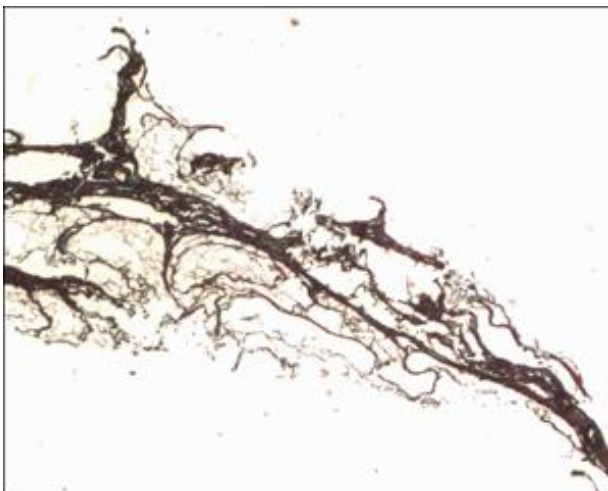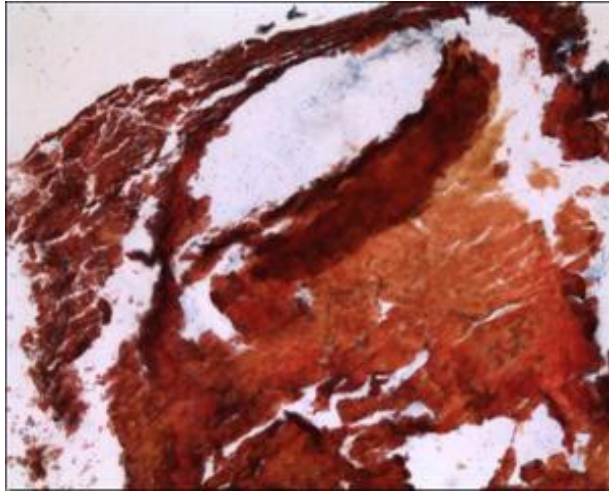
Fig 4.309

Stain – MSB

Magnification – x5

Sample from Leg

Degraded skin sample from leg

4.20.2 - Bowel

The sample of bowel from Mummy A129 is not well preserved. However, it is clear that the sample includes bowel contents as some starch cells from plant material can be easily identified. The collagenous bowel wall with a layer of smooth muscle is visible although most of the other elements are degraded beyond recognition.

No pathologies are visible.
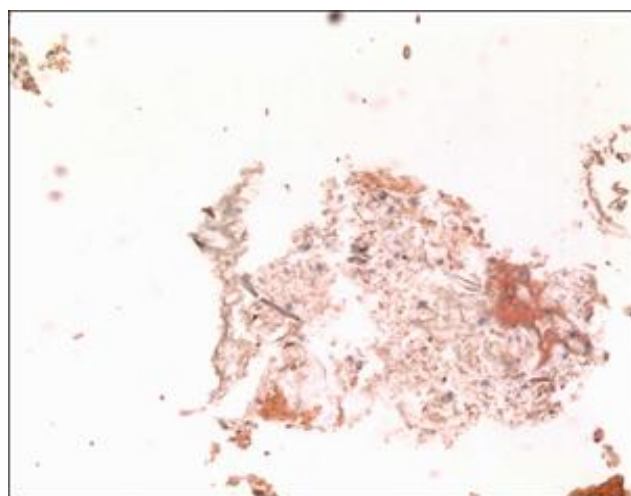
 Fig 4.310	Stain – MSB Magnification – x5 Badly degraded bowel sample
 Fig 4.311	Stain – MSB Magnification – x20 Starch cells (bright blue) within bowel sample – evidence of bowel contents (plant material)
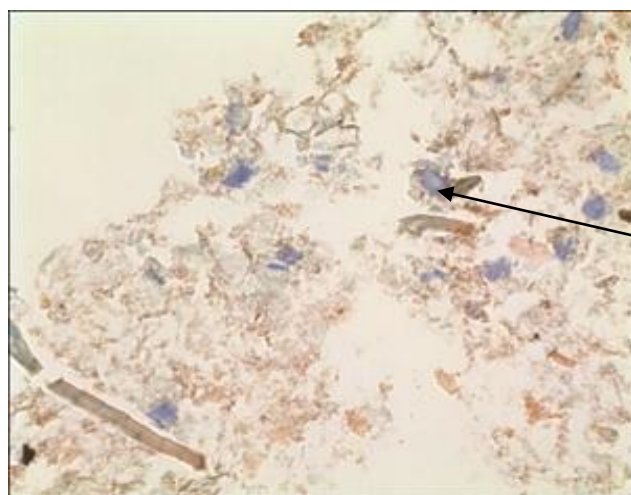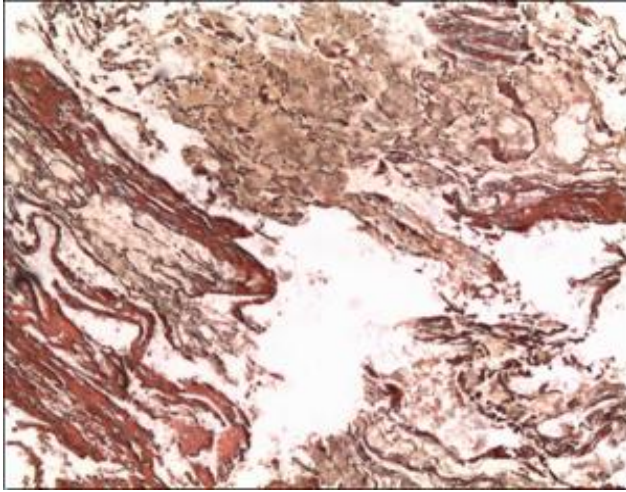
Fig 4.312

Stain – MSB

Magnification – x5

Collagenous bowel wall
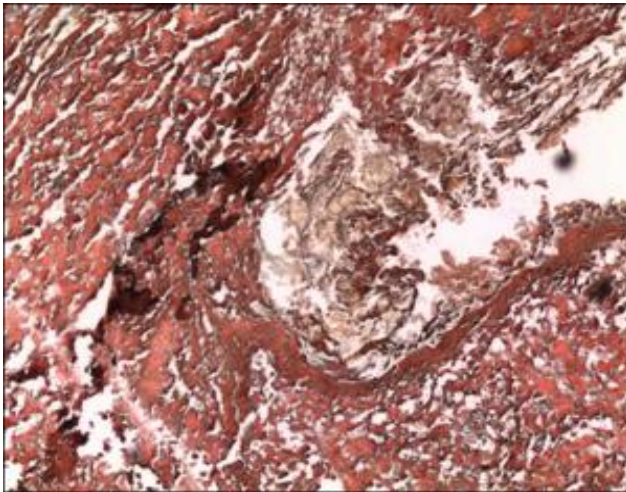
Fig 4.313

Stain – MSB

Magnification - x5

Collagenous bowel wall

4.20.3 - Liver

The sample of liver from Mummy A129 was first blocked in paraffin wax; however, the sample was in such a severe state of degradation that no sections could be cut. The sample was then blocked out in plastic resin (LR White, see Chapter 2.3.4), in the hope that the sample would hold together better during sectioning. The resulting resin section was extremely poor and cannot be identified as liver.

Within the sample, there are some crystals but it is impossible to know whether they developed post- or ante-mortem. It is probable that they are post-mortem entities.

Due to the severe degradation of the sample, no pathologies could be identified.

Fig 4.314

Stain – Toluidine Blue
Magnification – x20
Resin Section

Post-mortem crystal formation
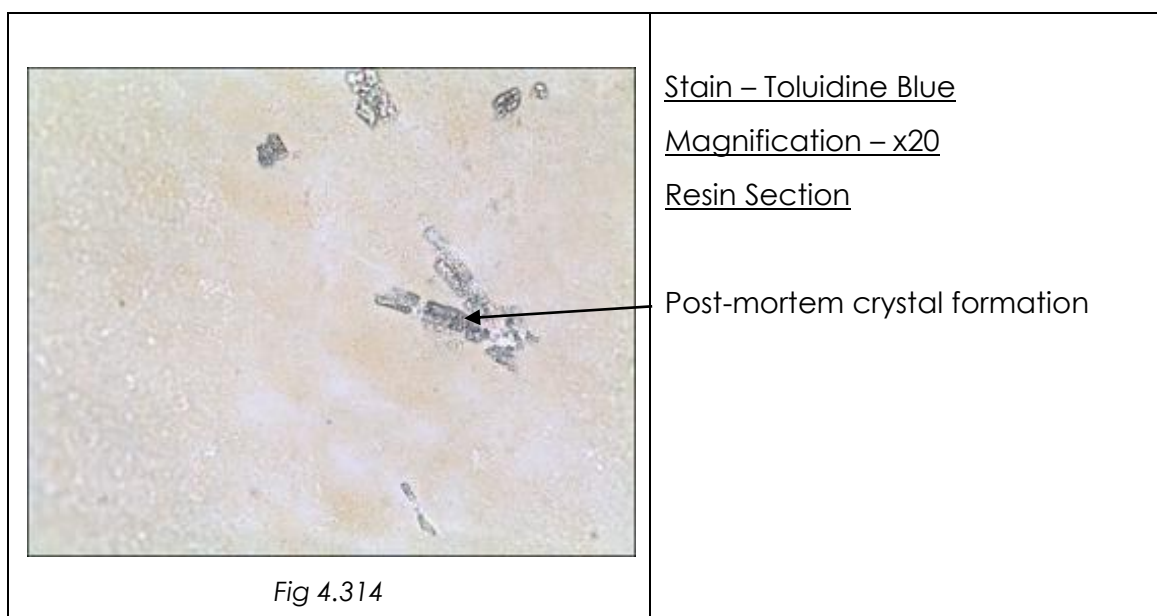
4.20.4 - Muscle

The muscle sample from Mummy A129 is in a very poor state of preservation and, as such, it is difficult to identify with any level of confidence.

Due to the level of degradation, no pathologies could be identified.
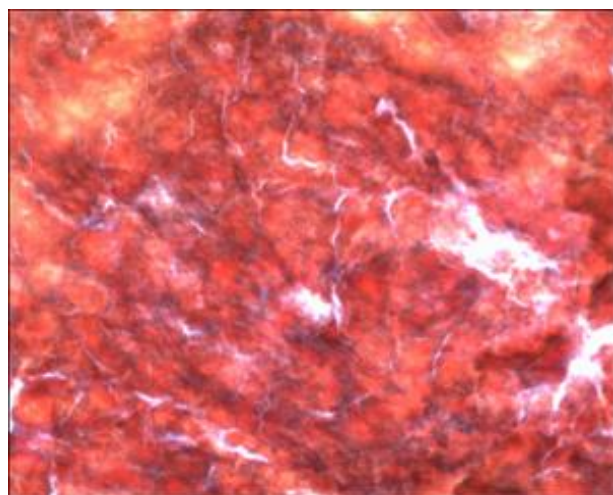
Fig 4.315	Stain – MSB Magnification – x20 Badly degraded muscle

4.20.5 – Bone (Rib)

The rib samples from Mummy A129 were quite well preserved, in that many elements were still easily recognisable. The osteocytes can be identified, as can the canaliculi.

The paraffin wax sections proved to be as informative as those blocked out in acrylic resin; both sections displaying evidence that the bone had been dissolved at some point by either fungi or bacteria.

The presence of woven bone ('repair' bone) in the sample could indicate that the person suffered from a fracture some months before death as healing has obviously taken place.
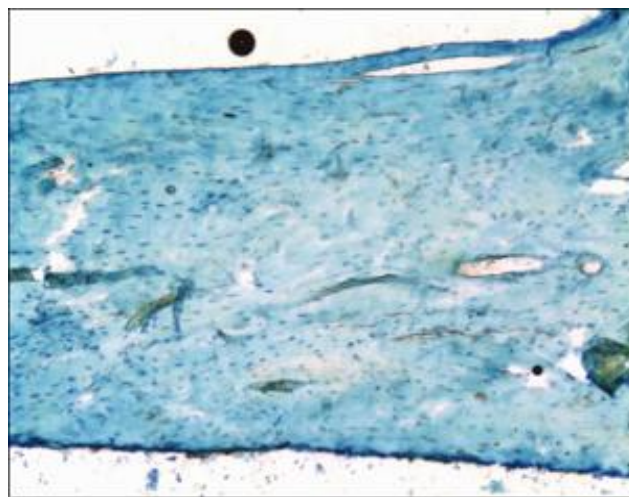
Fig 4.316	Stain – Toluidine Blue Magnification – x5 Cortical Bone
Fig 4.317	Stain – Toluidine Blue Magnification – x20 Woven Bone – osteocytes in disarray Osteocytes
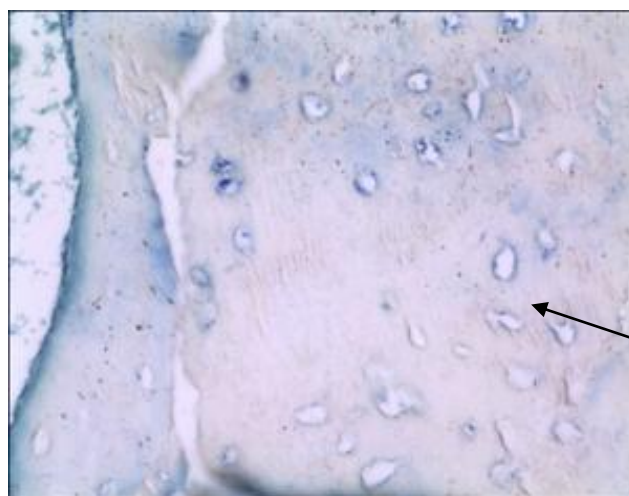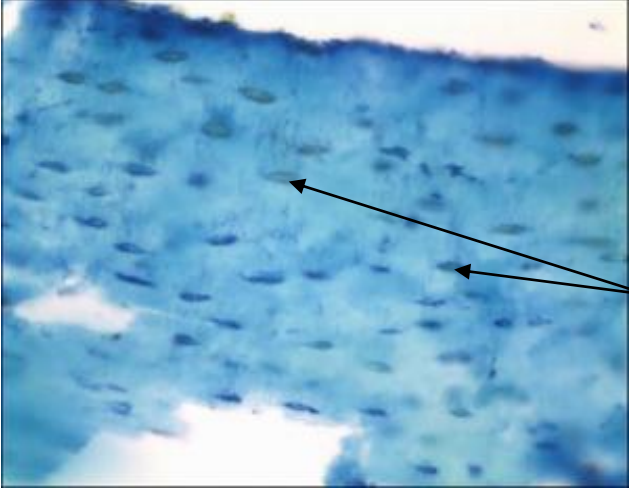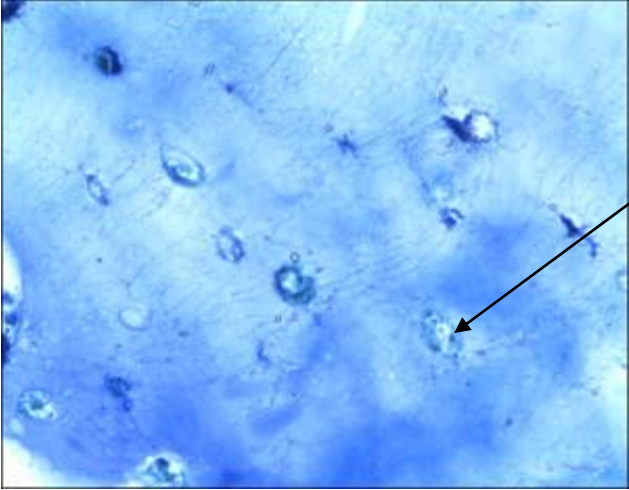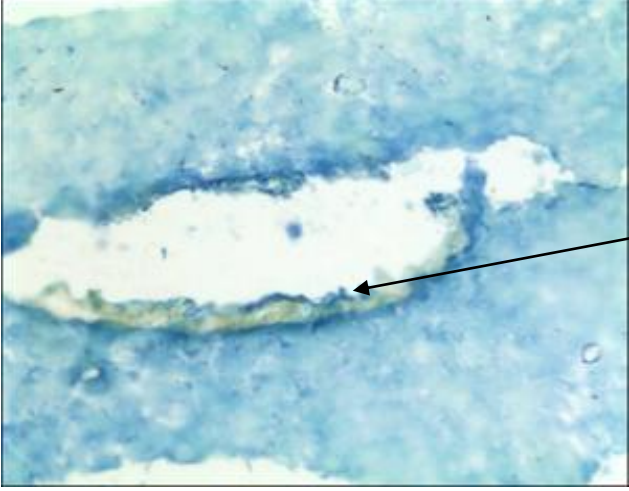
Fig 4.318

<u>Stain – Toluidine Blue</u>

<u>Magnification – x20</u>

Cortical Bone

Osteocytes

Fig 4.319

<u>Stain – Toluidine Blue</u>

<u>Magnification – x40</u>

Osteocytes with canaliculi

Fig 4.320

<u>Stain – Toluidine Blue</u>

<u>Magnification – x10</u>

<u>Resin section</u>

Area dissolved by fungi
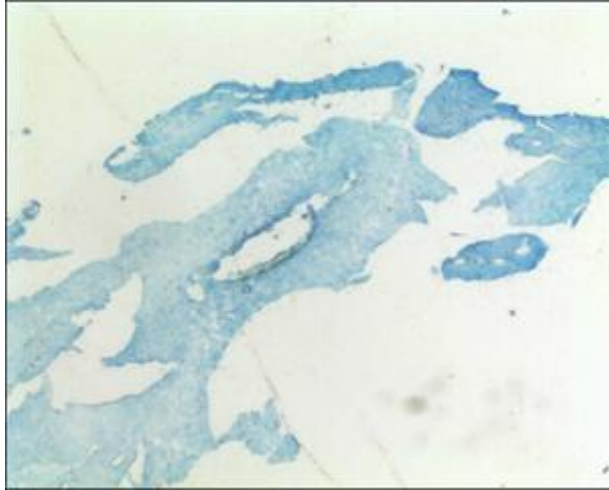
Fig 4.321

<u>Stain – Toluidine Blue</u>

<u>Magnification – x2.5</u>

<u>Resin Section</u>

Overview of bone sample

4.21 – ALL WRAPPED UP – DISCUSSION OF MUMMY A129

Given the 100 percent soft tissue preservation score assigned for Mummy A129 at the time of autopsy (Aufderheide 1998g; 3), the results of the histological examination of the tissue samples are disappointing. All of the soft tissue samples were much degraded and some (liver and muscle) could not be confirmed as their autopsy labelling.

The bowel sample was recognisable due to the presence of plant material within it, indicating bowel contents. Starch cells, while not numerous, were clearly visible indicating some sort of cereal plant, such as wheat or barley. However, not enough of the plant material survived for a confirmation of plant type.

The skin sample from the ear of Mummy A129 was the best preserved of the soft tissues. No epidermis could be identified; however, quite a large quantity of adipocere remained within the fat cells. Adipocere, also known as corpse, grave or mortuary wax, is an organic substance formed by the anaerobic bacterial hydrolysis of fat in tissue. The transformation of fats into adipocere occurs best in cold, humid environments. The large quantity of adipocere within the fat cells of Mummy A129 could suggest he died in winter when temperatures drop to four degrees centigrade; however, the humidity is Dakhleh is always low due to the lack of rainfall, the average being only 21.4 percent, reaching a high of 32 percent in December.

The rib samples from A129 were in a very good state of preservation. Both the paraffin wax and resin sections displayed good condition of osteocytes and canaliculi. Fungi had invaded some areas of the samples; the results of which were still visible (see Figure 4.320). The samples showed two distinct types of bone; woven and healthy cortical. The woven bone was underneath the healthy bone suggesting that A129 suffered a fracture at some point but this fracture had gone a long way through the healing process by the time of death.

Histological examination has not really provided any new information about Mummy A129, mainly due to the poor preservation of many of the samples. However, what is clear is the great difference between the soft tissue

preservation score given at the time of autopsy to the one that became apparent at the microscopic level.

Mummy A129 was wrapped in approximately twenty layers of textiles, still in situ at the time of excavation (Aufderheide 1998g; 2). The archaeologists and dissectors believe that most of the Kellis 1 mummies were wrapped, although this cannot be confirmed on twenty of the 49 bodies (Aufderheide et al 2003; 139). The following section will briefly discuss funerary textiles of ancient Egypt and examine what is known about the textiles used to wrap the Kellis 1 mummies, and whether this information reveals anything about the population.

4.21.1 – Funerary Textiles in Ancient Egypt

Throughout the history of Egypt, textiles feature prominently, needed from cradle to grave. As early as the Predynastic Period, the ancient Egyptians were already competent spinners and weavers. By the Old Kingdom, textile workshops had been established. Up to and including the New Kingdom, textile production appears to have been the realm of women, however, by the Roman Period, male-operated looms dominate (Strouhal 1997; 149). Despite simple weaving techniques, the Egyptians were able to produce extremely high-quality fabrics and fine clothing was one of the specialist products for which Egypt was known in Roman times (Robins 1998; 96).

Fig 4.322 – Scene of weaving from the tomb of Khnumhotep (Beni Hasan) (www. metmuseum.org)

Textile manufacture was a major industry in Egypt, especially linen weaving. In the Ptolemaic and Roman periods (from 323 BCE) production was strictly controlled by the State, both for quality and the quantity produced.

The majority of textiles are of linen, made from the bast fibre, flax. Flax is not a native of Egypt even though its usage dates back to prehistory; it is possible that it was imported to Egypt from the Levant. Flax is a member of the *Linaceae* family, which includes twelve genera. Two types of flax have been identified as used in the production of textiles in ancient Egypt from as early as the Predynastic Period; *Linum bienne* and, the main source in ancient times, *Linum usitatissium* (Vogelsang-Eastwood 2000; 269). All funerary textiles from the Kellis 1 Cemetery were made entirely of linen (Aufderheide et al 2003; 141).

Ancient Egyptian uses for textiles include:

- clothing
- household uses (curtains, bedding, lamp wicks, cushions, spice bags, etc)
- sacks for grain
- strainers for oil and wine
- equipping animals and vehicles drawn by them
- boat sails
- tents
- decoration of temples and palaces
- religious uses (clothing the statue of the god in the temples daily)
- medicinal uses.

One of the most important uses of cloth was related to funerary rites. Textiles would have probably necessitated the greatest single expense in the burial process. Not only used to wrap the body, cloth could be placed in the tomb in the form of covering for statues and shrines as well as the wrapping of victual offerings.

The amount of cloth used in a burial could be substantial. In the tomb of Wah, the estate manager for a Middle Kingdom vizier, 845 square metres of textile was discovered, including 375 square metres of linen used to wrap the body. The tomb of Tutankhamun contained 400 items of cloth, including clothes,

covers for ritual figures, linen arrow quivers, lamp wicks and trappings for chariots (Vogelsang-Eastwood 2000; 295).

There were a variety of sources for funerary cloth, dependent upon the financial resources to be spent on the burial. Some bandages were especially made for funerary purposes; however, this was the privilege of the newly deceased pharaoh or divine animals such as the Apis Bull (Vos 1993; 38). The deceased from wealthy households could possibly be wrapped in 'sanctified' mummy wrappings, which consisted of the old clothes previously used for dressing the statue of the god within the temple. However, the use of worn household linen for wrapping the dead was a time-honoured tradition in ancient Egypt and most mummies have evidence of these (Monserrat 1997; 37). A well-known example of this is the mummy of the Twentieth Dynasty weaver Nakht, who although furnished with a relatively fine coffin, his body had simply been washed and carefully wrapped in linen. The amount of linen used was less than in many mummies of this period, but the bandages were in good condition.   Included within the bandages were filling pads, which proved to be two large sleeveless tunics. The size of the tunics were about the same as that of Nakht, so it is likely the family contributed some his clothing as wrapping material (Millet et al 1998; 93).

Fig 4.323 – Osiris shroud - ~Third Intermediate Period
(www.metmuseum.org)

One or several shrouds could also be placed over and around the body. Most shrouds consisted of a single length of cloth, sometimes inscribed with chapters from the Book of the Dead. The most elaborate of these is called the Osiris shroud; a linen sheet placed over the bandages and fastened by ties woven

for the purpose. It could be decorated with a painted life-size figure of Osiris, although occasionally other gods were depicted (Vogelsang-Eastwood 2000; 295).

The excavations at Kellis have yielded a vast array of textiles, both from the settlement site and the cemeteries. It is clear from Greek and Coptic documents and the artefacts uncovered (spindles, spindle whorls, beating combs, loom weights) that textiles were manufactured in the town, however only two complete woven objects have been found. Fine linen was certainly produced in the Dakhleh Oasis and transported to the Nile Valley as is evidenced by the following receipt for such:

...of Hermopolis Magna, registered in the East City quarter, to Aurelius Horos, son of Mersis, camel driver from the oasis. I acknowledge that I have received from you one camel load (consisting of) - dried figs and dried grapes and fine linen (P. Kell. I GR. 51) (Worp 1995; 3-6).

The first a cloth hat discovered in the Temple of Tutu and the second, a child's tunic from a tomb in the Kellis 1 Cemetery (Bowen 1999; 8). Numerous remains of *Linum usitatissium* have been collected from the windblown sand in the town, in the rubble of collapsed mudbrick houses and mixed in with other botanical samples (Thanheiser & König 2002; 145).

Decorated fabric found at Kellis has been securely dated to the second to fourth centuries CE, however the majority of the fabric found at the site is unbleached linen. Sheep's wool, both natural and dyed, has also been discovered, although it is not mentioned in the Kellis Agricultural Account Book and the bones of sheep are poorly represented in the ancient faunal assemblage (Churcher 2002; 110). The quality of the textiles, as well as some of the decorative details, indicates that the weavers of Kellis were highly skilled. Many of the related artefacts (spindles and whorls, loom weights) found in domestic contexts suggest that spinning and weaving may have been a household industry (Bowen 1999; 11).

In the linen from Kellis is spun in a left direction, or s-spun, which corresponds to the majority of material found in Nile Valley contexts, wool and animal hair, by contrast is spun in a right direction, or z-spun. While wool and some linen from the settlement had been dyed, all of the bandages or cloths found in the Kellis

1 Cemetery were plain, except for one red linen shawl (Birrell 1999; 35). None of the wrappings displayed any evidence of inscriptions, and nor were any amulets or other artefacts found included between the layers (Aufderheide et al 2003; 142).

The bandages and cloths used to wrap the Kellis 1 mummies varied in style and quality. Many of them had been damaged at the time of looting, and it is possible that some bodies were rewrapped, whether this was with the original bandages or with new ones is unknown. There is no pattern to the wrapping of the Kellis 1 bodies. For example, the entire body of Mummy A1 was first wrapped in a large rectangular cloth that when folded over the body created three layers of thickness. Finally, belt-like linen strips encircled the body at about four centimetres intervals, in order to stabilise the wrapping. All textiles appeared to be loosely woven linen (not fine quality) (Aufderheide 1993; 2). In contrast, Mummy A129 was wrapped in approximately twenty layers of fabric, up to 50 centimetres long and twenty centimetres wide, although many bandages were narrow strips of six centimetres width. The arms had been wrapped separately for the first two layers and then incorporated into the entire mummy bundle (Aufderheide 1998f; 2). The linen was closely woven indicating that is was a good quality. However, it had been patched in a number of places, suggesting that it luxury item that was too good to throw out even when well worn. Evidence that this was a normal custom in Kellis comes from the substantial finds of patchwork fabrics within the settlement site; clearly a sign of textiles had been recycled (Bowen 1999; 10).

As is the case with many elements of burial customs found within the Kellis 1 Cemetery, the sample size of 49 mummies, 26 of which had been wrapped, is too small to discern any type of pattern, if indeed there was one. Mummy A129 was a child of only six years of age, however, much care had been taken with the wrapping of the body. Fine quality linen, albeit patched, had been used to envelope the child up to a thickness of twenty layers, held in place with daubs of resin. As stated in Chapter 4.9.1, further work on the treatment of children in the Kellis 1 Cemetery is needed once additional bodies have been excavated.

Mummy Identification Number	A129
Individual Age	Approximately 6 years
Sex	Male
Current Examination Methods	Histology
Previous Examination Methods	Gross Anatomical Examination
Soft Tissue Preservation % (autopsy)	100
Samples Used	Skin (leg), Muscle, Bowel, Rib, Skin (ear), Liver
Previous Palaeopathological Findings	None Found
Current Palaeopathological Findings	**Possible healed fracture**
Cause of Death	Not Known
Mummification Type	Six

Table 4.11 – Revised Minimum Standards Case Report – Mummy A129

CHAPTER FIVE – CONCLUSION

The main question asked in this project was – Is histology still a valid and useful scientific technique when it comes to the study of mummies? A second question was also addressed - Can historical and histological results combine, or at least complement each other, for a more complete picture of the individuals under examination?

The histological technique, in its pure form, is relatively cheap and simple, however, this means nothing unless it is able to deliver results that tell us something we didn't already know or had no way of finding out using other methods. In order to investigate this matter, a histological analysis of soft tissue and bone samples from ten mummies from the Kellis 1 Cemetery in the Dakhleh Oasis (Egypt) was carried out. The mummies were deliberately chosen because of the lack, or near lack, of ante-mortem pathologies when examined at the time of autopsy. The mummies had also undergone previous scientific examinations, including stable light isotope analysis (Dupras 2001), radiocarbon dating (Aufderheide et al 2004) and resin analysis using Gas Chromatography – Mass Spectrometry (Maurer et al 2002). The autopsy reports, which were available, recorded information such as mummification type, age at death, sex and an overall body preservation assessment (Aufderheide 1993a & b, 1998b, e & f, Cartmell 1993, 1998a & b, Zlonis 1993b). Utilising mummies, which already had research histories was an advantage, as histological findings could be easily checked against these. For example, a sample of coprolite was examined from Mummy A101, when checked against the autopsy report; it was recorded as being located in the transcending colon and rectum area. Any plant material identified had therefore come through nearly all of the digestive processes, enabling an idea of what type of plant remains are resistant to the digestive processes, such as the outer coating of cereal seeds and starch cells.

The process itself was simple. Mummified tissue is dry and brittle; it cannot be processed histologically in that state so rehydration of all samples was the first step. As fixation takes place at the same time as rehydration, bone samples were also immersed in this solution. Once rehydration had taken place, most samples were processed, as fresh tissue would be, with slight variations only on the automated processing and staining times. Most samples were blocked out in paraffin wax; however, some of the more brittle samples and the bone

samples were blocked out in acrylic resin. The resin is a much more expensive option and, in this project, not all samples blocked out in this medium were successful. However, for samples such as the heart tissue from Mummy A108, the York conglomerate material and intestinal contents from canopic equipment from the Late Period mummy, Asru, resin sections offered much insight into both identification and pathology.

The York conglomerate sample, which was fossilised not mummified, required an additional technique was required at the time of sectioning, due to the rigid nature of the sample. The adhesive tape technique enabled good sections to be cut from the resin blocks and staining could be done as routine.

Light microscopy was used on all sections, however, if sections appeared not to have taken to the stain, were unfocused or if identification was uncertain, other types of microscopy were employed. Polarised light microscopy was extremely useful for identifying plant material, fungal bodies or connective tissue, as cellulose, chitin and collagen (in each of these samples respectively) are birefringent. Focus stacking microscopy was incorporated for samples that did not lie flat on the glass microscope slide and Differential Interference Contrast Microscopy was utilised if sections hadn't taken to the staining process. This was mainly seen in resin sections.

It is the nature of ancient tissue that not every section will be a success, due to degradation of the tissue caused by time, environment or decomposition process, such as autolysis and putrefaction. However, sections that demonstrate extreme degradation still have a use in histological analysis. By considering which of the tissues have degraded may be an indication of a period between death and burial, or in the case of artificially mummified bodies, death and the embalming process. For example, Mummy A1 had very well-preserved skin, which included an epidermal layer. However, the liver and muscle were quite degraded but still recognisable. Mummy A1 was spontaneously mummified so it can be suggested that there was a short period of time between death and burial. The liver and muscle are both metabolically active during life, making them susceptible to immediate initiation of autolysis at death; a process that had clearly started in Mummy A1 but before it could take hold, the body must have been placed in the hot dry tomb sands. This delay, while allowing for autolysis to begin, could not have been not too

protracted because the epidermis, which also decomposes soon after death, was still present. The exact length of the delay would depend on the season. In summer, the heat would accelerate decomposition. In contrast, Mummy A129, has a poor level of preservation for all soft tissues, whether they were metabolically active during life or not, suggesting that there was a long enough delay between death and embalming (A129 was artificially mummified) for autolysis and putrefaction to take hold.

Histology has the ability to provide information that other techniques cannot. The histological study of soft tissue and bone samples from ten Kellis 1 mummies demonstrated a number of pathologies that had not been detected by gross anatomical examination or autopsy, and most likely, could not be by other scientific means. These samples include:

- Skin - can, in very broad terms, suggest time delay between death and burial or embalming (all mummies).

- Gastrointestinal tract – the preservation of the contents of the gastrointestinal tract enables insight regarding diet and disease, especially parasitic infection (Mummy A101). If the bowel wall remains preserved, it is also possible to observe mesenteric cysts, although it must be noted this find is very rare, if not unique and further work is needed for confirmation (Mummy A8).

- Heart – preservation of heart muscle is rare, although the related arteries and veins are often recognisable due to their connective tissue constitution. If preserved to any extant and in a diseased state, heart tissue can allow a diagnosis of a myocardial infarction that the individual had survived (Mummy A108).

- Liver – a high level of preservation of this internal organ is rare, however, if a diseased state such as cirrhosis is present, it can be clearly identified and can indicate a parasitic infection such as schistosomiasis, which in the case of Kellis, can indicate migration from Valley to Oasis (Mummy A5).

- Lungs – a common finding in the lungs of ancient Egyptian mummies is an accumulation of carbon- and silica-type particles in the lungs; a consequence of indoor hearths and the sand-filled environment respectively; the level of accumulation of these particles usually agrees with age at death; the older the individual is, the more

exposure to soot and sand they have had and, in turn the greater the level of accumulation in the lungs (Mummies A126, A13). Histological examination of lung tissue can also identify conditions such as emphysema and pneumonia (Mummy A102).

- Muscle – preservation of skeletal muscle can vary to extremely poor to being similar in appearance to fresh tissue; although not a common finding, a cyst in the muscle tissue can suggest the presence of the parasite *Trichinella spiralis* (Mummy A5).

- Bone – a histological examination of bone can inform greatly on the life and diet of the individual. If preserved well, and successfully processed, bone samples can identify fractures (Mummy A126), healthy, normal bone growth (Mummy A13) and times of nutritional stress (Mummy A15 - comparative sample).

The histological results listed above have been used as starting points for further discussion (Chapter Four) and this discussion has often deviated from the world of the scientific into that of the historical. In some cases, the findings have broader implications than simply the individual. Mummy A5, for example, not only had a cirrhotic liver indicating schistosomiasis, caused by a parasite for which there is no evidence in the Dakhleh Oasis, but also a possible second parasitic infection in the form of a cyst in the skeletal muscle, caused by the nematode *Trichinella spiralis*. Potential future work in this area includes investigating the potential relationship of parasitic infection and infectious diseases such as tuberculosis, as has been piloted at the University of Auckland (J Littleton, pers.comm.).

Not all of the ten mummies from the Kellis 1 cache proved to be worthy of histological discussion; however, there were features of each mummy worthy of further investigation. The discussion sections regarding circumcision in ancient Egypt (Mummy A1 – see Chapter 4.3) and funerary textiles (Mummy A129 – see Chapter 4.21) may seem extraneous to the histology-related themes of the other sections. However, these sections go to prove that histology should not and cannot be in isolation. It is best employed with other techniques, both scientific and historical, in order to obtain the most complete picture of the subjects under examination.

Histological examination of organic ancient material will always yield results, even if it is simply determining that the sample is too degraded to be of any further forensic value. In this project, histology answered the questions asked of it. It firstly identified the tissue under examination, enabled an assessment of preservation and made possible the detection of a number of pathologies. Secondly, the results from the histological examination could be used as a basis for broader discussion, incorporating excavation data and historical information. Although this project has focussed on ancient Egyptian material, histology can be employed for the analysis of organic remains of other ancient cultures. If the laboratory equipment (automated processors, microtomes, fumehoods), histology offers a cheap and simple method of obtaining valid and useful results. This project has, hopefully, demonstrated that the incorporation of histology into any study of ancient organic material is a prudent and worthwhile decision.

CHAPTER 5.1 – FURTHER WORK

While this thesis produced useful information regarding the identification, preservation and pathology of soft tissue and bone samples from ten mummies from the Kellis 1 Cemetery in the Dakhleh Oasis, it also highlighted certain areas of research that, with more investigation, have the potential to increase knowledge on the life, and death, of the ancient Egyptian people. Listed below are some of these areas.

5.1.1 – The Medical Papyri

While references to the medical papyri of ancient Egypt were not a major part of this thesis, some prescriptions of the Ebers Papyrus were discussed in Chapter Four when related to certain pathologies found in the mummies examined. It became clear when studying the previous translation and analysis work undertaken on the Ebers (Ebbell 1937, Ghalioungui 1987) that it is out of date and a new translation would be a great advantage to the research of ancient Egyptian disease and treatment thereof.

The Ebers Papyrus, like many of the medical papyri, is written in hieratic, a shorthand script of the more recognisable hieroglyphs and, while the Ebers has been written by a scribe in a wonderfully clear script, hieratic is not a language that even many Egyptologists are comfortable with. Unfortunately, this means

scholars citing the Papyrus are most likely unable to use the primary source material and must rely on the previous translations. The

The most recent translation was produced by Paul Ghalioungui and published in 1987. The book is not currently for sale and is difficult to find, which often leaves scholars basing their conclusions on the 1937 translation by Ebbell, whose imagination often got in the way of linguistic realities (Nunn 1998; 30).

For the Ebers Papyrus to be a effective resource when used in conjunction with the scientific findings on human remains, a new translation must be undertaken. In the 35 years since Ghaliougui's translations, research into the botany of the medical papyri (Campbell 2008; 216-236) has been able to name many of the previously-unknown plants used in the remedies. Incorporating such work would certainly allow for a more complete, and useful, translation.

5.1.2 – Mummification and Burial Processes

The 49 mummies excavated from the Kellis 1 Cemetery have not enabled any conclusive remarks to be made regarding a link between burial customs and social hierarchy. No clear patterns have been revealed. Most mummies were spontaneously mummified in the sands of the tomb (Birrell 1999; 35); however some appear to been subjected to the costly and time-consuming artificial mummification processes (Aufderheide et al 2003; 139). While the author of this thesis is not entirely convinced by Aufderheide et als' validation of artificial mummification for eighteen of the mummies, it is apparent a determination of social hierarchy in regard to burial customs is not possible at this time, with so few mummies examined.

Given the current economic climate and the lack of funding for excavation work in Kellis (Colin Hope, pers. comm.), there is little hope that any further mummies from the Kellis 1 Cemetery will be examined in the foreseeable future. However, if these circumstances improve, an increase in the numbers of mummies investigated may be able to establish patterns in mummification processes and the burial customs for the people of Kellis that presently cannot be realised.

5.1.3 – Children in Ancient Egypt

Within the sample of 49 mummies from the Kellis 1 Cemetery autopsied and examined by Aufderheide, Cartmell and Zlonis (2003; 137-150), eighteen were assessed by them as being under twelve-years of age at the time of death (approximately 37 percent). The ancient treatment of the bodies do not enable evaluations to be made regarding the social status of the children and a lack of grave goods in the Kellis 1 Cemetery allow for no personal histories of these children to be found (Birrell 1999; 35-38).

Unfortunately, for conclusions to be made regarding the relationship of children, social status and burial customs in Kellis, more child mummies from the Kellis 1 Cemetery would have to be investigated and as stated above in Chapter 5.1.2, this is currently not possible.

It may be possible to further the research into childhood diseases in ancient Egypt. This aspect of study was only touched in this thesis with the examination of the bone sample from a seven-year old child (see Chapter 3) and the lung tissue sample from Mummy A126 (see Chapter 4). Further histological examination of samples of both bone and soft tissue from subadult mummies may allow confirmation of the types of diseases that led to such mortality rate in ancient Egyptian children (Shaw & Nicholson 2008; 72-73).

5.1.4 – Histology of Samples other than Soft Tissue

The discussion of Mummy A101 has already highlighted the need for further work to be undertaken on plant histology. The study of the intestinal contents of ancient human remains has the potential to not only provide information on parasitic disease but also on the diet of the time and region.

Currently, it is very difficult to identify plants histologically when they are found as coprolites, either from within the intestinal tract or in latrine environments. Further research into this, for example the establishment of a histological database of plants of Egypt, could go a long way in plant identification. There are available collections of both ancient (Kew Gardens) and modern (KNH Centre for Biomedical Egyptology) Egyptian plants making this resource possible to create.

This project focussed mainly on soft tissue samples from the ten case study mummies, with only rib and a couple of femur samples being investigated. The reason for this, in this case, was sample availability. However, the quality of the bone samples that were examined (for example, the rib sample from Mummy A13) was such that there appears to be potential for further research in this area. This is especially true when analysing the histological images from the femur of a seven-year old child (Mummy A15) (see Chapter 3.5.1), which gave an insight into the life, and illnesses, of this young ancient Egyptian. An interesting future project could look at many bone samples of subadults from ancient Egypt, in order to firstly, see if the results from Mummy A15 are common and if so, to use the results as a basis to further investigate the types of diseases plagued the ancient Egyptian children.

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PERSONAL COMMUNICATIONS

Don Stenhouse	Bolton Museum	20 June 2011
Professor Kathryn Else	University of Manchester	23 August 2011
Dr David Dunne	Cambridge University	23 August 2011
Dr Judith Littleton	University of Auckland	30 November 2011
Professor Rufus Churcher	The Dakhleh Oasis Project	7 December 2011

APPENDIX ONE – HISTOLOGY TECHNIQUES

Protocols for Preparing Samples for Examination

1   The Rehydration and Fixation of samples

1)   20ml of the rehydrating solution (1% sodium lauryl sulphate in formal-saline) in universal sample containers.

2)   The samples were left for 48 hours and then removed from the universal sample containers.

2   Sample Processing

Samples processing was fully automated. The schedule of which is shown below.

Container	Fluid	Time
1	40% industrial methylated spirits (IMS)	1 hour
2	70% industrial methylated spirits (IMS)	1 hour
3	95% industrial methylated spirits (IMS)	2 hours
4	100% industrial methylated spirits (IMS)	1.5 hours
5	100% industrial methylated spirits (IMS)	1.5 hours
6	100% industrial methylated spirits (IMS)	1.5 hours
7	100% industrial methylated spirits (IMS)	Overnight
8	Xylene	1 hour
9	Xylene	1 hour
10	Xylene	1.5 hours
11	Wax with vacuum	1 hour
12	Wax with vacuum	1.5 hours
13	Wax with vacuum	2 hours

Schedule for sample processing. Steps 1-7 show the dehydration process and steps 8-10 show the clearing stage and steps 11-13 show the process of the sample being impregnating with wax (adapted from Bancroft & Gamble 2002; 93).

3   Preparation of Sections and Microscope Slides

1)   The tissue cassettes were stored in molten paraffin wax in a vacuum
        oven at 65°C. The lower vapour pressure and high temperature of the
        oven ensured that any volatile substances left over from the tissue
        processing steps boiled off.

2)   The cassettes were removed from the oven and placed in a docking
        station.

3)   The samples were carefully placed in the bottom of the cassettes to
        ensure that the samples were at the best angle for sections to be taken.

4)   The docking station was used to fill the entire cassette with molten
        paraffin. The cassettes were put on the cold plate to quickly cool the
        paraffin and prevent damage from crystal formation. The solid wax
        cassette was then stored in a freezer for 30 minutes.

5)   The cassettes were removed from the freezer, any excess wax trimmed
        off and the cassettes placed in a rotary microtome. The microtome was
        used to produce 5 micron-thick sections of the samples.

6)   The best sections were chosen and placed on microscope slides using a
        water bath.

7)   The slides were then placed on a cold 'hot' plate (50°C) for 20 minutes
        and then on a hot (70°C) plate to remove any water.

4   Pre-staining Slide Preparation

Sections to water:

Xylene stage:

1)   The slides were submerged in the first xylene container for two minutes.

2)   The slides were removed, shaken slightly to remove excess xylene, and then submerged in to the second and third xylene containers for ten slow dips in each.

Industrial methylated spirits (IMS) stage:

1)   The slides were removed from the xylene container and shaken well to remove any excess xylene. The slide was then submerged in the first container of IMS for ten slow dips.

2)   The slide is removed, shaken slightly to remove any excess IMS and then dipped into IMS containers two and three for ten slow dips each.

Distilled water stage:

1)   The slide was from the IMS container, shaken well to remove any excess IMS and then submerged for two minutes in the first container of distilled water.

2)   The slides were then removed, shaken slightly to remove any excess water and then submerged in the distilled water containers two and three for 10 slow dips each.

5   Staining Procedures

Giemsa Stain (adapted from Bancroft & Gamble 2002)

Materials:

Giemsa stock   - 4ml

Acetate buffered distilled water   - 96ml

Giemsa stock

Giemsa stain powder   - 4g

Glycerol   - 250ml

Methanol   -250ml

Method:

1)   Take sections to water (see section 2.3.4)

2)   Rinse in pH 6.8 buffered distilled water.

3)   Stain in working Giemsa for 7 minutes.

4)   Rinse in distilled water.

5)   Rinse in 0.5% aqueous acetic acid until section is pink.

6)   Wash in tap water.

7)   Blot until almost dry.

8)   Dehydrate (rapidly), clear and mount (see section 2.3.6).

Results:

Modern Tissue;

Protozoans and some other microorganisms   - dark blue

Background   - pink-pale blue

Nuclei   - blue

Haematoxylin and Eosin (adapted from Bancroft & Gamble, 2002)

Materials:

1) Harris' Haemalum

2) 1% Alcoholic eosin

3) 1% acid alcohol

Method:

1) The sections were taken to water (see section 2.3.4)

2) The slides were stained in a coplin jar of modified Harris' haemalum for 4-7 minutes.

3) They were then rinsed in hot running tap water.

4) The slides were differentiated in 1% acid alcohol until the background appeared clear.

5) They were then blued in hot tap water.

6) The slides were counterstained with 1% alcoholic eosin for 1 minute.

7) The sections were dehydrated, cleared and mounted (see section 2.3.6)

Results:

Modern Tissue;

Nuclei   - blue/black

Cytoplasm & connective tissue   - pink, orange, red

One Step MSB (Martius/Scarlet/Blue) (adapted from Lendrum et al. 1962)

Materials:

Staining Solution

Yellow Solution	– 45cm^3
Red Solution	– 30cm^3
Blue Solution	– 45cm^3

Yellow Solution

Martius yellow	– 100mg
Absolute alcohol	– 95cm3
Distilled water	– 5cm3
Phosphoungstic acid	– 2g

Red Solution

1% brilliant scarlet in 2.5% acetic acid

Blue Solution

0.5% aniline blue in 1% acetic acid

Method:

1) The sections were taken to water (see section 2.3.4).

2) The slides were stained in a coplin jar for 3 minutes with combined staining solution.

3) The slides were rinsed in tap water.

4) The sections were dehydrated, cleaned and mounted (see section 2.3.6).

Results:

Modern Tissue;

Nuclei	- blue/black	Muscle	- red

Collagen   - blue

Red blood cells   - yellow

Toluidine Blue pH 4.2 (adapted from Wolman 1971)

Materials:

Stock solution   – 0.1% aqua toluidine blue

Working solution   – 1 part stock solution to 10 parts distilled water (0.01%)

Method:

1) The sections were taken to water (see section 2.3.4)

2) They were stained using a coplin jar with 0.01% Toluidine Blue for 3 minutes

3) They were then rinsed in tap water

4) The slides were dehydrated, cleaned and mounted (section 2.3.6)

Results:

Modern Tissue;

Every component   - varying intensities of blue

Miller's Elastic Stain (adapted from Miller 1971)

Materials:

Miller's elastic stain

1% potassium permanganate

5% oxalic acid

Industrial methylated spirits (IMS)

Picro-sirius red   - 1% sirius red RB in saturated aqueous picric acid

Methods:

1)   The sections were taken to water (see section 2.3.4)

2)   The slides were stained in a coplin jar of 1% potassium permanganate for
        5 minutes. They were then rinsed in tap water for 2 minutes.

3)   The slides were submerged and stained in 5% oxalic acid for 5 minutes.

4)   The slides were again rinsed in tap water for 5 minutes and then rinsed in
        IMS for 2 minutes.

5)   The slides were left to stain in a coplin jar of Miller's elastic stain overnight.

6)   They were then rinsed in IMS until all the excess stain was removed
        (approximately 30 seconds)

7)   The slides were rinsed in tap water.

8)   The slides were counterstained in Picro-sirius red for 5 minutes.

9)   The slides were cleared and mounted (xylene stage of section 2.3.6).

Results:

Modern Tissue

Elastic fibres   - blue/black

Collagen   - red

Muscle   - yellow

6   Post Staining Slide Procedure

Dehydrate, Clean and Mounting:

Industrial Methylated Spirits (IMS) stage:

1)   The slides were submerged in the first IMS container for 10 slow dips and then shaken slightly to remove excess IMS.

2)   This process was repeated for IMS containers two and three.

Xylene stage:

1)   The slides were removed from the third IMS container and shaken well to remove any excess. They were then submerged in the first xylene container for 10 slow dips. The slides were then removed and shaken slightly to remove any excess xylene.

2)   This process was repeated for xylene containers two and three.

Mounting:

1)   A small amounting of the mounting medium, Xam, was applied to glass cover slips.

2)   The cover slips were then placed Xam side down on the microscopes slide over the stained section.

3)   The slides were then pressed and held firmly down for about 10 seconds.

4)   The slides with the stained sections and glass cover slides were then left overnight to dry.

7   Steps for preparing with LR White Acrylic Resin blocks (Newman 1987)

This method is a laboratory medicine modification of the original embedding procedure.

Reagents required

Ethanol

Chloroform

Pre-catalysed LR White resin containing 0.9% benzoyl peroxide (catalyst)

- Place samples into separate compartments of the circular basket from the LR White processor and then place the lid on top.
- Place basket back in the processor where the samples will be fully immersed and agitated in the following series of solutions.
  - 5 containers of 100% ethanol (samples immersed and agitated in each container for 1 day)
  - 2 containers of chloroform (samples immersed and agitated in each container for 1 day)
  - 1 container of 100% ethanol (samples immersed and agitated in container for 1 day)
  - 3 containers of pre-catalysed LR White resin containing 0.9% benzyl peroxide (samples immersed and agitated in each container for 1 day)
- After 11 days the LR White resin will have fully diffused through the samples and so they can now be removed from the processor.
- Place the samples into separate compartments of an ice cube tray and half fill them with pre-catalysed LR White resin.
- Place this in a vacuum (pressure of -2 bar) and leave overnight. Return the pressure to atmospheric pressure.
- The samples in the tray should now be placed in a pressure chamber (pressure of 2 bar). This is a sealed vessel with an O2 free, dry nitrogen environment.
- The pressure chamber containing the tray with the samples should now be put into a 42°C oven and left overnight. This will polymerise the LR White resin.
- The hard resin blocks can now be carefully removed from the tray.

- Cellotape a piece of OHP (overhead projector) film to the table.
- Mix thoroughly together a 50p sized amount of car filler and a 5p sized amount of benzoyl peroxide. The car filler if the adhesive and the benzoyl peroxide act as a hardener.
- Apply this mixture to the base of the resin block and then place the block onto the chuck (be careful not to get the mixture around the sides of the block).
- The mixture will harden in a few minutes and the block will then be ready to section on the microtome.

8   Toluidine Blue Staining Procedures for Resin Sections (Wolman 1971)

Reagents Required

Toluidine blue

Deionised water

Ethanol

- Place the section in a trough of ethanol on a wire mesh frame until the section curls up and then relaxes. Using tweezers gently pull the section until it is flat.
- Lift the section out of the ethanol on the wire mesh and place in a trough of deionised water. The surface tension of the water will make the section flat.
- Remove the section from the water and place in a trough of toluidine blue for 5 minutes.
- Remove the section from the stain and place in another trough of deionised water.
- Using mylar graphic film pick up the stained section on the matt side and place on the hot plate for 30 minutes to dry.
- The sections are now ready to be mounted.

9   Mounting Resin Sections

The stained sections are now dried on pieces of mylar graphic film and they are mounted onto slides using the UV exposure unit.

- Place the graphic film (with the stained section on it) on a piece of OHP film on the UV exposure unit.
- Drop a small amount of loctite glass bond glue onto the section. Loctite is a glass adhesive and a UV polymerisation resin.
- Place a glass slide on top of the section with glue on it (the slide should be put on upside down).
- Turn the slide over and place a piece of OHP film over the top. The film stops any glue that spills out from sticking to the UV unit.
- Close the lid of the UV unit and fasten shut. Leave for 30 seconds so that the cushioned lid can apply even pressure to the slides.
- Turn on the UV unit for 2 minutes – this will polymerise the loctite glue.
- Open the lid and remove the OHP film. Carefully peel away the mylar graphic film. The stained section will remain on the glass microscope slide.
- Add a small drop of loctite glue to the section on the slide and then place a glass cover slip over the top.
- Place a piece of OHP film over the slide and close the lid of the UV unit for 30 seconds.
- Turn on the UV unit for 2 minutes.
- Open the lid and remove the film. Using a razor blade carefully cut away any excess glue around the edges of the slide.
- The slides are now ready to be examined under the microscope.

APPENDIX TWO – AUTOPSY REPORT

EG-A-4

University of Minnesota
Duluth Campus
Paleobiology Laboratory
Duluth, Minnesota 55812
U.S.A.

Autopsy (4)

UMD Accession Number **54**

UMD File Code **EG-DK2-4-E-O**

~~Field UMD~~ Accession Code **31/420-CS-1/4-8 Body E**

Mummy Autopsy Protocol and/or Osteology of Archeological Skeleton
Protocolo de Autopsia de Momias y/o Osteologia de Esqueletos Arqueologicos

I. Identification Data (Antecendentes Generales)

Principal Director / Jefe Directo **TONY MILLS**

Site Name / Nombre Del Sitio **DK2**

Tomb No / De Tumba **4**

Body No / # De Cuerpo **E**

Unit No / # De Unidad **O**

Excavated By / Excavado Por ~~PAUL~~ **MICHAEL BIRRELL**

Day/Month/Yr
Date / Fecha **1992**

Reference / Referencia

Analyzed By / Analizado Por **LARRY CARTMELL**

Date / Fecha **5 Dec 93**

No. of Registry Notebook / # Del Cuaderno de Registro

Row / Fila

Box / Caja

Cultural Phase / Fase Cultural

Sex / Sexo: M   M?   **(F)**   F? -   Undeterminado / No Determinado U

Sex Based On / Sexo Basado En **External Genitalia- Pelvis - Breasts**

Age / Edad **20-22**

Based Principally On / Basado Principalmente En **Pubic Symphysis - Femoral epiphysis closure**

II. Description of Funerary Bundle (Descripcion Fardo Funerario)

Position of body/Posicion del Cuerpo **Extended - Right Arm at side c̄ hand over lateral portion of upper thigh. Left Arm at side c̄ forearm over iliac crest & hand over upper inner thigh**

1

Jul 19, 1993 12:00 AM

54.

H-A-53

Sketch the external body and cultural objects here
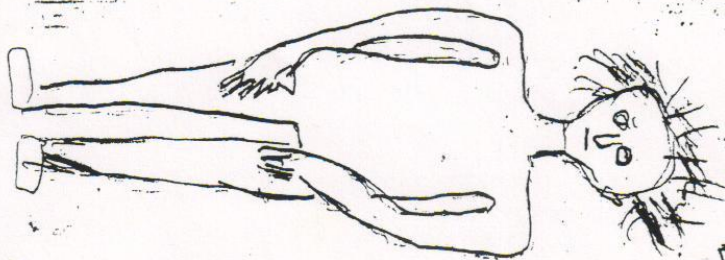
reddish Brown hair
35 cm in length

Describe body and cultural objects here

The body is that of an Adult Female lying supine prone
in the extended position. No cultural objects
are present on the external body. The skin
is intact except for the following three Areas.
1) 6x2 cm R. Cheek   2) 7x2 cm L. Cheek
3.) 6x5 cm R Lower Ant tib - Fib.
        The Ant Abd wall has been previously opened
by Another Prosector This measures 23 x 12 cm
& when removed reveals An Anterior curving Spine.

2

UMD Accession Number   54

Cultural Objects / Obj. Culturales: ○ Pres ● Abs/Aus   Lithic Litico ▨   Metal Metal ▨   Wood Bosque ▨   Textile Textil ▨   Hide Piel ▨

Grass skirt ▨   Reed Mat ▨   Cord or Rope ▨

III. Type of Mummification / Estado de Conservacion   ● Spontaneous/Espontaneo ○ Anthropogenic

---

IV. External Examination of Body / Examinacion Externa del Cuerpo

Preservation Condition / Estado de Conservacion:
■ Mummy/Momia
▨ Partial Mummy
▨ Skeleton

Completeness of Body / Completitud del Cuerpo:
● Complete/Completo
○ Incomplete/Incompleto

Trunk Skin Preservation:
■ Good/Bueno
▨ Intermediate
▨ Poor/Malo

Skeletal Tissues / Tejido Oseo:
■ Good/Bueno
▨ Intermediate
▨ Poor/Malo

External Genitalia Preservation Score (0-3) [   ]

Assign a value of 0 to 5 based on the amount of tissue present (the computer will calculate percentages and index values)

	Head Cabeza	Chest Pecho	Abdomen	Arms Brazos	Legs Piernas	% Preservation % Conservacion
Bone Hueso	5	5	5	5	5	100
Soft Tissues Tejidos Blandos	9	4	1	3	3	56

Soft Tissue Index / Indice de Tejidos Blandos   56

(All measurements are in cm)   Head Circumference (Maximum) / Circumferencia de la Cabeza [5 1]

Crown to Hip / Cabeza-Cadera [70]   Hip to Knee / Cadera-Rodilla [38]   Knee to Heel / Rodilla-Talon [43]

Upper Arm / Brazo [29]   Forearm / Antebrazo [26]   Hand / Mano [16.5]   Length of Foot / Largo del Pie [21]

SKIN / PIEL   ● Present/Presencia ○ Absent/Ausencia

Tatto / Tatuaje: ○ Present/Presencia ● Absent/Ausencia
Eruptions / Erupciones: ○ Present/Presencia ● Absent/Ausencia
Fungus / Hongos: ○ Present/Presencia ● Absent/Ausencia

Wound / Herida: ○ Present/Presencia ● Absent/Ausencia
Tumor / Tumor: ○ Present/Presencia ● Absent/Ausencia
Abscess / Abcesos: ○ Present/Presencia ● Absent/Ausencia

Discoloration / Coloracion: ○ Present/Presencia ● Absent/Ausencia

3   UMD Accession Number [5 4]

498

HEAD / CABEZA ● Present/Presencia ○ Absent/Ausencia

Ectoparasites / Ectoparasitos ○ Present/Presencia ● Absent/Ausencia

Antemortem Frac / Fractura a. Mortem ○ Present/Presencia ● Absent/Ausencia

Postmortem Frac / Fractura p. Mortem ○ Present/Presencia ● Absent/Ausencia

Scalp Hair / Cabello ● Present/Presencia ○ Absent/Ausencia

Color & Descrip of Hair / Color del Pelo ● Reddish brown hair 35 cm in length

Type of Hairstyle # / Tipo de Peinado # | NA |

Foreign Body in Mouth / Cuerpo Extrano en la Boca ○ Pres ● Abs/Aus

Cranial Deformation ○ Pres ● Abs/Aus

Type of Cranial Deformation

EYES / OJOS ● Present/Presencia ○ Absent/Ausencia

Eye Preservation Score (0-3) | 1 |

EARS/OREJAS ● Pres ○ Abs/Aus ■ Left ■ Right

Perforated Lobes / Lobulos, Perforados ○ Pres ● Abs/Aus

NOSE / NARIZ ● Present/Presencia ○ Absent/Ausencia

Fractured Nose / Fractura Nasal ○ Present/Presencia ● Absent/Ausencia

Nasal Septal Dev / Septum Nasal Desv ○ Present/Presencia ● Absent/Ausencia   ○ Right/Der ○ Left/Izq

Nasal Tampons / Tapones Nasales ○ Present/Presencia ● Absent/Ausencia

BODY HAIR / VELLO CORPORAL ● Present/Presencia ○ Absent/Ausencia

Beard / Barba ○ Present/Presencia ● Absent/Ausencia

Mustache / Bigotes ○ Present/Presencia ● Absent/Ausencia

Pubic / Pubico ● Present/Presencia ○ Absent/Ausencia

Axillary / Axilar ● Present/Presencia ○ Absent/Ausencia

Arms / Brazos ○ Present/Presencia ● Absent/Ausencia

Legs / Piernas ● Present/Presencia ○ Absent/Ausencia

Hair Prservation Score (0-3) | ~~4~~ 2 |

TRUNK / TRONCO

Fractures / Fractura ○ Present/Presencia ● Absent/Ausencia

Wound / Herida ○ Present/Presencia ● Absent/Ausencia

Circumcision / Circuncision ○ Present/Presencia ○ Absent/Ausencia

Rectal Prolapse / Prolapso Rectal ○ Present/Presencia ● Absent/Ausencia

Vaginal Prolapse / Prolapso Vaginal ○ Present/Presencia ● Absent/Ausencia

Umbilical Cord, Vaginal / Cordon Umbilical en vagina ○ Present/Presencia ○ Absent/Ausencia

Umbilical Cord on Infant / Cordon Umbilical en nino ○ Present/Presencia ○ Absent/Ausencia

Breasts / Senos ● Present/Presencia ○ Absent/Ausencia

Describe / Describa

Breast Preservation Score (0-3) | 2 |

NAILS / UNAS ● Present/Presencia ○ Absent/Ausencia

4

UMD Accession Number | 54 |

VI. Unit Codes for Specimens Saved (enter number, beginning with 1, and brief description in box below)

#1 ( ) HAIR LWC ; #2 ( ) HAIR #3 ( ) Finger nail
#4 ( ) Fingernail LWC (5) ( ) toe nail (6) ( ) HAIR LWC
#7 ( ) L Breast #8 ( ) R. Breast ~~BRAIN~~
#9 ( ) R. Lung #10 ( ) Left Lung #11 ( ) Heart
#12 ( ) diaphragm #13 ( ) Poss bowl Contents #14 ( )
Liver ~~#~~ #15 ( ) Left EAR #16 ( ) Right EAR #17 ( )
Left EYE #18 ( ) Right eye #19 ( ) Muscle #20 ( ) SKIN
21 ( ) IV Disc 22 ( ) L3 Vertebrae #23 ( ) RIBS
24 ( ) Muscle DNA 25 ( ) & Muscle Radiocarbon 26 ( ) bone
DNA #27 ( ) Mid Shaft Femur SFA 28 ( ) mid shaft femur
#29 ( ) Rib Cartilage

VI. Autopsy (Describe)/Autopsia (Describa)

The body is an Adult female in her
early 20's. There is good skin preservation
with Abundant hair. The body had been
previously entered in recent times. The
central portion of the anterior abd wall had
been entered. The defect measures 16 x 10 cm &
the ~~~~ portion of Abd wall is still
present. NO EVIDENCE OF ABDOMINAL INCISION DURING ANTIQUITY IS PRESENT. The Chest plate is removed
& reveals both lungs to be flat & placed
posteriorly. The pericardial sac is opened &
reveals a dark 6 cm mass which is
labeled heart. Both diaphragms are intact.
The liver is present below the R diaphragm
in the RUQ. This measures 10 x 6 x 2cm &

54

is dark brown to black in color. No other organs can be identified.

Summary

20 to 22 yo ♀ c̄ long hair. Chest organs & liver present with no pathology, one tooth cavity. Had been entered in modern times, but no evidence of abdominal incision during antiquity can be identified.

No evidence of application of resin is evident ~~externally or~~ internally, but skin shows evidence of ~~an~~ incomplete, thin layer of resin application.

7

UMD Accession Number [54]

501

VII. Postcranial Measurements (mm)

Humerus:	Left	Right		Femur:	Left	Right
Max length				Max length		41.3
Max head diam				Max head diam		13.5
AP midshaft diam				AP midshaft diam		2.7
ML midshaft diam				ML midshaft diam		2.6
Midshaft Circum				Midshaft circum		8.0
Ulna:				Tibia:		
Max length				Max length		
Radius:				AP midshaft diam		
Max length				ML diameter		
Fibula:				Midshaft circum		
Max length						

Skull:

Max length	16.7	
Max width	13.6	Cephalic index
Max circumference	49.2	

Stature (cm) 156.1   Formula(e) used   TROTTER 1970

Bone Pathology/Patologias Oseas

NONE Observed, EXCEPT FOR LEFT
TRANSNASAL CRANIOTOMY.

8

UMD Accession Number   54

VIII. Diagnostic Summary/Resumen y Diagnostico

C V Neg

T ☐ M ☐
D ☐ E ☐
F ☐ P ☐

R E S P Neg

T ☐ M ☐
D ☐ E ☐
F ☐ P ☐

S K E L
1. ANTEMORTEM LOSE OF ONE TOOTH.
2. DENTAL CARIES, OCCLUSAL (ONE TOOTH)
3. POSTMORTEM TRANSNASAL CRANIOTOMY

T ☐ M ☐
D ☐ E ☐
F ☐ P ☐

G I NP

T ☐ M ☐
D ☐ E ☐
F ☐ P ☐

U G NP

T ☐ M ☐
D ☐ E ☐
F ☐ P ☐

N E R V NP

T ☐ M ☐
D ☐ E ☐
F ☐ P ☐

M S T NP

T ☐ M ☐
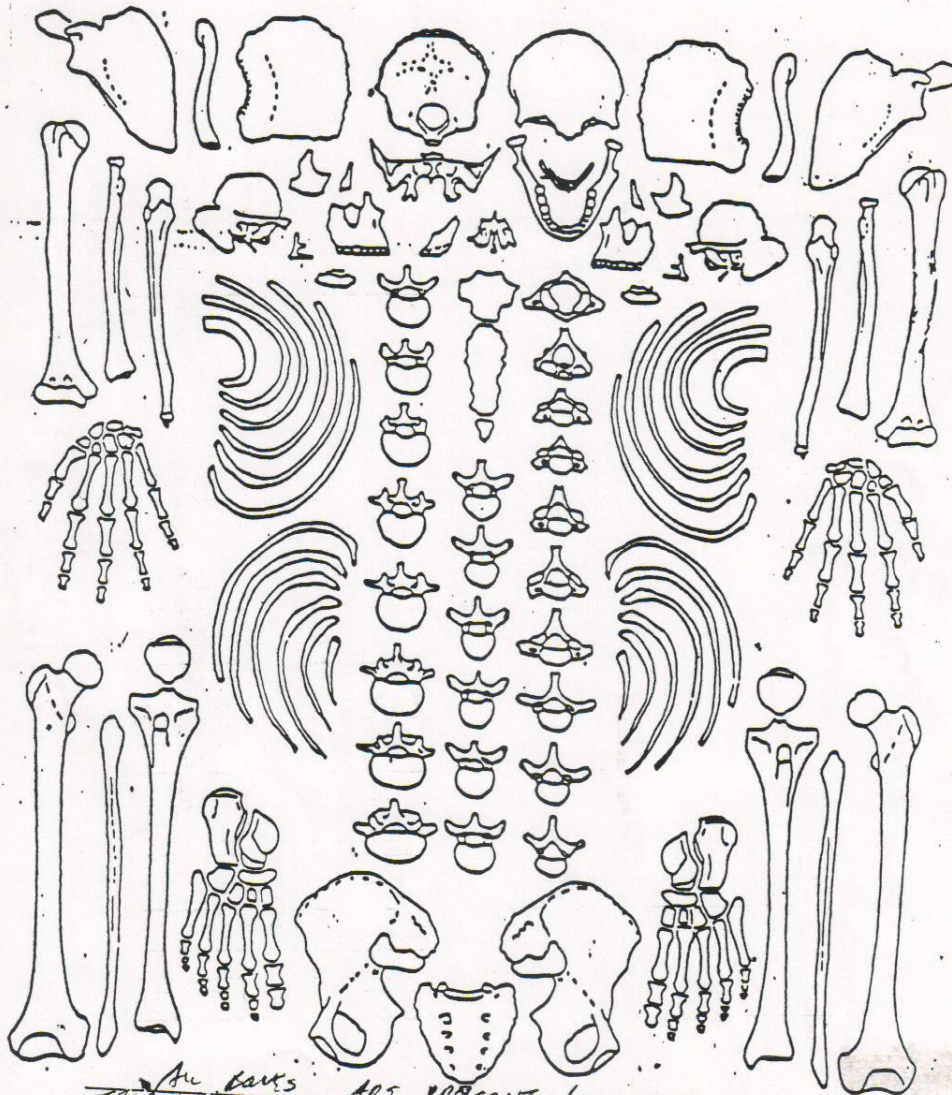D ☐ E ☐
F ☐ P ☐

O T H E R NP

T ☐ M ☐
D ☐ E ☐
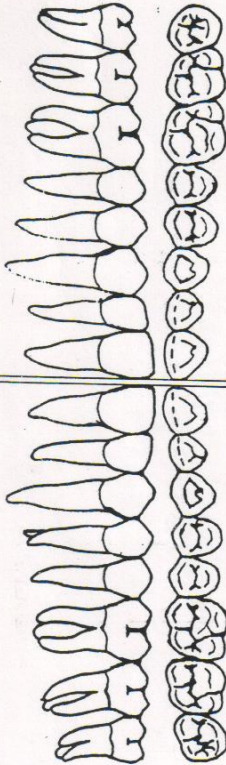F ☐ P ☐

9

UMD Accession Number ☐ 54

ALL BONES ARE PRESENT

ALL BONES ARE PRESENT, LEFT TRANSNASAL CRANIAL
TREPANATION PRESENT BUT NO RESIN, BRAIN OR DURA CAN BE FOUND
IN THE SKULL. NASAL DEFECT = 2.0 cm.

504

Museum _____

Registration # _____

Culture _____

Site _EG-DR-4-E-6_

Site# _____

Access# _54_

M.N.I. _____

Object _____

COMMENTS

0 = NONE
1 = WEAR, DENTURE -
2 = DENTURE +
3 = PULP CANAL VIS
4 = >3

ANNOTATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Alveolus PRESENT																
1. Present in Arch	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2. Absent Tooth PRESENT	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	●
3. Malpositioned AM LOSS	NA	+	0	+	0	0	0	0	0	0	+	0	+	0	+	NA
4. Anomalous Form ENAMEL CRACKED	NA	0	0	0	0	0	0	0	●	+	NA	0	0	0	0	NA
5. Hypoplasia	NA	0	0	0	0	0	0	0	0	NA	NA	0	0	0	0	NA
6. Crown Traits																
7. Attrition	NA	1	1	1	1	1	2	2	2	NA	NA	1	1	1	1	NA
8. Calculus	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NA
9. Caries	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NA
10. Alv. Abscess	0	0	0	0										0	0	0
11. Alv. Bone Level																
12. Hypercementosis																
13. m.-o. dia Crown																
14. Fa.-Li. dia Crown																
15. Length of Crown																
16. Length Overall																
17. Absent from Arch - Primary																
18. Present in Arch - Primary																

PRIMARY ANNOTATION ☞

A B C D E   F G H I J

Estimate of Age _____ Sex _____

Photographs _____

Radiographs _____

Examiner _____ Date _____

54

Museum _____

Registration # _____

Culture _____

Site E G – DK2 – 4 – E – 0

Site# _____

Access# 57
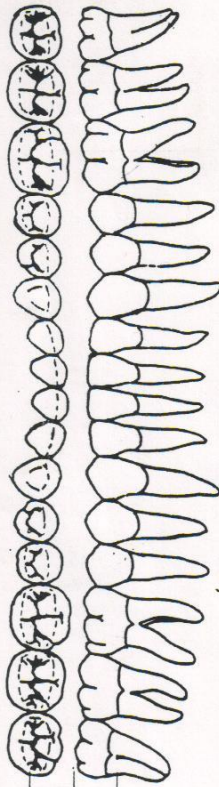
M.N.I. _____

Object _____

COMMENTS

ANNOTATION	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17
1. Present / Alveolus present	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†
2. Absent with Arch / Abscess	†	O	†	†	†	†	†	†	†	†	†	†	†	†	†	†
3. Radiographic Alv Loss	O	†	O	O	O	O	O	O	O	O	O	O	O	O	O	O
4. Abnormal...	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
5. Hypoplasia	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
6. Crown Traits																
7. Attrition	O	N/A	1	1	1	O	1	1	1	1	1	1	1	1	1	1
8. Calculus	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
9. Caries	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
10. Alv. Abscess																
11. Alv. Bone Level																
12. Hypercementosis																
13. m.-o. dia Crown																
14. Fa.-Li. dia Crown																
15. Length of Crown																
16. Length Overall																
17. Absent from Arch - Primary																
18. Present in Arch - Primary																

PRIMARY ANNOTATION

T S R Q P O N M L K
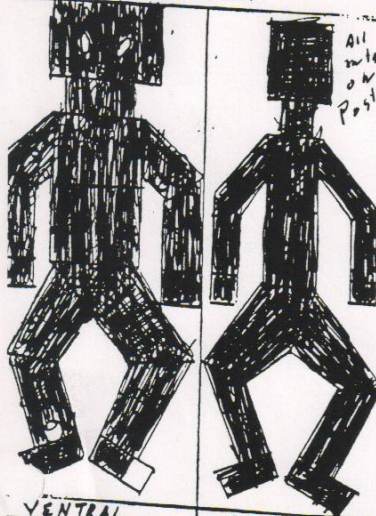
Estimate of Age _____   Sex _____

Photographs _____

Radiographs _____

Examiner _____   Date _____

TISSUE PRESERVATION SKETCH

■ = SOFT TISSUES PRESENT
▨ = SOFT TISSUES PARTLY PRESENT
□ = SOFT TISSUES ABSENT

All intact on position

VENTRAL   DORSAL
BODY PART MISSING

DENTITION

PER:	RIGHT		LEFT
WER:			

iodontitis: Attrition:

N SYMBOLS: M3 M2 M1 PM2 PM1 C I2 I1 | I1 I2 C PM1 PM2 M1 M2 M3

ALVEOLUS PRESENT: WRITE TOOTH SYMBOL IN APPROPRIATE LOCATION
TOOTH IS IN ALVEOLUS, UNDERLINE TOOTH SYMBOL
DISEASE PRESENT, WRITE FOLLOWING SYMBOLS UNDER ALVEOLUS LOCATION
 * = ANTEMORTEM LOSS
 # = FISTULA
 + = CARIES

OCCIPUT

54