Considering the use of Gas Chromatography-Mass Spectrometry (GC-MS) in Inferring the Relationship Between Long-Distance Trade and Animal Mummification in Ancient Egypt

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Abstract

From a consideration of existing literary and biochemical analyses, it can be suggested that imported ingredients were regularly utlised in the process of anthropogenic animal mummification in Ancient Egypt. Through the use of Gas Chromatography-Mass Spectrometry (GC-MS) of 27 mummified animal remains (supplied by Buckley & Tunney and Buckley & Fletcher) this thesis identified the presence of imported embalming agents in 75% of the samples tested. From the data provided, this study was able to consider the potential relationship between the mummification of animals, and trade networks across the ancient world.

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Acknowledgements

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Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as references.

Chapter 1: Introduction

Research Hypothesis

The process of mummification is defined as the use of natural or anthropogenic bodily preservation of remains, achieved through human intervention (McKnight et al 2015, 2108). While such finds have been uncovered from across the world, ranging from South America to East Asia, the practice is most often associated with the Ancient Egyptians. Through the use of the region's naturally arid climate and complex embalming practices, Egyptian priests were able to preserve soft tissue remains in such a way that these still survive (relatively intact), thousands of years on. Mummified remains often produce great intellectual and academic curiosity, due to their peculiarity and association with death and the afterlife. Great media attention is often drawn to the mummified remains of important individuals from Egyptian society. These include famous examples such as the mummified remains of Pharaohs Tutankhamen and Ramses II (Aufderheide 2010, 234). Analyses of mummified human remains have been an important part of Egyptian archaeology, allowing for the consideration of both techniques in mummification, as well as the health, age, appearance and socio-economic importance of these figures from Egyptian history.

Far more numerous than human mummies however are the embalmed remains of animals found from catacombs across Egypt. Excavations of such funerary complexes have revealed the remains of mummified mammal, reptile, bird and fish specimens, preserved and deposited in the millions. Traditionally, Egyptologists have utilised mummified animals as a means of identifying the proliferation of the animal cults, which from the 3rd Millennium B.C. dominated religious practice in Ancient Egypt. While such remains do appear to be indicative of such religious developments, it is important to consider other possible uses for mummified animals within an archaeological methodology. More specifically, can we use these remains to identify socio-economic trends in Ancient Egyptian history? In order to test such a hypothesis, this thesis will make use of GC-MS analyses of the embalming agents used in a number of mummified animal specimens, to identify the potential use of imported substances from beyond Egypt's borders in the mummification process. In doing so, this study will attempt to quantify the hypothesised widespread use of long-distance traded ingredients in the mummification of animals. Such findings will then be considered as a pilot study in which we can assess the validity and merits of using mummified animals as part of a wider archaeological methodology with which to infer the correlation between culture, economics and politics in Ancient Egypt.

Rationale

While anthropogenic mummification itself is a phenomenon that is seen in communities ranging from Peru to Japan (Cockburn et al 1998, 121-336), the deliberate preservation of animals appears to be largely limited to the civilizations in Ancient Egypt. It should be noted however that spontaneously mummified remains of numerous species have been discovered in association with human graves in Peru and Chile (Aufderheide 2010, 415). Literary resources such as Herodotus and Diodorus detail such practices, in Ancient Egypt as early as the Ptolemaic Period. Evidence of such findings have been identified by European sources as early as the 17th century, with the recording of the 'bird pits' at Saqqara by Johann Michael Vansleb in 1678 (Martin 1997, 181-191). However, it is not until the early 20th century that we begin to see the first attempts at recording these remains in any form of archaeological methodology. In particular, French Egyptologists Louis Charles Émile Lortet and Claude Gaillard published two volumes of *Faune momifiée de l'ancienne Égypte* (1905-1909), which recorded and catalogued large numbers of mummified animal remains from across Egypt (Lortet and Gaillard 1905) (Lortet and Gaillard 1909). This primarily involved descriptive work, a typical feature of early studies, along with limited use of radiographs (Dunand and Lichtenburg 2006, 108). Often any considerations of mummified animal remain are simply appendices to studies into human mummification (ibid). More recently however, academic research into animal mummification has advanced with the growth of modern archaeological methodologies and scientific analyses. Extensive studies into mummified remains of animals and animal cult worship more generally, have been undertaken by the likes of Salima Ikram (American University Cairo), Paul Nicholson (University of Cardiff) and Aidan Dodson (University of Bristol). These publications have formed an important context for the research conducted in this thesis (see Chapter 3).

Modern scientific analyses arguably show the biggest breakthrough in terms of understanding the mummification of animals as part of Egyptian socio-economics. Radiographic studies undertaken by the University of Manchester (McKnight et al 2015, 2108-2120) (see Fig. 1.0) gained widespread media attention for their identification of the widespread practice of pseudo-mummification. Moreover, GC-MS (Gas Chromatography-Mass Spectrometry), such as those from Buckley et al allow for the identification of individual biochemical components of the embalming agents used in the mummification process (Buckley et al 2004, 294-299). This latter study is the most relevant to the aims of this thesis, as they identify the potential for the use of GC-MS in identifying the origins of the ingredients used in animal mummification (see Chapter 4). A methodology similar to that of the aforementioned publication will form the core of this body of research, although will ultimately have different objectives.

While Buckley et al aimed to identify the use of similar embalming mixtures in human and animal mummification in the same chronology (see Chapter 3), this thesis will instead attempt to identify the presence of ingredients in the embalming agents of mummified animals that have been traded from beyond Egypt's borders. This will primarily be achieved through the interpretation of GC-MS analyses, compiled and supplied by Dr. Stephen Buckley, Miss Deborah Tunney and Professor Joann Fletcher of the University of York. This data will be examined in an attempt to identify the use of imported ingredients in the embalming agents of the mummified animals in this study. Subsequently, these findings will be considered in the wider context of existing studies of animal mummification and long-distance trade. This will then be used to consider the degree to which we can infer a reciprocal relationship between the overtly religious practice of animal mummification, and the exchange of goods into Egypt from the wider Mediterranean and Middle Eastern world. Such findings will allow us in turn to consider a number of key questions. These include identifying how prevalent the relative use of imported ingredients is in animal mummification? Where are these specific ingredients likely to have been imported from? Does this mirror what we know about the Egyptian long-distance trade economy as a whole? How much can this tell us about the interconnectivity of economic and socio-religious practice? And how effective is the use of GC-MS in inferring this relationship? Such findings should help to explain to a greater degree, the complex relationship that exists in Ancient Egypt between nature, cosmology, religion, politics, economics and culture.

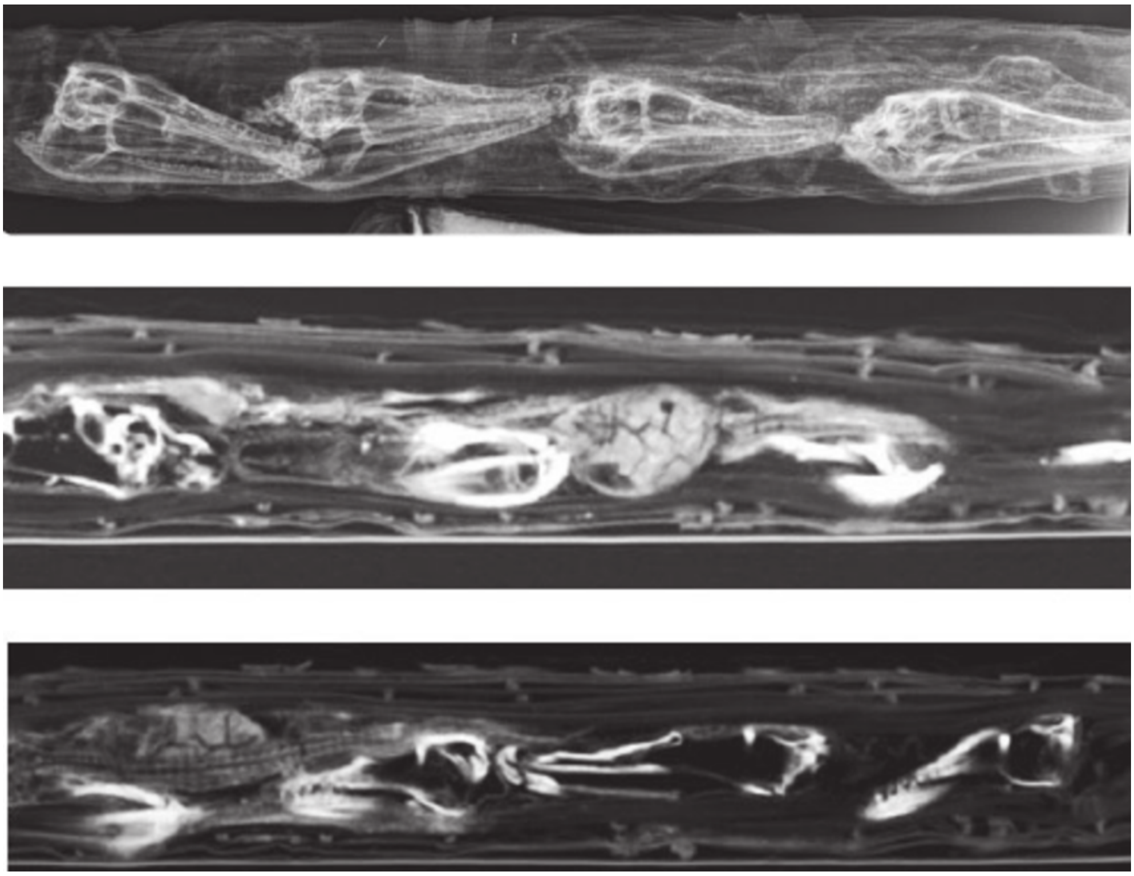

Fig. 1.0: X-Ray imaging of mummified animal remains conducted by the University of Manchester (Atherton-Woolham and McKnight 2014, 9-17).

Aims and Objectives

In order to meet the specific aims and objectives of this study, this thesis will consider a number of specific questions, in order to assess the relationship between animal mummification and socio-economic networks:

Aims:

- To identify the nature of the long-distance trade economy in Ancient Egypt.
- To understand how the mummification of animals was undertaken and administered.
- To identify embalming agents used in the mummification of animals, traded into Egypt from abroad.
- To consider the relationship between animal mummification and trade in later Ancient Egypt.
- To consider any directions for future research.

Objectives:

- To examine archaeological and literary evidence for the trade of goods into Ancient Egypt, using preexisting publications.
- To consider the existing archaeological and textual evidence for methods, trends and practice in animal mummification.
- To review previously published biochemical analyses of mummified remains, in order to identify common embalming ingredients as a reference for this thesis.
- To interpret the findings of two unpublished GC-MS analyses of mummified animals, provided by Buckley & Tunney and Buckley & Fletcher.

- To use this data to identify the role of the import economy in the mechanics of animal mummification (and vice-versa) in later Ancient Egypt.
- To identify the issues with the methodology of this thesis, in order to suggest future directions and ways to develop the research further.

In examining mummified animal remains in this manner, this thesis hopes to highlight the dichotomy that exists between Egyptian social, religious, political economic practice. Furthermore, this research can hopefully act as a pilot study into the importance of imported goods in the embalming process.

Chapter 2: Long-Distance Trade in Ancient Egypt

Initially, the mummification of animals and long-distance trade would appear to be relatively disparate practices. Traditionally, mummification has been viewed very much in terms of its religious significance, with little thought given to the wider socio-economic implications of the practice. However, given the social significance and scale of animal mummification in Ancient Egypt, at least some level of economic significance is inevitable. The aim of this thesis is to consider whether animal mummification would have had a direct impact on imports into Egypt, and by extension wider economic social, economic and political activity throughout Ancient Egyptian history. In order to understand this complex relationship, we must consider three factors: the nature of long-distance trade and exchange, the socio-economic role of animals in Egyptian society and the materials used in the mummification of animals. In considering these forms of evidence, we can begin to connect the seemingly ritual practice of animal mummification into the wider socio-economics of Ancient Egyptian life.

Trade in the Ancient World

When attempting to interpret the role of long-distance trade in Ancient Egypt, it is important to consider a theoretical framework in which to analyse how trade and exchange functioned in Egyptian society. For this we must consider the founding debate within economic anthropology, triggered by the work of Bronislaw Malinowski and Marcell Mauss in the early 20th century. Malinowski and Mauss argued for the importance of 'reciprocity', or mutual gift-exchange and non-market offerings, as the dominant form of exchange over traditional market economies in pre-capitalist societies (Thornton and Skalnik 2006) (Mauss 2011). Karl Polanyi took this debate further in his work 'The Great Transformation' (1944). In this, Polanyi suggested that ancient trade and exchange should not be considered a process of rational decision-making and logical use of limited means, disassociated from politics, religion and culture (Polanyi 1957, 47). This theory (Substansivsim) opposed the conventional view of trade and exchange (Formalism), has formed the basis of discussion surrounding the nature of the ancient economy of the last half-century. Polanyi argued that the broader definition of past economic practice provided by substansivism was better placed to deal with pre-capitalist societies (ibid). Given the cultural, geographic, and social diversity seen through Ancient Egyptian history, there is much to be gained from applying Polanyi's perspectives on ancient trade in Egypt. It is important not to consider perspectives of the ancient economy as cross-cultural trends, but to be aware of local factors that could influence the processes of trade and exchange.

In contrast, this perspective can be criticised for potentially neglecting the role of the market economy in the distant past. Such criticism is relevant when considering trade and exchange in Ancient Egypt. Depictions of Egyptian markets can be seen as early as the Old Kingdom, which show markets near water (Moeller 2015, 381). This potentially supports the common lack of archaeological evidence for markets in Ancient Egyptian towns (ibid). Evidence for similar practice comes from contemporaneous sources in Mesopotamia, where written resources detail that the places of trade and markets were located in the vicinity of the city gates (May and Steinert 2013, 14). Several earlier sources have suggested the lack of archaeological evidence for markets indicates that trade and exchange in the early Ancient Near East functioned through market-less state-controlled systems of exchange (Hammond 1972, 41). However one must be aware that there is no intrinsic link between physical markets and the use of a market economy, so such observations should be approached with caution. In contrast, records from Egypt and Mesopotamia do indicate that market based trade and exchange was present from at least the Old Kingdom in Egypt and Sumerian Period in Mesopotamia. The economy of Ancient Egypt did not exclude state administered reciprocity however. It is important to consider all the forms of transfer that can be considered forms of trade, not only Polanyi's triad of reciprocity, redistribution and market exchange. Polanyi fails to consider the five forms of the transfer of goods that could have formed an important part of pre-modern trade and exchange (M.E Smith 2004, 84):

- Allocation in the unit or centre of production.
- Gifting without expected return (family level and diplomacy).
- Taxes (obligatory transfers from individuals to state).
- Tribute (wealth transfers between states).
- Theft and Plunder

While these characteristics are difficult to distinguish from one another archaeologically, it is important to be aware that the trade of goods is not limited to socially imbedded gift exchange or logic-based market economy. Consequently, this perspective can be applied to better understand the nature of the Egyptian international exchange institution (e.g. long-distance merchants, administered trade and ports of trade) and how such systems changed as a result of political, cultural and social factors.

In order to best consider how the Egyptian economy functioned, the nature of the economic systems must be considered. In their work *'Trade in the Ancient Economy',* Garnsey et al give an effective overview of the nature of the Ancient Mediterranean economic systems. This allows for a consideration of the primary issues when studying the progression of trade and exchange during this period, and provides a foundation for further investigation. An important factor to be considered is that the economy remained predominantly rooted in agriculture throughout this period (Garnsey et al 1983, 10-12). Therefore, it has been suggested that the ancient economy probably functioned as a model for cellular self-sufficiency (ibid). Individual farmsteads, districts and regions probably remained largely self-sufficient, and grew the majority of what they needed (ibid). Exceptions remain in regards to the very largest ancient cities (Athens, Rome, Memphis), although such large cities that required substantial imported surplus were a rarity (ibid). In most cases, towns were the centre of authority for government and religious cults, and a centre of residence for local landowners (ibid). Towns also provided hubs for market exchange, most likely of produce and craft goods intended for local consumption (ibid).

In contrast, long-distance trade is assumed to have been relatively small (ibid). Overland and sea transport was too cost inefficient to allow for transport, except for luxury goods (ibid). The suggested reasons for long-distance trade forming such a small part of the gross product are threefold. First of all, climactic conditions throughout the Mediterranean Basin are relatively consistent (ibid). In addition, the need for transportation of agricultural product was minimal, due to the crops types differing little throughout the region (ibid). Secondly, most economies lacked the investment in production to compensate for the high cost of transporting goods over long distances (ibid). Towns could not specialise in the manufacture of cheaper goods, instead relying on prestige goods to generate profits on long-distance trade (ibid). Lastly, it should be considered that the demand for prestige goods was limited due to the poverty of the majority of the population (ibid).

While there is an argument for the urban development of the Mediterranean due to expanding trade relations, this may simply be a factor amongst a general growth in the agricultural economy of the period from 1000 B.C to 500 A.D. Pollen records from this period show an increasing gradual trend for agricultural production. This was due to the political move from independent city-states to large empires (Alexandrian, Carthaginian, Roman), and technological improvements such as iron tools, screw presses and rotary mills (ibid). Increasing production resulted in increased profits for wealthy landowners, driving urban development as they chose to move into the cities (ibid). When considering this however, the rise of a landowning elite could subsequently have influenced long-distance trade through an increased demand for high-value items. This may have facilitated the growth in long-distance trade, along with the social developments of shared risk investment, large sailing ships, and silver and gold coins (ibid).

Additionally, trade was not the only way that goods would have been transported over distance (ibid). Taxation, imposition of rent, and gift exchange is difficult to distinguish in the archaeological record from trade (ibid). Therefore, it has to be considered that long-distance trade was only one of a number of causes of the movement of goods, and thus archaeological remains associated with long-distance trade should be approached with caution.

The Trade Economy in Ancient Egypt

When studying the import of embalming agents used in the mummification of animals, it is relevant to consider the nature of Ancient Egyptian trade economy. An archaeological and textual analysis of exotic goods trade into Egypt allows us to consider a number of possible factors that may influence this economic practice. These include the points of origin for goods arriving into Egypt, how these goods are transported, and how such a system is administered and financed? Ascertaining how such systems of exchange functioned allows us to consider how the Egyptian trade economy develops throughout Dynastic and Later Period Ancient Egypt. In turn, we can relate this perspective on the Egyptian economy to the identification of any imported ingredients in the GC-MS analyses collated in this thesis.

The Nature of Egyptian Trade

Outwardly Egyptian foreign trade and exchange appears to follow much the same pattern as the rest of the Ancient Mediterranean. Goods traded into Egypt were typically expensive and low in volume, and arrived indirectly through a series of merchants and middlemen, although often under royal or elite administration. Trade also appears to occur predominantly with the regions directly adjacent to Egyptian territory (namely the Levant, Nubia and Punt), although these could additionally act as conduit points for goods from further afield. For example, Lapis Lazuli would have been sourced in Central Asia, but reached Egypt along trade routes through Palestine (Shaw 2002, 321). Whether through acquisition or production, these regions that straddled the borders of Egypt provided a number of valuable resources that were high in demand in Egyptian society. In order to access these resources, the Egyptian import economy appears to consist predominantly of two routes of exchange. One leads north into the Levant and the wider Mediterranean and Near East (Broodbank 2013, 285). From this region, Egypt could acquire wine, resins, oils and hardwoods such as cedar (ibid). In addition, they could attain silver and turquoise from Anatolia and Minoan pottery from Greece (Callander 2002, 178). The other ran south and allows goods travel from Nubia, East Africa (Punt) and Arabia (Broodbank 2013, 285). From Nubia and Punt to the south came gold, aromatic resins (frankincense and myrrh), ebony, ivory, wild animals and skins, amethyst and copper (Shaw 2002, 320) (Malek 2002, 116). Understanding how the use of these trade networks differ over different chronological phases can allow for a consideration of how embalming agents in mummification arrive into Egypt. This in turn can provide some context as to the potential impact of these goods, in relation to the wider socio-economic progression in Ancient Egypt.

What Defines Egypt?

An important factor in considering the role of the Ancient Egyptian import economy is constituting what defines Egypt's national boundaries. Throughout the four thousand years of Ancient Egyptian history, the borders of Egypt are relatively fluid, and dependent on the political and military situation at different chronological phases. For example, throughout much of the 19th Dynasty (1292-1189 BC) the Egyptian military controlled much of modern Lebanon, Jordan, Palestine, Israel and Syria, in competition with the Hittite Empire for trade routes (Van Dijik 2002, 298). For the purposes of this thesis however, I will class imports as those materials brought into Egypt from outside of the Nile Valley and Delta regions. This has been done for two primary reasons. First amongst these is that the Egyptians seem to show a distinct cosmological distinction between their ordered kingdom, and the allegedly chaotic world that lies beyond the natural borders created by the Nile Delta and Valley (Broodbank 2013, 286).

Given the apparent view of Egyptian peoples that anything beyond this point constituted a different cosmological entity, it could also be assumed that any goods beyond this point may be considered foreign. Whether such a perspective continues in the native population into later Ancient Egyptian history, where Egypt was part of much larger empires, is unknown. Furthermore, the use of a single definition of Egypt's boundaries helps to avoid the issues created by shifting borders, and the Egyptian colonial expansion into the Levant and Nubia. This allows for a consistent distinction between native and imported goods, across a large chronological period.

The Origin of Import Networks in Predynastic and Early Dynastic Egypt

Evidence for the import of goods from beyond the borders of Egypt can be witnessed as early as the Predynastic Period. Palestinian style ceramics, suggested to contain wine, oil or resin, have been identified as early as the Maadi and Naqada (4400-3000 BC) cultures (Shaw 2002, 321) (Midant-Reynes 2002, 58). Indeed, the northward expansion of Protodynastic peoples in Lower Egypt, including settlements such as Buto, has been suggested to be in part in order to access these Levantine resources (Midant-Reynes 2002, 59-60).

It is in the 1st Dynasty (3218–3035 BC), and the unification of Lower and Upper Egypt, that the first instances of state-controlled and administered trade can be seen. Mud brick encampments in Southern Palestine have been interpreted as representing border control points, from which Egyptian officials could administer control and tax the flow of goods into the country (Bard 2002, 77). Such a political control over trade and can be seen in archaeological sites from this chronological phase. 1st Dynasty tombs or elite and royal individuals at Abydos and Memphis were found to contain large quantities of Syrio-Palestinian pottery (Wilkinson 2002, 158-159) (see Fig. 2.0). These have been interpreted as acting as containers for the expensive oils imported from the region (ibid). While these vessels have historically been defined as *'Abydos Ware'* and associated with a southern Levantine production, recent petrographic analyses have suggested that this group actually encompasses multiple different pottery types, including

‘Metallic Ware’ type vessels produced in the northern Levant (Hartung et al 2015, 295-327). This has been used to argue for the use of maritime trade routes for valuable oils and resins from the region as early as the 1st Dynasty (ibid). The association of exotic goods with wealthy or influential individuals is a theme that is evident throughout much of Ancient Egyptian history, as the possession of such items would have required significant political or personal wealth.

In the 4th Dynasty we begin to see the first attempts to secure those trade routes to the south. Under Sneferu (2613-2589 BC), a military expedition was launched into Nubia, with economic hardship in Egypt making the resource-rich Nubia a tempting target (Malek 2002, 106). From the 6th century, several more expeditions were sent from the southern city of Elephantine, which grew to be the economic hub for goods from the region (Malek 2002, 116).

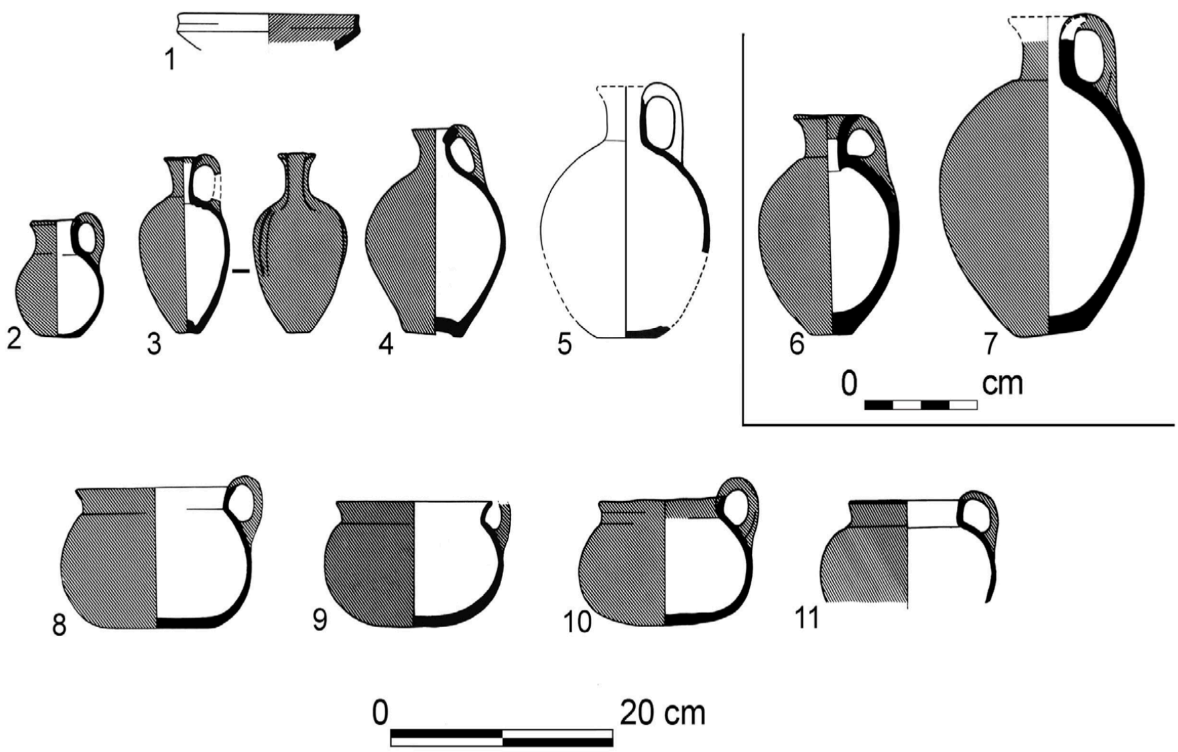

Fig. 2.0: Illustrations of a selection of ‘Abydos Ware’ type pottery, produced and traded from the Southern Levant in the Early Bronze Age (Braun 2009, 25-48).

Long-Distance Trade in Dynastic Egypt

Throughout Dynastic Egypt, we see an expansion of those two predominant routes of exchange that are established in the Predynastic and Protodynastic period. As the economic and political authority of the Egyptian state grew, the demand for high-value goods from abroad increased. Subsequently, we see the development of both systems for the physical movement of goods into Egypt, and for the control and administration of these exotic imports from the Egyptian hierarchical elite.

Levant and Mediterranean:

Over time, the overland trade routes through Palestine were superseded by maritime communications with numerous Levantine city-states such as Byblos (Bard 2002, 78). From the 12th Dynasty, the rulers of these city-states were under significant authority and influence from the Egyptian state, aiding the trade of goods from these regions (Callender 2002, 179). One of the best sources of evidence for this system of trade in Dynastic Egypt comes from a series of inscriptions at Mit Rhina, created during the rein of Amenemhat II (1911-1877 BC) (Broodbank 2013, 360). The second of these inscriptions details the records of two ships returning from the central Levant, including precise documentation of the cargo carried (ibid). According to the inscription, this cargo included 231 lengths of Lebanese Cedar, 65 captives, 23kg of silver, 133kg of bronze, 435kg of copper, 19kg of white lead, 37 daggers decorated with gold, silver and ivory, 225kg emery and 537kg of grinding sand, diverse other stones, quantities of oils and resins, spices such as coriander and cinnamon and 73 fig trees, alongside the kings annals listing gifts to temples (Broodbank 2013, 360). Such records provide an understanding of the kinds of imported materials sourced from the region, and details the predominant means by which these goods arrive into Egypt. Other textual evidence provides some information on the methods by which these exotic goods are transported. Paintings from Beni Hassan for example show donkey caravans carrying goods, alongside traders in Levantine style clothing, suggesting the movement of Levantine merchants into Egypt (Broodbank 2013, 360). Another important source of evidence for the methodology of Egyptian trade to the Levant, Mediterranean and Near East comes from the Amarna Letters. These Akkadian language clay tablets provide an archive of diplomatic correspondences between the Egyptian admiration and its representatives in the Levant during the New Kingdom (Snell 2008, 395). These provide significant information on the importance of the Egyptian elite in the process of acquiring exotic imports. In particular, these correspondences detail the frequent gifting and tributing relationships that account for much of the movement of goods across borders between numerous Near Eastern and Mediterranean kingdoms (ibid). Furthermore they explicitly state the influence of the political and religious aristocracy (including the temples) in providing the economic resources necessary to acquire these goods at high-costs (ibid).

Nubia, East Africa and Arabia:

Egyptian influence in trade relations with Nubia and Punt is dominated by large-scale political and military expeditions. In the Middle Kingdom, Amenemhat III ordered the construction of military outposts at Semna and Quban to protect the Nubian gold supply (Callender 2002, 159), while Senusret I conquered Upper Nubia and incorporated the territory into the Southern Egyptian Nome in order to control the trade of goods directly. Furthermore, stelae and wall carvings (such as those at Sa'waw) show a series of expeditions were sent to the Pun (modern Somalia, Ethiopia, Eritrea and Djibouti), often with a military presence associated (Callender 2002, 179). Perhaps the most well known example of such an expedition is that of Hatshepsut (18th Dynasty). Carved scenes at Deir el-Bahari show in great detail the size of the expedition as well as the myriad of goods including myrrh trees (planted in Hatshepsut's mortuary tomb), gold and live elephants, giraffes, leopards and baboons (Bryan 2000, 239) (see Fig. 3.0). Expeditions such as these can be seen as a means by which the Egyptian aristocracy could both forge new trading partnerships with people's native to these regions, and maintain the security of these trade routes.

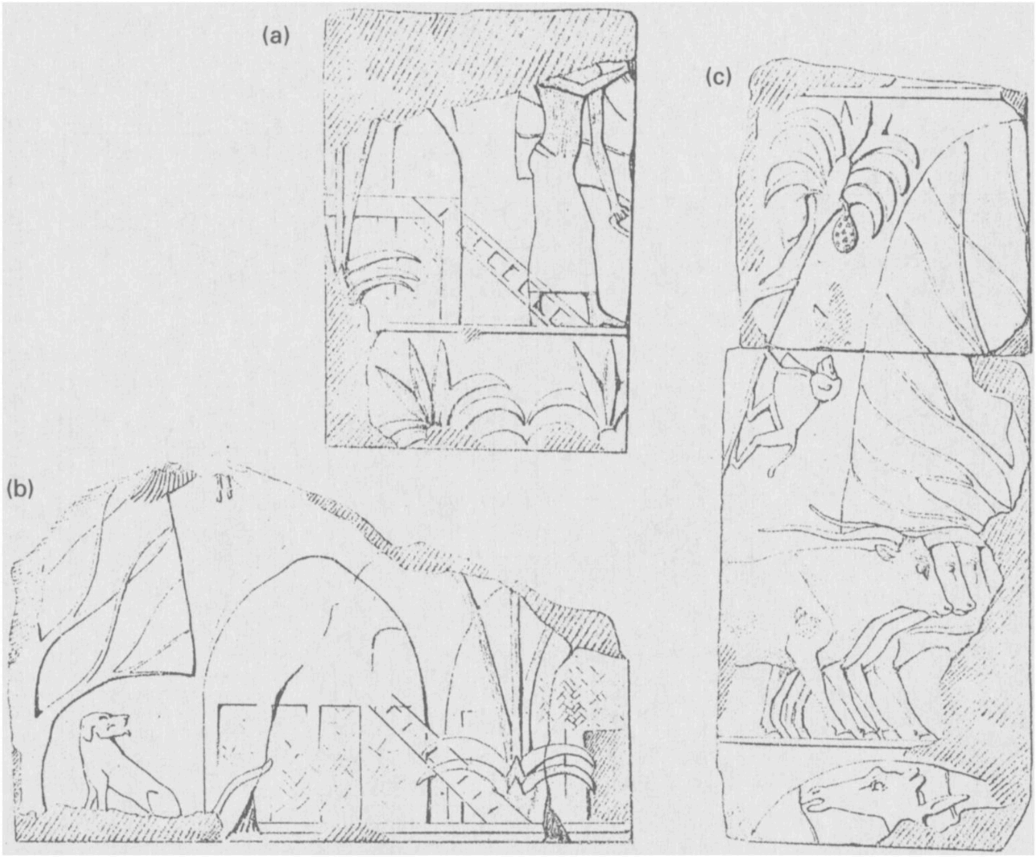

Fig. 3.0: Three loose fragments from the south wall of the Deir el-Bahari c olonnade, including the depiction of a wild baboon. (Phillip 1997, 431).

The Import of Goods in Later Ancient Egypt

With the collapse of the last native dynasties, Egypt experienced a prolonged period of direct rule from a succession of foreign political authorities:

3rd Intermediate Period (1069-664 B.C.): A period of economic and political instability concurrent with the wider Eurasian Late Bronze Age Collapse, which saw the fragmentation of Egypt following the death of Ramses XI (Taylor 2002, 330-368). Over the subsequent centuries, the region was fractured and divided; between the rulers of the 21st Dynasty and the High Priests of Amun at Thebes, rival Libyan, Nubian and Kushite factions, and finally with the incorporation of Egypt into the Neo-Assyrian Empire (ibid).

Late Period (664-332 B.C.): From 664 B.C., Egypt experienced a period that saw the rise and fall of the last native Egyptian dynasties, beginning with the 26th or Saite dynasty, initially as Neo-Assyrian vassals (Lloyd 2002, 369-394). These last native dynasties (the 26th, 28th 29th) were divided between two phases of occupation and subjugation from the Achamenid Persian Empire (the 27th and 31st Dynasties), which ended with the conquest of Egypt by the Macedonian Greek armies of Alexander the Great (ibid).

Ptolemaic Period (332-30 B.C.): Following the death of Alexander the Great, control of Egypt passed to Ptolemy Soter, one of the Diadochi (leading generals who divided the empire after Alexander's death) who founded the Ptolemaic Dynasty (Lloyd 2002, 395-421). During the subsequent three hundred years, the ruling class in Egypt became ethnically and culturally Greek, while the primary economic and political centre moved north to Alexandria, which became a major centre of Greek culture and trade in the Eastern Mediterranean (ibid). During this period, the Ptolemaic rulers adopted numerous native Egyptian customs. These included the use of the term Pharaoh, as well as Egyptian styles in dress, monuments, royal marriages between siblings, and the partaking of traditional Egyptian religious practices (ibid). Throughout much of its early history, the Ptolemy's ruled as a powerful Hellenic Dynasty with influence spreading into the Levant and Nubia (ibid). However, frequent native rebellions and Hellenic dynastic civil wars weakened the kingdom, eventually resulting in the annexation of the region by the Roman Empire (ibid).

Roman Period (30 B.C.-A.D. 395): From 30 B.C., the Roman Empire annexed Egypt and incorporated the region as a provincial territory, after a lengthy period of vassaldom (Peacock 2002, 422-445). Roman control of Egypt made use of a similar system of governance as the previous Ptolemaic Greek rulers, but with a greater emphasis on the military (ibid). In addition, Roman rule in Egypt saw the introduction of a strict ethnic hierarchy, with Romans and Greeks placed above native Egyptians in regards to civil issues such as taxation and punishment (ibid). While Roman and Byzantine control persists in Egypt until the 6th century

A.D., the worship of animal cults and mummification is typically assumed to end with the adoption of Christianity as the official Roman state religion (ibid).

It is within this chronological phase in which this thesis shall focus most concertedly, given the vast majority of mummified animal remains are associated with this period (see Chapter 3). Most crucially, this will involve the discussion of how the absorption of Egypt in larger political entities effects both the transmission of exotic goods, and how such a system of trade was controlled.

Late Period:

Perhaps the most archaeologically identifiable evidence for influence of foreign powers on the import economy in Ancient Egypt is with the growth of independent trading poleis in the Nile Delta by Phoenician and Greek merchant communities in Late Period Egypt. The most important site attributed to these Greek traders was the city of Naucratis, which lay on the Canopic branch of the Nile River and provided excellent communications for both internal and external trade (Lloyd 2002, 374). Settlers and traders from the Greek city-states founded Naucratis in the 8^{th}-7^{th} centuries B.C., as a settlement from which Greek merchants could practice trade with relative independence, brining in goods from across the Eastern Mediterranean (ibid) (see Fig. 4.0). Naucratis functioned as a semi-autonomous Greek community, beginning as a trading emporium, but eventually forming into a permanent Greek colony under Egyptian administration (Curtin 1984, 78). All Greek trade in Egypt was by law required to pass through Naucratis from 570 B.C. This allowed Egyptian authorities to effectively regulate and tax the goods transported for a source of revenue, as a means of controlling prestige exchange (Lloyd 2002, 375). Similar restrictions were placed upon Phoenician traders, who formed the other dominant mercantile group, and were required to trade their goods through ports and settlements in the Eastern Delta (Curtin 1984, 78). The ability of the Egyptian authorities to control and tax these foreign merchants provided an extensive source of revenue for the Egyptian state, and Egypt welcomed merchants from

Greece and Phoenicia to settle in these communities. Herodotus' accounts detail the complicity of the Egyptian authorities in the settlement of the Greek merchants at Naucratis:

"Amasis (the last native ruler before the Persian invasion) favoured the Greeks and granted them privileges, the chief of which was the city of Naucratis as a commercial headquarters for any who wished to settle in the country" (de Sélincourt 2007, 151-152).

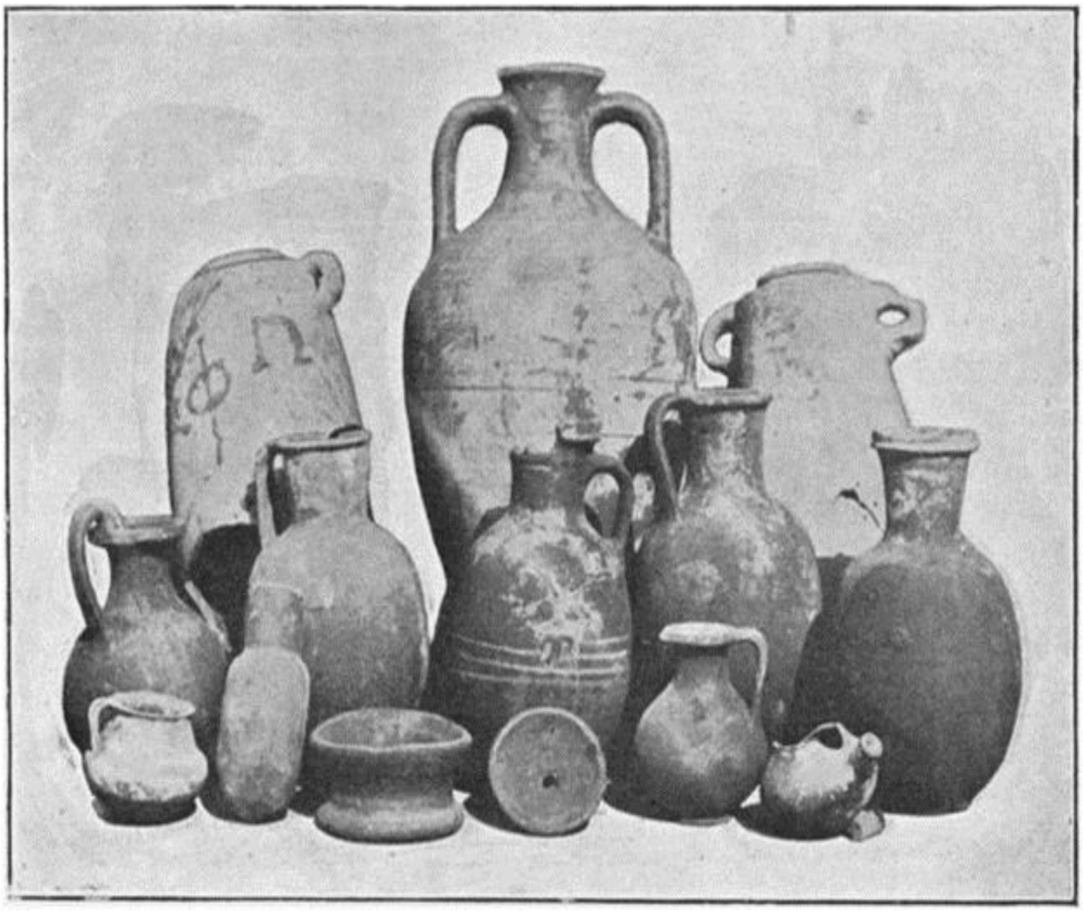

Fig. 4.0: Pottery excavated by at Naucratis Hogarth (1903), including imported Syro-Palestinian vessels (the two torpedo amphorae at the back) (Villing et al 2017, 6)

Greek trade via Naucratis is also visible within the archaeological record. Egyptian corn was traded to Macedonia, while statuettes and scarabs manufactured at Naucratis have been uncovered in Rhodes (Flinders-Petrie 1932, 166). The commercial relations with Greece are also evidently reciprocal, as Greek wine jars have been excavated at the site of Daphnai on the Tanitic branch of the Nile River (ibid). The influence of Phoenician and Greek trade began to wane towards the end of the 26th Dynasty. The conquest of Phoenician ports such as Tyre by successive Persian and Macedonian invasions moved the focal point of trade to the newly founded city of Alexandria, while Naucratis was gradually absorbed into Alexandrian Egypt as a fully-fledged Polis rather than as a vital conduit of Egyptian trade (Flinders-Petrie 1932, 163-164). The evidence from Naucratis and other Greek and Phoenician trading centres suggests the growing influence of foreign control in administering Egyptian trade (particularly Greek), and sets a precedent for the subsequent eight hundred years.

Greco-Roman Egypt:

Evidence for the import of goods from beyond Egypt's borders, and the growth of governmental systems to administer and tax such trade routes, becomes far more prominent with the absorption of Egypt into larger regional empires (see Fig. 5.0, 6.0). One of the most important factors in this is cultural homegenisation of large areas of the Near East. While this includes the Achamenid Persian Empire, such a trend is perhaps more visible in the Hellenic states created as a result of the conquests of Alexander the Great, including Ptolemaic Egypt. Linguistic and cultural similarities now existed in the successor states from Greece to India, with Greek becoming the language of trade in the East (Curtin 1984, 80). This facilitated direct trade over much larger distances, and both in Ptolemaic Egypt and in the succeeding Roman Period (ibid).

Fig. 5.0: Map of the extent of the Ptolemaic Kingdom and other Hellenic successor kingdoms (Spielvogel 2016, 95).

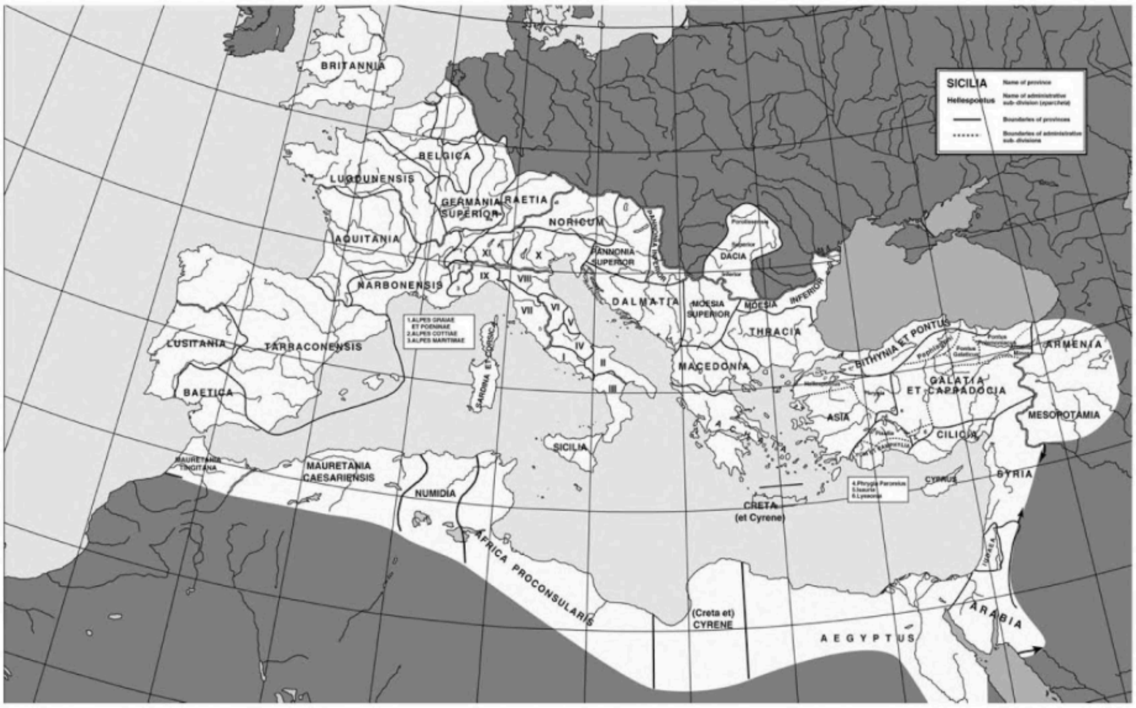

Fig. 6.0: Map of the extent of the Roman Empire at the death of Trajan (A.D. 117) (Potter 2008, xxxi).

The Levant and Mediterranean:

Perhaps the most obvious evidence for such a trend in the Levant can be identified through the archaeological evidence for a significant Greco-Roman expansion of harbors along the Levantine coast. Port cities such as Sidon and Tyre were founded by the Phoenicians, and facilitated much of the maritime trade from the Levant throughout Ancient Egyptian history. Archaeological evidence seems to suggest this trend continues, even following Hellenic and Roman conquest of the region. Marriner et al conducted lithographic and biostratigraphic sampling of sediment from the silt deposits at the ancient harbors at Tyre and Sidon (see Fig. 7.0).

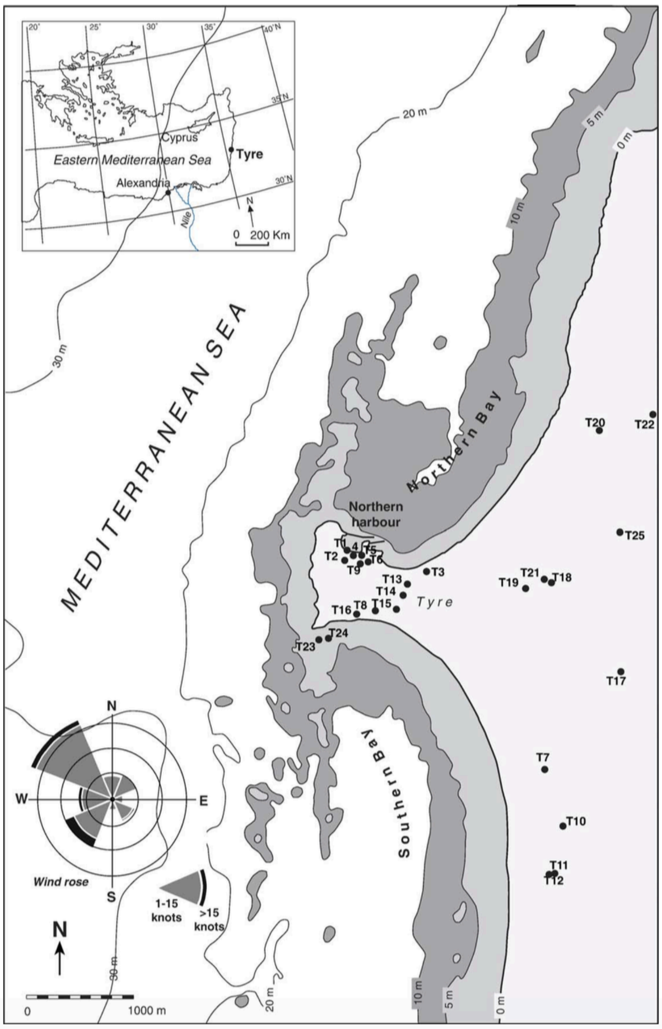

Fig. 7.0: Bathymetric map of the Levantine port of Tyre, including location in Eastern Mediterranean (Marriner

These analyses revealed both fine grained mud and sand deposits, as well as ostracod taxa that are typically associated with brackish and marine lagoonal environments (Marriner et al 2006, 1-4). Findings such as these suggest these harbours were low-energy marine environments, and therefore protected by sea defenses (ibid). This is more likely than not have occurred following the Roman occupation, given the advancements made by the Romans in regards to harbour wall engineering through the use of hydraulic concrete (Oleson et al 2004). Other similar sedimentary samples taken from these harbours also suggest a substantial degree of dredging of the shallow bottom (Marriner and Horhange 2005). Both studies cited suggest a far greater degree of maritime engineering of the Levantine ports at Tyre and Sidon in the Greco-Roman Period than in previous eras. These findings suggest the development of deep and well-sheltered harbours, which would have allowed the docking of large, deep-hulled trading vessels, and a greater docking capacity (Marriner et al 2006, 1-4). Such changes would have allowed goods to be imported and exported through these ports in far greater volumes, reducing costs. Reductions in the cost of imported goods from the Levant would increase the volume of trade of the goods from this region into Egypt. Given the majority of imported ingredients historically imported from the Levant into Egypt are biological in nature (oils, resins, wine, woods), these generally do not survive. This makes identifying the trade of these products from the Levant in the Greco-Roman Period difficult to identify archaeologically.

East Africa, Arabia and India:

Following their conquest of Egypt, the Ptolemy's sought to open up trade to the Red Sea and India by constructing extended road networks and guard posts through the Eastern Desert to extend land based trade to the region (Tomber 2012, 201-215). Ptolemy II also re-opened a canal system built by earlier Persian occupiers that connected shipping lanes in the Nile and Red Sea, and oversaw the construction of several ports in the Red Sea to facilitate trade with Africa, Arabia and India (ibid). Government involvement in trade is particularly evident regarding Africa. This is due to Ptolemaic military commanders wishing to use Red Sea trade routes as a source for procuring war elephants, as access to sources in India were removed by rival successor states such as the Seleucids (ibid). The Ptolemy's also oversaw the constriction of two deep-water ports in Alexandria, which had swiftly become the centre of trade throughout the Eastern Mediterranean (ibid). Such trade through Alexandria drove up the prices of rent (mostly through private ship owners and traders) and therefore, trade functioned as a significant source of income for the Ptolemaic state (ibid).

Most of the luxury goods obtained from Arabia and India arrived at the Red Sea ports and then moved overland along a series of fortified roads through the Eastern Desert (Young 2001, 47). These roads ended at the city of Coptos on the Nile River, from which Roman officials could store goods for taxation and regulation (ibid). This tax functioned as a toll, collected by the military in order to maintain the roads and military way stations to the Red Sea ports (Young 2001, 48). Coptos therefore played an important role in the trade of these goods, but as a link rather than an end location (as goods were not permitted to be sold in Coptos) (Young 2001, 51). Goods had to be transported from Coptos, along the river Nile, to Alexandria, where a 25% duty was required (ibid). Alexandria was an important centre of commerce in the Eastern Mediterranean, as it was the point from which goods traded through Egypt from the Red Sea would be further transported across the Roman Empire (Young 2001, 52). Alexandria also functioned as an important site of manufacture, utilising the exotic materials traded from Arabia and the Indian subcontinent to produce luxury products, from materials such as glass and silk (Young 2001, 53). Pliny, for example, described the process by which Alexandrian craftsmen would rework Arabian incense for resale to wealthy citizens in both Rome and its external territories (Young 2001, 53). Trade was conducted mostly by the Greek-speaking residents of Egypt (particularly Alexandria), most likely acting as a continuation of the trade routes first administered during the Ptolemaic Dynasty (Young 2001, 54). As with the Ptolemaic period, Roman officials heavily taxed the trade of luxury goods through officials in both Alexandria and Coptos (Young 2001, 69). These taxes were used to maintain a military presence on the roads from the Red Sea ports, both in order to supervise the collection of tariffs and to protect from the problems of banditry (Young 2001, 72-73).

The Antonine Period saw an increased volume of trade from the ports of the Red Sea, due to the construction of a canal system (built during the rule of emperor Trajan) connecting the Red Sea and Nile River. The construction of the Trajan Canal now made the trade of bulk goods such as grain and textiles between Egypt and India cost effective (Young 2001, 75-77). However, the land-based routes and caravans remained active in the transport of higher value, lower bulk goods to Coptos, which more easily absorbed the increased costs of overland trade (ibid). Additionally, we see the construction of a major road system (the Via Hadriana) during the Antonine Period, as effective road networks through the Eastern Desert maximised the tax income available to the Roman administration through commerce (Young 2011, 78-79).

The later 3rd Century A.D. saw the decline in trade via the Red Sea, evident by an increasing lack of finds in the Red Sea ports during this period, and a decrease in the volumes of Roman coins found in India (Young 2011, 82-83). This is probably a result of the civil wars that blighted this period, which triggered rampant inflation and a loss of confidence in Roman currency (ibid). The invasion and rebellion of various tribal groups also disrupted the overland routes through the Eastern Desert (Young 2001, 85). However, we do see a recovery in these trade systems in the Late Roman Empire, under the peace and order of Diocletian and Constantine (Young 2001, 86). This period also saw a surge in the use of the Trajan Canal following the destruction of Coptos, due to a series of rebellions and invasions (ibid). However, competition for these trade routes now existed from Axamite and Persian merchants, who had established themselves during the chaos of the 3rd century A.D (evident through greater proportions of Axamite and Persian coins) (Young 2001, 87). This period saw the end of the classical commercial systems, which gave way to Byzantine, and eventually Arab trade routes and practices in Egypt (Young 2001, 88).

Trade in Ancient Egypt: Free Market vs. Political Economy?

How important are independent merchants in relation to the administrative elite?

What we can potentially see from Egyptian trade in Dynastic Egypt is a willingness on the part of the Egyptian ruling elite, and by extension the military, to reinforce and protect these trade links through invasions and expeditions. Hatshepsut's expedition was commissioned in order to reopen trade routes disrupted by the Hyksos occupation of Egypt (Bryan 2002, 239). Such an occurrence is not uncommon, as evidence for long-distance trade in Egypt declines in times of political or economic uncertainty, such as in the 19th Dynasty when Egypt and the Hittites warred over control of important trade routes in Syria (Van Dijik 2002, 298). Whether through military intervention or bureaucratic administration, long-distance trade was under significant control and influence from the established elites in Egyptian society. Therefore, it must be noted that any exotic goods associated with the process of animal mummification are likely to have been administered directly by those in positions of wealth and influence in Egyptian society. It is important to note however, that imports from Nubia and Punt were probably still dominated by independent merchants, as evidenced by the inscription identified from the sarcophagus of an Arab trader who died in Memphis (Simpson 2002, 91).

Evidence from Greco-Roman Egypt is important in illustrating the role played by large empires in facilitating long-distance trade. Alexander's conquests created a cultural homogeny that encouraged economic relationships over far larger distances. Trade between the successor kingdoms in Eurasia (including Ptolemaic Egypt) appears to have become more direct, and geopolitical barriers to trade, less obstructive. This became even more apparent with the Roman Empire, where goods could travel from India to Rome while being administered and taxed by the same political entity. The role of Egypt as a conduit of goods from the east was a vital part of the Roman economy, and ensured the development of engineering projects such as the guarded roads and canals connecting the Nile and Eastern Desert. Greco-Roman trade also highlights the importance of state control of trade and exchange. The control of ports and taxation systems allowed the Ptolemaic and Roman governments to use the demand for exotic goods to fuel the local economy, and to maintain imperial authority in the region.

What can this infer about systems and control in the Egyptian import of economy?

An analysis of the Ancient Egyptian import economy shows clearly the importance of the ruling elite in the controlling and financing the supply of goods from abroad. While independent merchants appear to be the physical carriers of goods, it is the ruling elite that provides the resources, bureaucracy and political authority to acquire these goods. This is important to note when considering the use of goods imported into Egypt. It suggests in effect that the arrival of these goods is the direct result of the influence of the ruling aristocracy. This group in most cases provides both the demand for these high value imported goods, and the complex system of control points and taxation that allow this group to benefit economically from this economic interaction. Such an understanding of how high value exotic goods arrive into Egypt will allow us to interpret any imported materials used in animal mummification, within the context of wider Egyptian trade economy. This in turn can allow us to infer the role of the ruling elite in the supply of goods utilized in the process of embalming in the Egyptian animal cults. This is particularly relevant when considering embalming agents for animal mummies, given the assumed authority of the religious elite in politics throughout both dynastic and later period Ancient Egypt.

Chapter 3: Mummification of Animals in Ancient Egypt

In order to understand the relationship that existed between the mummification of animals and long-distance trade, we must consider the socio-economic environment in which these embalmed remains were produced and deposited. This involves the cultural, economic and social role played by differing animal species throughout Ancient Egyptian society. From archaeological and textual evidence, we can see that animals were a vital part of economic and social life in Egypt. It can be argued therefore that mummified remains of animals may be used as a form of archaeological evidence, in which we can interpret the role of different species in Egyptian economic, social and religious life. It is therefore important to consider the origin o6f animal cult worship and the social progression of animal deification in understanding the complex relationship between nature, culture and economy. This can in turn be used to assess the how the ruling elite, trade and religious practice are connected in Ancient Egyptian society.

Human-Animal Relationships in Ancient Egypt

An important aspect of understanding the mummification of animals in Ancient Egypt, is to consider is the development of Egypt's naturalist cosmology. The fertile lands of the Nile Valley (Upper Egypt) and Delta (Lower Egypt) were seen to be the centre of the world in the Egyptian cosmology (Meeks and Favard-Meeks 1996, 82-91). Outside of them are infertile deserts, associated with a chaos that lies beyond the world (ibid). This environment provided an obvious influence on cosmology and mythology in Ancient Egypt. Egyptians saw water and sun as symbols of life, and thought of time as a series of natural cycles (Tobin 1989, 10-199). The Nile floods, and the agricultural fertility associated with these, dictated this belief system (ibid). Given the arid and barren deserts that surrounded the Nile, Egyptians saw their land as an isolated place of stability surrounded by danger and chaos (Tobin 1989, 10-11).

Fig.8.0: Predynastic artistic depictions of native Egyptian animals (Yeakel et al 2014, 14473)

Fig.9.0: Paleolithic rock-art depicting bovines with stylised human figures at Qurta 1, Panel 1 (Huyge 2009, 110)

It can be argued that such a dependence on the environment, both ritually and economically, helps to explain the perceptions of animals in Ancient Egyptian society. Humans intrinsically linked the species in close proximity to population centres along the Nile to the mythology of Egypt. Their behaviour, environment and use by people can all be seen to feed into these attributes, being assigned to different gods and goddesses in the Egyptian pantheon. It is important therefore to attempt to eliminate what has been referred to as the 'artificial dichotomy' between humans and the natural world. This concept postulates that in many human cultures, there would have been no attempt to disenfranchise humans from the rest of the natural world, and animals and humans would have been viewed as part of the same cosmological system (Bezerra de Melo 2012). While such studies typically consider non-western indigenous peoples, there is much merit in considering how such a research technique should be applied in studying the human-animal interaction in Ancient Egypt. While Dynastic Period Egypt was an economically advanced and urbanised nation state, the complexity of the Egyptian relationship with nature, and the totemic interaction with animal species, suggests a culture to which nature and humanity are not mutually exclusive. Therefore, it is important when studying the human-animal interaction in Ancient Egypt to consider the complexity of the relationship, without imposing the restrictions associated with the modern perceptions on how humans would have perceived and interacted with the wider Egyptian ecosystem.

Role of Animals in the Development of Religious Belief

When attempting to study the relationship that existed between human-animal interaction and ritual practice in Ancient Egypt, one must consider the origins. The recognition of an intimate relationship between certain deities and distinctly identified animals may be a concept far older than the Ancient Egyptian state (Aufderheide 2003, 396). Evidence for the totemic worship of local animal species comes as early as 7,000-19,000 years ago with the discovery of pre-Holocene petroglyphs at el-Hosh and Qurta (see Fig. 9.0). These depict naturalistic representations of numerous bovines (75%) as well as birds, fish, crocodiles, gazelles, hippopotami and hartebeest (Huyge et al 2011, 1184-1193). These are within close proximity to a number of late Paleolithic settlements, suggesting the association of the petroglyphs with these communities (Huyge 2009, 109-120). Particularly in the case of the el-Hosh fish traps, these petroglyphs are suggested to represent a ritual means of increasing the effectiveness of fishing gear, while the remainder are possibly a form of topographic maps of the local wadi systems (ibid). While artistically dissimilar to Predynastic artistic depictions of animals (see Fig. 8.0), they can potentially be argued to represent the first evidence for Egyptian deification of animals as part of a naturalistic cosmology. Early ceramic designs employing animals during the Naqada II Period (3500-3150 B.C.) can be interpreted as an effort to display themselves as deity symbols (David 1982, 24-26). D'Auria et al however, suggest the possibility that Predynastic animal images may have served as regional totems, becoming attached to deities at the onset of the Dynastic Period (D'Auria et al 1988, 230). In this regard we have to be cautious when discussing the connection between animals and deities in Ancient Egypt, as while animals are clearly special creatures with a connection to the gods, to suggest the animals are deified directly is problematic (Ikram 2005, 6). In either case, it is in these early periods therefore, that we must focus our efforts to understand such relationships (Aufderheide 2003, 396).

Animal symbols may have been interpreted as images that reflect a population's social stratification (ibid). The selection of such animal symbols may have been motivated by the need for a form sufficiently flexible to respond to social changes over time (Levy 1995, 9-19). Egyptians were comfortable with the practice of assigning a given animal symbol, to different gods, which had different functions at different times (Aufderheide 2003, 396). A prominent principle of modern behavioural science is that the fear of death underlies much of human behaviour. Ancient humans encountering natural phenomena beyond their understanding, can be expected to have been assigned the cause of such events to act~~s~~ by one or more supernatural forces (deities) (Hamilton-Paterson and Andrews 1979, 13). Since early humans were hunters, their dependence upon the availability of animals would have been self-evident (Aufderheide 2003, 396). Fluctuations in ready accessibility to animals were a frequent threat to life (ibid). As the causes of varying hunting successes were not always obvious, we can expect such hunters to assume that the barren periods were acts of these supernatural forces (ibid). The act of appeasing such deities would appear to be the only avenue available to unsuccessful hunters for influencing the gods to act in their favour (Howey 1972, 148). Such perceptions are commonly believed to be responsible for the deity-appeasing taboos among early societies, and for sacrifices practiced by more structured populations (Aufderhiede 2003, 396).

Despite the fact that some groups may have idolised the animal itself, the term 'animal worship', often applied to any relationship between humans and animals involving supernatural concepts, is in many cases a misnomer (Ghandi 1954, 4). To understand Egyptian animal mummification, it is essential to be aware of the precise nature of such a relationship (Aufderheide 2003, 396). At most, the deity may be transiently occupying the animal's body to manifest itself (an incarnation) to direct the animal's behavior (ibid). Since certain animals are vital to a hunter's survival, specific deities become associated with specific animals (ibid). These beliefs are likely to have persisted into Dynastic Egypt, even with the shift to a bureaucratically administered agricultural economy. Ritual perspectives were strongly connected to the interactions Egyptians had with animals, wild species that inhabited the Nile Valley and Delta, and domesticated species such as pastoral animals and pets.

Animal Mummification

From the complex naturalistic cosmology of Ancient Egyptian society, we see a trend towards the deification of the natural world in religious belief. In such a cosmology, the mummification of animals can be seen as a means by which Egyptians relate the natural world they depended on for survival, into everyday religious practice. This anthropogenic preservation of numerous animal species varies widely between different chronologies and geographic localities in Egypt. Therefore, it is important to consider the wider trends in animal mummification and cult worship, before attempting to understand the potential correlation between this practice and long-distance exchange in Egyptian society.

The Mechanics of Mummification

Mummification is defined by Aufderhiede as the physically preserved corpse or tissue that resembles its living morphology, but resists further decay for a prolonged post-mortem interval (Aufderheide 2007, 41). This principally involves the transformation of living tissue into a state of arrested decay (ibid). Mummification can typically be considered to be either spontaneous; the result of natural conditions, or anthropogenic; the result of human activity and intervention (ibid). The latter predominantly involves the use of use of materials and methods to limit the post-mortem enzymatic in living tissue (Aufderheide 2007, 43). These chemical reactions are those that break down the large protein, fat and carbohydrate molecules in the cellular structure of the body (Aufderheide 2007, 41). This process (Autolysis), initiated by intracellular enzymes (lysosomes), begins almost immediately after the death of the organism (ibid). Further enzyme action is introduced with the arrival of bacteria; either from internal sources (oral and fecal) or from the environment, generating molecules these bacteria can absorb for nutrients (Aufderheide 2007, 42). This enzymatic tissue liquefaction will be accompanied by the arrival of tissue consuming scavengers such as maggots and beetles, resulting to the ultimate decay of the organism (ibid).

An important factor in understanding the methodology of mummification understands the factors that influence enzymatic decay. The most relevant of these to the study of anthropogenic mummification in Ancient Egypt is the water. Most enzymes operate in a watery environment, so the removal of water can often retard tissue decay (Aufderheide 2007, 43). Enzyme action is also inhibited at lower temperatures, departure from the optimum pH and the denaturing of enzyme molecular structure through the use of alcohol and formaldehyde (ibid). Furthermore, we can see the use embalming agents designed to limit the decay caused by external sources such as bacterium, fungi and insects. Anthropogenic mummification is seen to limit these factors through three key processes:

Desiccation:

Desiccation involves the removal of water from deceased tissue in order to limit enzymatic decay and lessen microbial buildup (Aufderheide 2007, 44-45). Either use of the natural aridity of the Egyptian ecosystem or through desiccating agents such as natron, a naturally occurring mixture of salts, predominantly sodium carbonate (Ikram 2005, 20-21).

Evisceration:

The removal of the internal organs to remove sources of water and bacteria that could produce ideal conditions for enzymatic tissue decay (Ikram 2005, 18-19).

Embalming:

Application of hydrophobic and/or antiseptic resinous agent to internal cavities and external tissue/wrappings in order to inhibit enzymatic and bacterial decay of soft tissue (Ikram 2005, 20-21).

It is the latter of these processes that is most pertinent to this thesis, as the use of imported ingredients is most typically associated as being used in these embalming agents.

Origins in Neolithic and Predynastic Egypt

Mummification, in both humans and animals, is traditionally believed to have been discovered as an accidental process. Mummification occurred with spontaneous desiccation, due to the arid climate that dominated Egypt. True mummification using preservative agents is not considered to have appeared until the Old Kingdom, in around 2500 B.C. (Aufderheide 2007, 43). However, recent research from Jones et al has potentially pushed this date back by at least 1500 years, using gas chromatography-mass spectrometry (GC-MS) and thermal desorption/pyrolysis (TD/Py)(Jones et al 2014, 12). AMS-dated remains from Badarian (Late Neolithic) and Predynastic pit graves from Mostagedda (4500 BC-3350 BC) were found to have contained pine resin, aromatic plant extracts, plant gum, natural petroleum, plant oils and animal fats (Jones et al 2014, 1-12). These embalming agents comprised of complex recipes of the same ingredients (in similar proportions) to those used at the peak of Pharaonic mummification 3,000 years later (ibid). Given the antibacterial properties and localised soft tissue preservation, Jones et al concluded that these finds could represent early experimentation that may have evolved into the mummification practice associated with Dynastic Egypt (ibid). While these samples are human remains, they help to suggest the origins of the embalming practices that would come to be used in mummifying animals at a later point in Egyptian history.

The earliest evidence for ritualised animal burials is dated to the Predynastic Period, in cemeteries such as those at Hierakonpolis (5,700 BC). Here prestigious artifacts such as pottery, carved ivory and gold, silver, turquoise and garnet jewelry have been found in close proximity to human, dog and elephant remains (Adams 1998, 46-50). Such burials are found across a number of species and sites, including cattle burials at Nabta Playa (Wendorf and Schild 1998, 97-123). Although these remains show no soft tissue preservation, this ritualised process of animal remains associated with human burials and artifacts mirror those seen in dynastic tombs and funerary complexes, although on a much smaller scale. Therefore, these burials can be seen to reflect some of the earliest instances of ritualised attitudes towards faunal remains in Egypt, and could possibly reflect a point of origin for the animal cults and associated animal mummification.

Chronology of Animal Mummification

As previously discussed, anthropogenic animal mummification is likely to have originated in much the same way as that of humans, with arid natural conditions being utilised as a means of preserving biological material (Aufderheide 2005, 220). Ritual animal burials have been uncovered as early as 5,700 years ago, with the discovery of three animal graves containing baboon, cattle, dog and elephant remains in association with 11 Predynastic tombs of high status individuals (Adams 1998, 46-50), In addition, linen-wrapped animal bodies were included in Upper Egyptian tombs as early as the Badarian Predynastic Period (5500-4000 B.C.) (Aufderheide 2005, 396). However, the general consensus in academia is that the prominent period in which animal mummification occurs comes much later, from around 800 B.C. –A.D. 400 (Ikram 2005, 7). However we must be cautious when determining an end point to the practice, as paganism and pagan religious practice in the Roman Empire declined throughout the 3rd and 4th centuries A.D with the spread of Christianity (Aufderheide 2005, 404).

Such a phase of Egyptian history is defined by a consistent period of foreign influence and invasion. It is this continuous foreign intervention that has been suggested to directly cause the proliferation and expansion of the animal cults, and subsequently, an expansion in mummification. In *"Divine Creatures"* Ikram suggests that this growth in animal mummification can be attributed to either of two factors. The first of these is potentially the use of animal cult worship and mummification as a means of reasserting native Egyptian religious and cultural traditions in the face of occupation by a series of foreign cultural groups (Ikram 2005, 7). Alternatively, such a progression could be attributed to the participation of these incoming cultural groups into Egyptian religious practice (Ikram 2005, 8). Ptolemy Soter is well attested for attempting to integrate the new Hellenic leadership into Egyptian religious practice, as a political tool with which to control the native population (Wellendorf 2008, 34-38). Whether a result of cultural independence or foreign interest (or an amalgamation of the two), it is important to consider the growth of the animal cults in relation to the events that dominated Egyptian socio-economic progression in this latter stage of Ancient Egyptian history. In doing so, we can provide context in which we can consider the mummified specimens provided by Buckley & Tunney and Buckley & Fletcher, that form the focus of this thesis.

Differing forms of Animal Mummification

An important consideration when attempting to understand the potential relationship between the mummification of animals and long-distance trade is the role of mummified remains in Egyptian society. In order to assess the potential factors that could cause these two seemingly disparate practices to interlink, we must consider the context of the religious and social factors that influence the desire to embalm animal remains, and how these remains are presented in the archaeological record. Typically, we can divide those animal remains found embalmed and preserved in Egyptian archaeological contexts into four distinct typologies:

Pets:

Mummified animals interpreted as being pets or companion animals have occasionally been found in close proximity to the remains of what are assumed to be their owners (Ikram 2005, 2). These creatures are suggested to have been embalmed shortly after the death of their masters, with the aim of carrying these pets along with them into the next life (ibid). Examples of such practice appear as early as the Naqada II period, as seen with the attempts at ritual burial of elephant remains at Abydos (Freidman 2004, 131-165). Such a practice however appears to vary substantially. Mummified burials at Hierakonpolis are possibly either pets, or part of an exotic animal collection designed to indicate the wealth and status of the local elite (ibid). On the other hand, the discovery of a man named Hapymin from the early Ptolemaic Period interred with a mummified pet dog curled around his feet, suggests a much closer personal bond between the individual and the animal (Petrie 1902, 39-40).

As well as being identified contextually, mummified pets can potentially be identified from embalmed remains themselves. Mummified baboons found at KV50 and KV51 (Valley of the Kings) had their canine teeth removed (Ikram and Iskander 2002). This indicates their use as pets, as t,he removal of these teeth would limit the risk of the baboons biting, and is not generally present in other mummified baboon remains (ibid). While finding of the mummification of pets is a fascinating insight into human-animal interaction in Egyptian society, suggesting any potential religious element to the keeping and embalming of these pets is difficult to consider from the mummified remains alone (Ikram 2005, 4).

Food and Victual Mummies:

The term 'Victual Mummies' refers to the mummification of food items ready for human consumption (Ikram 2005, 4). This is widely considered to have been done in order to provide the tomb-owner and interred soul with food to bring into the afterlife, so that they could feast for eternity (ibid). Food items have been discovered embalmed, and wrapped from species including pigeons, cattle, geese, ducks and sheep (ibid). This included cuts of meat from the flanks, ribs and entire legs (ibid) (see Fig. 10.0). The greatest proportion of victual mummies has been uncovered from the New Kingdom (1550-1070 BC) cemeteries in the Thebes region, although evidence for the practice can be identified as far back as the Old Kingdom (Ikram 2005, 5).

Sacred or Cult Animals:

Sacred or cult animals are chosen for mummification on account of a set of specific physical characteristics. These characteristics are agreed to represent either the physical presence of a god in that animal, and thus worshiped as an incarnation of said god (ibid), or as a link to the divine apotheosis of the Egyptian kings (ibid). These animals were then buried with great pomp and ceremony at the point at which they die of natural causes (Ikram 2005, 11). The spirit of the god is then considered to enter the body of a similarly comparable living animal, mirroring the beliefs surrounding the Dalai Lama in Tibetan Buddhism (Ray 2002, 19). By far the most famous example of this practice is the Apis bull (see Fig 11.0), which was seen as the incarnation of the creator god Ptah (Dodson 2005, 72). Evidence for this practice comes both from mummified remains within the Serapeum at North Saqqara, and contemporaneous accounts such as those of Diodorus Siculus:

"Whenever one has died and has been buried in splendor, the priests who are charged with this duty seeks out a young bull which has on its body markings similar to those of its predecessor. When it has been found the people cease their mourning and the priests who have care of it first take the young bull to Nilopolis, where it is kept for forty days, and then, putting it on a state barge filled with a gilded stall, conducted it as a god at the sanctuary of Hephaestus at Memphis" (Diodorus 1721, 44).

These animals were held in such high regard that political leadership appeared to be influenced by the practice, even amongst foreign rulers. Accounts from Herodotus suggest that Persian Emperor Cambyses II caused great outcry after killing the Apis bull (Depuydt 1995, 119-126), indicating the importance these animals held to the Egyptian people. Cattle cult worship extends beyond the individual Apis bulls. We also see the mummification of the cows that mothered the Apis Bull (referred to as the Mother of Apis), with these remains interred at a separate nearby tomb structure in North Saqqara (Dodson 2005, 89). Such practice can be seen as a development of the importance of cattle in society from Egyptian prehistory (see Chapter 3). However, it is important to note that the practice of mummifying scared or cult animals is not only limited to cattle. Prominent examples of this include Soknebtunis, who was mummified as a representation of the crocodilian deity Sobek at Tebtunis (Bresciani 2005, 202), while the Ram of Elephantine was associated directly with the god Khnum (Ikram 2005, 5).

Votive Mummies:

Of the mummified remains uncovered in the archaeological record, those classed as votive offerings are by far the most numerous (Ikram 2005, 10). It has been suggested that tens of millions of mummified animal remains can be attributed directly to this practice (ibid). A votive mummy is typically identified as an

offering consisting of a specific mummy, dedicated to a corresponding deity, so a donor's prayers could be answered in eternity (Ikram 2005, 9). These are suggested to have functioned similarly to votive candles in Christian churches (ibid). Such mummified remains differ from sacred or cult animal mummies in that these remains are not unique, and rather than being considered to embody different gods, they acted as emissaries to the gods (Martin 1981, 9). These would then be purchased and offered by pilgrims at shrines dedicated to relevant gods (ibid). Votive mummies would be prepared in special embalming houses (*Wabets*), and after purchase, presented to the god by priests and kept in storage (Ikram 2005, 10). Once a year, during a special festival, the mummified animals would be taken in procession and buried en-masse in extensive catacombs that would be sealed with mud bricks until the next celebration (ibid). Excavated mummified remains seem to exhibit different grades or qualities, suggested to be dependent on how much a pilgrim wished to spend (ibid). It is therefore assumed that more lavishly wrapped remains with cartonnage masks are more expensive, while those more simply prepared are cheaper (Ikram 2005, 10-11).
Votive mummies also appear to be utilised alongside more traditional forms of offerings, including images of the gods in question (Ikram 2005, 11). It has been suggested that these may have had a different value to mummified remains (both spiritual and monetary), and have been utilised in different circumstances (ibid). Often these consist of images of the animal in question, made of materials such as wood, metals (such as bronze) and stone (ibid). Such a production for sale to pilgrims has been supported by evidence for the captive breeding of animals, for the purpose of mummification across multiple species (Ikram 2005, 12). Workers in the animal necropolises have been suggested as responsible for the feeding, cleaning and veterinary care of these animals, as well as the embalming process (Ikram 2005, 14).

Unlike pets and sacred or cult animals however, votive mummies were not for the most part allowed the luxury of a natural death (Ikram 2005, 13). Many have evidence of being deliberately killed, with many cat mummies being killed between the ages of nine and twelve months (Armitage and Clutton-Brock 1981, 185-196). Radiographs of a portion of these remains reveal broken necks, while others have evidence for their skulls being crushed with some form of blunt instrument (ibid). Furthermore, some canid mummies show signs of strangulation, while other animals such as ibis' and raptors may have been dispatched by being dipped into vats of melted embalming agent (Nicholson 2005, 50) (see Fig. 12.0). It has been suggested that this killing of young animals is done to reduce the cost of votive mummies, and aid the hasty mass preparation in order to satisfy the vast demand (McKnight 2010). Further evidence for this attempt to reduce costs is the presence of what are known as pseudo-mummies. Unwrapping and radiographs of mummified animal remains reveal some that are empty, or filled with small amounts of animal materials from multiple creatures (ibid). These have been interpreted as potential fakes, designed to deceive pilgrims (Ikram 2005, 14). However, it is important to consider whether such a process is simply related to economic gain, or possibly that some part of the animal or a similar species (or a similar appearance) may be enough to constitute an appropriate offering (ibid).

Given the general consensus that votive mummies constitute the vast majority of mummified animal remains in the archaeological record (Ikram 2005, 11), for the purposes of thesis it will be assumed that the remains in the data provided by Buckley & Tunney and Buckley & Fletcher fall into this category. With that in consideration, we can study the mummified animals subjected to GC-MS with this context in mind, and potentially identify the use of imported ingredients as part of this process of the mass production of votive mummies.

Fig.10.0: Mummified beef rib from the tomb of Egyptian noblewoman Tjuiu (18th Dynasty) c.1386-1349 B.C. (Clark et al 2013, 20392-20395).

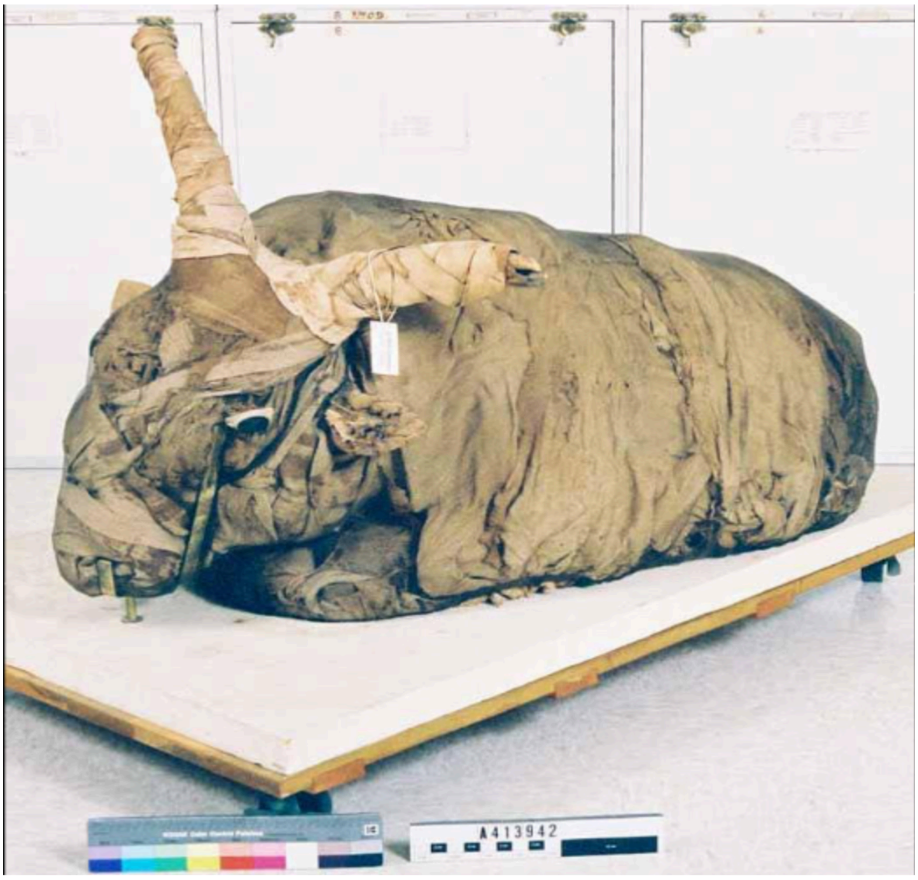

Fig.11.0: Mummified bull associated, with the Apis Cult (Smithsonian National Museum of Natural History 2017).

Fig. 12.0: Example of a votive mummy (bird of prey) (Cornelius et al 2012, 129-148).

Species of Animals Mummified

Of the around 70 million mummified animals uncovered from across Egyptian archaeological contexts, many different species across numerous taxonomic classes can be identified. Suggesting broad trends in terms of the distribution between different taxonomic groups is difficult due to the massive volumes of remains either destroyed, or removed to European and North American collections as a result of grave robbery and antiquarian archaeological investigations. It has been widely recorded that towards the end of the 19th century, around 180,000 (around 19 tonnes) of mummified cats were exported to Britain to be destroyed and used as fertiliser (Malek 1993, 129). Such a practice appears to be relatively common across Europe, so much so that they were used as ballast on ships (ibid). From the Animal Mummy Database, an online resource collating information on mummified animals within museum collections worldwide, 1137 specimens have been recorded. Of these, 74% are attributed to just four groups: cats (23%), ibis (23%), birds of prey (17%) and crocodilians (11%) (Animal Mummy Database 2017). While it is difficult to ascertain whether this sample is representative of the wider trends, it does appear to mirror the academic consensus of most common species mummified as votive offerings (Ikram 2005, 1-13). What is clear is that Egyptians mummify a wide variety of species, as offerings to specific deities, or in some cases multiple gods and goddesses. For the purpose of this thesis it is important to consider the groups of animals that appear to be mummified as votive offerings most regularly:

Birds:

Birds of Prey: Defining the precise species in this group is difficult to do with mummified remains, and it appears that the Ancient Egyptians only identified these hawks and falcons as a single species. Mummified evidence for this group of birds is prevalent (often found in the millions), and typically associated with the god Horus (Aufderheide 2010, 403). Recent investigations have suggested that these birds were intensively bred for the purpose of mummification, supported by the 3D imaging of kestrel remains, which revealed the force-feeding of this specimen with mice prior to embalming (Ikram et al 2015, 72-77).

Ibis*:* While now extinct in Egypt due to increasing aridity, *T. aethiopicus* (African Sacred Ibis) once was the predominant species of wetland birds along the banks of the Nile River (Del Hoyo et al 2014). Associated with the god of knowledge and logic Thoth, mummified Ibis remains have been found in huge numbers at sites such as Saqqara (1.75 million) and Tuna-al-Gebel (4 million) (Aufderheide 2010, 399-400). Such numbers are supported by evidence for at least a degree of captive breeding of this species by Egyptian priests, with the objective of killing and mummifying for votive offering production (Nicholson 2005, 51).

Mammals:

Cats: The domestic cat (*Felis catus*) is an important species in Egyptian society, with evidence from kitten remains at Heirakonpolis (inferred to be the ancestral species *F.silvestris*) suggesting the domestication of cats from as early as 3800-3600 BC (Van Neer et al 2014, 103-111). These animals played an important role in eradicating vermin, as well as being household pets (Aufderheide 2010, 401).

Such close interaction with Egyptian communities led to the association of *F.catus* with the goddess Bastest, who embodied protection, love, family and music (Scott 1958, 1-7). Consequently, we see the mummification of cats on a large scale, with evidence for the captive breeding of cats for mummification at the city of Bubastis described by Herodotus:

'Cats which have died are taken to Bubastis where they are embalmed and buried in sacred receptacles' (de Sélincourt 2007, 109-108).

Dogs: In the archaeological record for ancient Egypt, we can identify the mummified remains of numerous canine species. While identifying individual sub-species is difficult, these have been inferred as belonging to either domesticated dogs (*Canis* familiaris) or the Asiatic Jackal (*Canis aureus*) (Jhala and Moehlman 2008). Both domesticated dogs and jackals are associated with Anubis, the god of mummification and the afterlife (Kitigawa 2013, 344-354). While found from sites across Egypt, mummified dogs are most commonly associated with the city of Asyut, the ancient capital of the 13th nome of Egypt (ibid).

Mongoose: Contemporary accounts from Herodotus suggest the mummification of the Egyptian Mongoose (*Herpestes Ichneumon*) in much the same way as cats and dogs (De Selincourt 2007, 109). Egyptian mythology tells of the sun god Ra morphing into a giant mongoose to fight and kill the evil snake god Apopis (Detry et al 2011, 3519). This mirrors the natural behaviour and diet of this species, which preys regularly on, and has developed a resistance to the venom of, the Desert Cobra (*Walterinnesia aegyptia*) (Ovadia and Kochva 1977, 541-547). Such interactions between mongooses and snakes are well attested in contemporary sources, such as the writings of Pliny (Detry et al 2011, 3519). This species is also known to have been kept as a pet (Detry et al 2011, ibid). Numerous mummified remains of this species have been discovered from sites across Egypt (Aufderheide 2010, 403).

Baboons: An examination of the archaeological and artistic record from Ancient Egypt shows frequent evidence for the presence of baboons, most often suggested to be either Yellow Baboons (*Paopio* c*ynocephalus*) or Hamadryas Baboons (*Papio hamdryas*). This is based on modern geographic distributions and artistic depictions. In itself, this is interesting, as both the Yellow Baboon and Hamdryas Baboon are the only species recorded that is not native to Egypt (Gippoliti and Ehardt 2008) (Kingdon et al 2008). Several Egyptian texts and carvings allude to the importation of baboons amongst other exotic goods from Punt, such as in the depictions of Hatshepsut's mission to the region at Deir el Bahari. This is supported by recent oxygen isotope analyses on two mummified baboon remains from the British Museum, that indicated these specimens were most probably born in what is now Eritrea and Eastern Ethiopia, an area suggested by scholars to be the location of Punt (Dominy et al 2015, 122-123). The ritual importance of this species comes from its association with the god of wisdom and intelligence Thoth, likely due to the intelligence of these animals (Aufderheide 2010, 400). Evidence also appears to exist for the captive breeding of baboons, as well as the keeping of these species as exotic pets (Goudsmit and Brandon-Jones 2000, 116).

Shrews: Another common form of mummified remain is the embalmed bodies of small rodent species, often identified as shrew remains. Determining the precise sub-species is difficult without any provided context, however, a likely option is the Egyptian Pygmy Shrew (*Crocidura religiosa*). The Egyptian Pygmy Shrew is an endemic species to Egypt that habits arable land, although mummified remains have been discovered from 6 separate shrew species (Barrat 2016). *C.religiosa* gained its name from the French zoologist Geoffroy St Hilaire in 1826, who described the species based on mummified remains from Thebes (ibid). Along with the ichneumon mongoose, shrews were seen as the representation of the nocturnal aspect of the god Horus (Aufderheide 2010, 405).

Reptiles:

Crocodilians: While only isolated Nile Crocodile (*Crocodylus niloticus*) populations survive in Lake Nasser in the far south of the country in the present day, it has been suggested that two sub-species would have inhabited the Nile River during Ancient Egyptian history. Of these, the Nile Crocodile is the best known, and traditionally the species associated with the mummified remains of crocodilians. However, recent genetic analyses have indicated that at least some of the mummified remains of crocodilians can be attributed to the species identified as the Sacred Crocodile (*Crocoddylus suchus*). Now only found in West Africa, this species is morphologically similar to the Nile Crocodile, but remarkable for its lack of aggression in comparison to the latter species (Hekkala 2011, 4199-4215). It has been suggested by sources such as Herodotus, that some crocodiles were selectively chosen for mummification, captured, and placed in captivity:

'Some Egyptians reverence the crocodile as a sacred beast; others do not, and treat it as an enemy. The strongest belief in its sanctity is to be found in Thebes and round about Lake Moeris; in these places they keep one particular crocodile, which they tame, putting rings made of glass or gold into its ears and bracelets around its front feet, giving it special food and ceremonial offerings. In fact while these creatures are alive they treat them with every kindness, and, when they die, embalm them and bury them and bury them in sacred tombs.' (de Sélincourt 2007, 110-111).

It is therefore possible such writings are referring to Sacred Crocodile specimens, and that this species is identified separately from Nile Crocodile populations in spite of a similar morphology.

Crocodilians of both species were mummified for votive offerings to the god of war and fertility Sobek, who was typically shown to embody the traits of crocodilians (Bresciani 2005, 199-205). Remains of mummified crocodiles have been found across Egypt, but particularly at sites in the Fayum depression where the extensive wetlands form a particularly ideal habitat for these creatures (ibid). Evidence also exists for the captive breeding of these species for the purposes of mummification, with both preserved eggs and breeding pools uncovered from the site of Medinet Madi in the Fayum (Bresciani 2005, 204-205).

Fish:

Fish*:* While specifying a species is difficult, mummified remains of both the Nile Perch (*Lates niloticus Eutropius niloticus*), Nile Catfish and members of the genus *Clarius* (air-breathing Catfish) have been discovered (Ikram 2005, 41 and Leek 1976, 131). In particular, large numbers of mummified *L. niloticus* remains have been recorded from tombs to the west of the city of Esna, directly along the Nile (ibid). Fish in general appear to be associated with the goddess Neith, a deity closely tied to the mythology surrounding the Nile River (Aufderheide 2010, 406).

Other:

Egg: Given the evidence for the breeding of raptors, ibis and crocodilians, eggs could be attributed to any of the aforementioned species. Mummified eggs have been argued to function as votive offerings dedicated to the sun god Ra, due to the cyclical nature of eggs as a representation of the sun. In addition, they can be seen as potential evidence for mass-breeding, as seen at Medinet Madi (Ikram 2005, 225).

Mummified Animals and Sites of Production

In order to most effectively consider any potential correlation between the mummification of animals and long-distance trade, it is important to be aware of the archaeological context of the mummified remains examined in this study. Specifically, this can include the sites at which the remains were uncovered through archaeological excavation. In order to understand the socio-economic implications of animal mummification, it is imperative to discuss a number of the most important archaeological sites and regions associated with these embalmed animal remains. In doing so, mummified animal remains can be contextualised through their association with these particular localities. Mummified animal remains have typically been uncovered from sites associated directly with animal cult worship, in large caches within underground tombs (see Fig. 13.0). These sites identified with mummified animal remains tend to be associated in particular with animalistic deities in Ancient Egyptian religion. Regional localities and funerary sites are often associated with one or more specific gods and goddesses, including Bubastis in the Nile Delta and the feline deity Bastet, along with Hawara in the Fayum depression and the crocodilian god Sobek (Aufderheide 2010, 401-402). Exactly how these sites became associated with these specific gods and goddesses is difficult to ascertain, but are more likely than not dictated by developments in the local environment. This is perhaps most identifiable in relation to sites in the Fayum, where sites of mummified crocodile production and distribution are located in proximity to shallow, wetland ecosystems, that provide a natural habitat for these species (Bresciani 2005, 200-205). It can be suggested therefore, that the location of these regions of animal cult proliferation evolve as a direct consequence of the species that inhabit the local area, and species these Egyptian communities would have consistent interactions with. This supports the presence of these sites predominantly along the fertile wetland regions directly adjacent to the Nile Delta and Valley, where the majority of Egypt's native animal species are found. However, we must also consider that such a location places these sites in close proximity to large Egyptian towns and cities along the river, and may be as much a case of association and economic interactions with large urban communities, than due to the native species present.

While embalmed animal remains have been uncovered from across Egypt, these finds can be associated particularly with a number of large cemetery sites from across Ancients Egypt's administrative regions, known as nomes from the Ptolemaic Period. A significant proportion of those sites identified by Ikram as important centres of mummified animal deposition are located in close proximity to the ancient capital at Memphis. This is perhaps unsurprising, as

Memphis has been suggested to be the predominant centre of religious and cultural activity throughout Ancient Egyptian (Snape 2014, 177). This remains the case even following the movement of political and economic control towards Alexandria in the Ptolemaic Period (ibid) Perhaps the most noteworthy of the animal cemeteries in Ancient Egypt is directly associated with the city, namely the Sacred Animal Necropolis at North Saqqara. Given the constraints of this thesis, considering each excavated animal cemetery in detail would be impractical. As a result, North Saqqara will be used as a case study for the contexts in which animal remains have been uncovered. This can be used to understand the nature of the practice in Egyptian history.

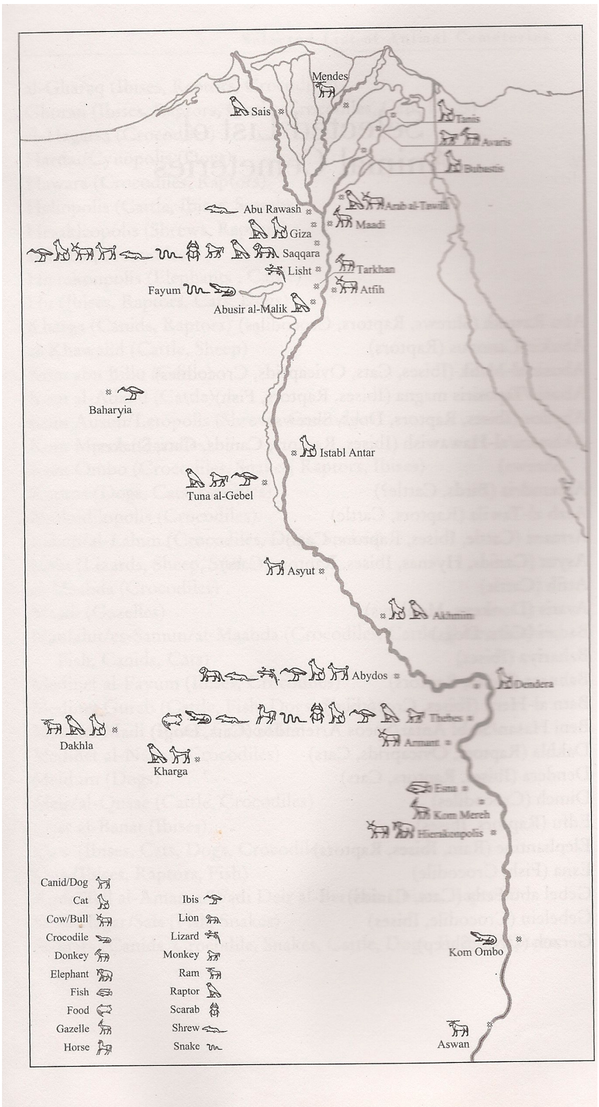

Fig. 13.0: Map of selected Egyptian animal cemeteries, drawn by Nicholas Warner (Ikram 2005, xvii).

North Saqqara (1st Nome Lower Egypt):

North Saqqara served as the necropolis for the ancient capital of Memphis, and it is by far the most famous site of animal mummification (Nicholson 2005, 46). Saqqara itself has been associated with royal burials since at least the Old Kingdom (Snape 2014, 117). However, it is the much later animal necropolis to the north of the site that is most pertinent to this thesis (see Fig.13.0). Recorded by European visitors as early as the 1600's, it was with W.B Emery's excavations from 1964-1971 that the scale and importance of North Saqqara was considered academically (Nicholson 2005, 56). These studies along with those of Geoffrey Martin (1973-1974), Martin Smith (1976), Smith and Jeffrey's (1977) and Paul Nicholson (1983-present) uncovered mummified remains and the built structures revealing a number of species-specific catacombs (Nicholson 2005, 71). Perhaps the most prominent of these is the massive granite sarcophagus at the Serapeum, associated with the burial of the Apis bull (after its death, and transport of the animal from nearby Memphis from around 1300 B.C.) (Ray 1978, 151). It has been suggested that post-mortem veneration of the Apis bull would have resulted in extensive facilities to cater to pilgrims looking oracles, including embalmers, astrologers and statuette manufacturers (Nicholson 2005, 46).

While the Serapeum is the largest of the specific animal tombs, extended enclosures developed from the Late Period onwards have been discovered (Martin 1981, 7). These have been identified with tomb complexes dedicated to cattle, baboon, dog, hawk and two ibis catacombs, with their location determined by what Nicholson calls the 'Sacred Geography' (Nicholson 2005, 51). Effectively, the positioning of these catacombs appears to have been deliberately chosen for religious reasons, as the ibis and baboon tombs are in close proximity, due to their shared association with the god Thoth (Nicholson 2005, 48). In these catacombs, large excavated tunnels have been discovered, within which millions of mummified remains have been uncovered (Nicholson 2005, 49-58).

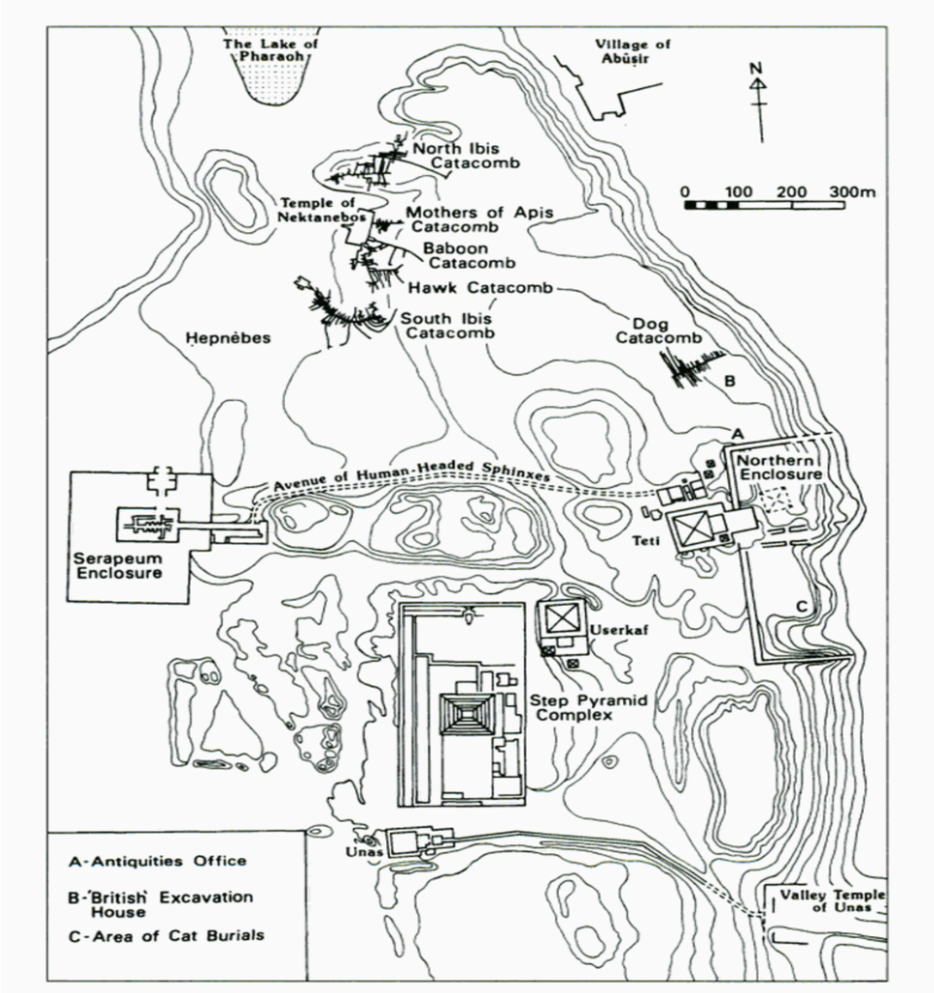

Fig.14.0: Map of the Scared Animal Necropolis at North Saqqara (Nicholson 2005, 47).

Such large volumes of mummified animal remains have been found alongside archaeological evidence for the presence of a thriving economic community (Nicholson 2005, 49). This appears to be particularly prevalent in the Late Period. Excavations of the South Ibis galleries in sector 7 of the site by Martin in 1981, reveal Late Period and Ptolemaic subterranean galleries cut through archaic and Old Kingdom mastabas (Martin 1981, 7-8). Associated with these catacombs are the discoveries of a number of workman's dwellings in Blocks 1-3, suggested to be accommodation to the communities responsible for the cutting of these galleries (Martin 1981, 20-23). Additionally, evidence supports the presence of masons to maintain the shrines, as well as vendors, selling votive items such as bronze figurines (Nicholson 2005, 49). Such findings suggest the development of residential communities in support of the priestly class (known in the Ptolemaic Period as *Katachoi*) as part of an extensive economic system related to the industry of animal mummification. The presence of imported Late Period Levantine pottery in the form of storage jars suggests the trade of goods from across the ancient world to Saqqara (Aston and Aston 2010, 136-137). This infers the potential for long-distance trade in support of religious and economic activity at the site (ibid). Such findings help with the consideration of the potential interconnectivity between mummification of animals and socio-economic activity throughout Egyptian history. While Saqqara only accounts for one site amongst a number of large cemetery sites across Egypt, its great size and importance make it a good potential case study for wider trends across Egyptian society.

The Management of Votive Mummy Production

What is clear from the archaeological record is that the mummification of animals in later Ancient Egypt was conducted on a massive scale, with as many as 70 million possibly produced (BBC News, 2015). Therefore it is important to understand the mechanics of management of the production of votive animal mummies. This in turn allows for an understanding of how this practice relates to the wider socio-economic and political environment, and whether the supply of embalming material functioned through free-market principles, or with significant oversight and control from the ruling authority?

How was votive dedication managed?

Excavations at large animal necropolises such as Saqqara and Tuna el Gebel have given us an insight into how the mass scale mummification of animals for votive offerings would have been managed. An important element of this is an analysis of the seasonality of the votive animal industry. Evidence from these sites suggests that mummified remains were produced in special embalming houses, known as *Wabets* (Ikram 2005, 1-9). These remains would then be purchased by visiting pilgrims, presented to the associated gods, and then placed in storage (ibid). Once a year, during a special annual festival, these mummified remains were then placed in a procession and buried en-mass in expansive catacombs and sealed with mud-brick walls until the next year (ibid). Such findings suggest that while the dedication and deposition of mummified remains took place on a seasonal cycle, the production of these creatures happened continuously through the year. This in turn suggests that the materials necessary for the embalming process would be required throughout the year. Subsequently, the temple authorities would have to be able to accommodate such demands in order to maintain production rates.

An important question is as to how the local temples enabled the acquisition and storage of the materials, and where might this have happened? Key to this seems to be that local temple systems seem to be tied closely to the political authority. While this seems to be the case throughout much of Egyptian history, it is perhaps most evident in the Ptolemaic Period. Greek style temple decorations at the Tuna el Gebel administrators precinct suggest the importance of the ruling political nobility in the running of the temple complexes (Kessler and Nur-el Din 2005, 132-133). Furthermore the presence of Greek Serapis structures at Tuna el Gebel, Saqqara and Alexandria infer the role of the monarchy, continuing a standing tradition of Egyptian royal cults (ibid). At Tuna el Gebel we also see the presence of administrative rooms associated with the Ptolemaic authorities, designed for the keeping of records (Kessler and Nur-el Din 2005, 135). This once again suggests that the local political authority has an important role in administering and overseeing the activities of these religious sites, and supports the suggestion of the Ptolemaic government actively reorganizing the animal cults (Kessler and Nur-el Din 2005, 157).

Such direct political control can be seen to influence the supply of goods to these temple complexes responsible for animal mummification. Evidence suggests that towards the end of the reign of Ptolemy I, the state was guaranteeing the regular delivery of turpentine resin, most likely for use in embalming agents (ibid). Furthermore the Amarna letters suggest; albeit from and earlier chronological phase, that the temple and elite authority had a significant influence on the import of exotic goods from abroad (Snell 2008, 395). This is in most part due to possessing the necessary influence and economic resources to acquire these goods (ibid). While these letters also detail gifting and tributing relationships for goods between regional royalties (ibid). However given the quantities of imports considered, this seems unfeasible. More likely, this movement of embalming goods probably involved independent merchants, administered, supported and financed by state and elite entities. Evidence for this comes in the form of Aramaic papyri from Tuna el Gebel, that suggest the presence of foreign merchants and mercenaries passing through the temple complex, and participating in Egyptian feasts (Kessler and Nur-el Din 2005, 141). Meanwhile pre-Ptolemaic inscriptions on used amphora from the same site, native to the Phoenician coast, mentions "Oil (belonging) to the King of Tyre" (ibid). Furthermore, excavations at North Saqqara identify the presence of Levantine storage jars from the Anubion (Aston and Aston 2010, 136-137). These findings provide evidence, both for the import of materials from this region, but also the potential site of storage of these ingredients prior to their use in the *Wabets*.

Such findings suggest the importance of the latter Ancient Egyptian elite on the control of both the production of mummified remains, and the supply of ingredients necessary for this process. This is perhaps unsurprising, given the existing evidence for the use of religion as means for the Ptolemaic rulers in particular to maintain control of the native population. Such a system of control accounts for both the growth of the animal cults and mummification in general, and subsequently the increased attempts to control the necessary embalming ingredients for this process. Given the massive number of mummified remains discovered at sites such as Saqqara and Tuna el Gebel, huge quantities of these ingredients would have to be provided on an annual basis. With many of these ingredients having to be imported from abroad (see Chapter 4), this suggests the need for an effective administration, and significant financing, to support this high demand. This further supports the argument for the intervention of the state and wealthy elite in the production of mummified animal remains in later Ancient Egypt. Whether this growth in the demand for these votive offerings is the result of foreign interest in cult practice, or a reaction from the native population to foreign rule, is still up for debate. However such findings do support the importance of an elite bureaucracy in supporting the mass increase in mummy production from the Late Period onwards, more likely than not profiting from it both economically through sales to pilgrims, and politically through control of the population.

Mummified Animals and Egyptian Socio-Economics?

From a consideration of the species embalmed as votive offerings, it is clear that mummified animals have a clear religious and cultural importance in Egyptian society. However, it is also evident from the findings at cemetery sites such as Saqqara, that these mummified offerings also have clear economic and industrial implications. This is due to the fact that these remains would have been mass-produced for sale to pilgrims, and can be seen as part of a wider network connecting religious practices. Such context of mummified remains from the archaeological record is important in considering any potential correlation with use of imported materials, as the practice appears to bridge the gap between cosmology, religion, society and economics. This contextual information can be used when attempting to assess the hypothesised connectivity between the mummification of animals and the long-distance import of ingredients utilised in the embalming process.

Chapter 4: Scientific Analysis of Embalming Agents in Mummified Remains

The primary focus of this thesis surrounds the identification of the individual biochemical components used in the embalming process. An important element of this a discussion of both the techniques used in other academic research to identify embalming recipes in mummification, and those materials used in the preservative process. Understanding both of these factors will inform the direction of this thesis, and provide context for the results collated from Buckley & Tunney and Buckley & Fletcher.

Use of Biochemical Analyses

Some of the earliest recordings of the materials used in the embalming process come from contemporary historians, including accounts such as those of Pliny (Abdel-Maksoud and El-Amin 2011, 134). However it is not until the 20th century that we begin to see academic attempts to quantify such trends. Early scientific analyses of the embalming recipes in mummification, such as those of Alfred Lucas, primarily involved solvency tests (Lucas 1999, 270-326). This technique however raises many issues, namely the fact that many different embalming materials (namely resins and bitumen) behave in a similar way in the presence of such solvents (Lucas 199, 308). Its is in the last two decades of research that perhaps has had the greatest impact on the ability to biochemically identify the components of embalming mixtures, namely the widespread use of Gas Chromatography-Mass Spectrometry (GC-MS) in bioarchaeological research. Margret Serpico and Raymond White provide a useful review of both embalming recipes in general, and how Gas Chromatography and Mass Spectrometry can be used in order to identify the individual biochemical compounds in embalming mixtures, which will form the basis for this overview.

GC-MS Methodology

Gas Chromatography-Mass Spectrometry is the combination of two chemical processes, Gas Chromatography (GC) and Mass Spectrometry (MS). In GC, the sample is dissolved in solvents applied to the top of a glass column and packed with an absorbent material (Serpico and White 2006, 417). Solvents of various compositions are applied to the top of the column, and slowly percolate down under the force of gravity (ibid). Depending on their composition, the various components within the mixture of solvents and the sample will 'stick' (be absorbed) to the stationary phase packaging material in much the same manner as thin layer chromatography (ibid). However in GC, the sample is carried by gas through the column (ibid). The movement of the different compounds will be impeded by the stationary phase, causing them to leave the base of the column at different rates corresponding to their length of time within the column, or retention time (ibid). When they exit the column, the compounds are detected in relation to their retention time as a series of peaks (ibid). The area under each of these peaks reflects the amount of the relevant compound present (ibid) (see Fig.14.0). This sequence of peaks can be matched to a known reference sample, in order to determine the source materials in the sample (ibid) (see Fig. 14.0). These compounds can then be entered into a mass spectrometer (MS), where they are bombarded with high energy electrons, which cause these compounds to break down into fragmental patterns, determined by their molecular structure (ibid). Different compounds will show different fragmentation patterns, which allows the compounds to not only be separated, but to identify their structure and weight (ibid).

Unfortunately GC-MS cannot counter entirely the issue of the degradation of chemical compounds in ancient samples (ibid). Moreover complex molecules will stick to the column and not pass through (ibid). One means of overcoming this is through the use of pyrolosis, in which the sample is heated rapidly to break its compounds into smaller fragments (ibid). The use of both GC-MS and pyrolosis has significant advantages when examining the embalming agents used in mummification. These techniques allow in many instances for the individual biochemical compounds within a mixture to be identified, both in terms of source material and quantity. This allows for a far more accurate examination of the biochemical makeup of embalming agents than solvent solubility analyses.

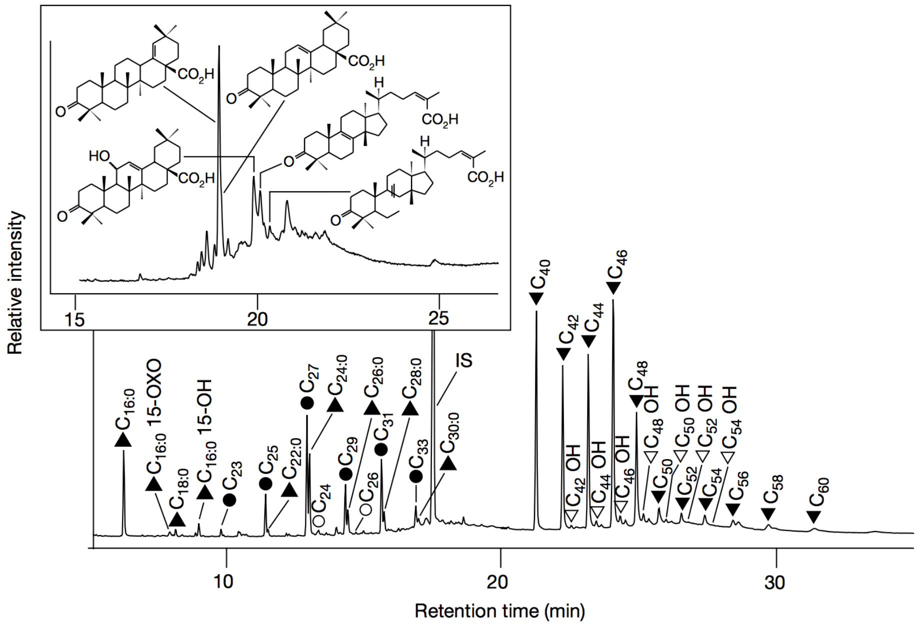

Fig.15.0: Example of chromatographic readout from GC-MS analyses of mummified remains (Buckley and Evershed 2001, 340)

Using GC-MS to Identify Embalming Agents

Native

Oils, Fats and Waxes:

An important component of embalming agents is the use of lipid-based compounds. These lipids are sourced from plants, animals and dairy products, often as a byproduct of other industries (Serpico and White 2006, 412). Oils, fats and waxes show very similar chemical compositions. The number of carbon atoms determines the distinction between these groups, along with the number, position and geometry of double bonds (ibid). Those with no double bonds are described as being saturated, while those with double bonds are considered unsaturated (ibid). Unsaturated fats are most common in plant sources, namely vegetable oils, and saturated fats in animal material (ibid). The identification of these lipids is conducted biochemically through the proportions of different fatty acids. An important factor to consider in this process however is that lipid composition is subject to changes over time due to environmental factors (Serpico and White 2006, 413). Changes in consistency over time can be caused either through oxidization polymerization (polyunsaturated fats breaking down, and the triglycerides cross bonding to form larger molecules), or through the breaking of bonds between fatty acid and glycerol molecules (ibid). The former leads to formation of semi-solid ‘drying oils’, while the latter creates free fatty acid chains (ibid). The most likely use of these lipids is for their hydrophobic tendencies, preventing the rehydration of tissue and potential enzymatic decay.

GC-MS currently represents the most effective methodology of for analyzing ancient lipids (Serpico and White 2006, 417). However this identification process is still problematic. While it is possible to identify the specific fatty acids through GC-MS, this may not necessarily provide any information of the identification of the source of these fatty acids (ibid). Given the tendency of lipids to alter in ancient samples, the proportions of these fatty acids that would provide normally provide an identification, may bear little relationship to their original amounts (ibid). One exception to this is in the case of castor oil. Castor oil contains high proportions of the relatively stable ricinoleic acid, which is not found in other lipid sources (Serpico and White 2006, 418). For that reason, while plant oils and animal fats are normally difficult to identify individually, castor oil has been regularly identified in both human and animal mummified remains (Łucejko et al 2017, 1-12). Sourced from the castor bean, this pale yellow liquid consists almost entirely (90%) of an 18-carbon monosaturated fatty acid chain called ricinoleats (Barceloux 2012, 212). Castor oil has numerous modern uses, including in cosmetics as a moisturizer, as a lubricant and a component of biodiesel (ibid). Most interestingly to the purpose this thesis, castor oil is also utilized as an ingredient in numerous medicines and mould inhibitors as an antifungal agent (ibid). Furthermore, experiments conducted by Rahmati et al found that castor oil seed extract inhibited the growth of *Bacillus* *subtilis, Staphylococcus aureus, Pseudomonas aeruginosa, Salmonella typhi, Escherichia coli and Candida albicans* bacteria in lab conditions (Rahmati et al 2015, 1-12). This apparent effect on bacterial and fungal microorganisms could both explain its use in mummification, and its application as an internal ointment following desiccation (Ikram 2005, 18).

GC-MS analyses also reveal the use of waxes in the embalming agents of Egyptian mummies. The most accessible of these would have been beeswax, sourced a byproduct of the production of honey (Serpico and White 2006, 411). Waxes such as beeswax are identifiable from other oils and waxes in GC-MS, due to the reduced ratio palmitic and stearic acid in waxes (4 or 5:1) than other lipid sources (1 or 2:1) (Serpico and White 2006, 420). Their suggested use in embalming agents comes from their hydrophobic properties, as well as potentially providing an adhesive for the application of linen wrappings (Serpico and White 2006, 411).

Honey:

Some early sources state the use of honey in the process of preserving the dead in Ancient Egypt (Lucas 1999, 26). Additionally the discovery of jars containing honey residues in Egyptian tombs (such as that of Tutankhamen) suggests some form of ceremonial use (Cortés et al 2011, 304). Such a use of honey would perhaps have some merit, as the material has been shown to provide some antiseptic properties (Molan 1992, 5-28). However the author has been unable to find any recent GC-MS analyses of mummified remains that infer the presence of honey as a component of the embalming agent (Buckley and Evershard 2001, 837-841) (Buckley et al 2004, 294-298) (Maksoud and El-Amin 2011, 138). As such, the suggestion of the use of honey in Egyptian embalming must be treated with caution.

Imported

Resins:

Resins are defined as the viscous material produced from bark distillates or the saps of numerous tree species (Aufderheide 2007, 55). Liquid when heated, they harden to a crystalline structure at room temperature (ibid). These appear to be applied while heated to the surface and eviscerated internal cavities of mummified corpses (Ikram 2005, 20-21). Evidence suggests their use in embalming stems from their ability to form a hydrophobic barrier to prevent rehydration of the tissue, and often have associated antiseptic properties (Aufderheide 2007, 55). Visual identification of resins used on mummified remains is difficult, as embalming materials often appear as an indistinguishable black mass of material. Early scientific analyses such as those of Alfred Lucas relied on the use of solubility tests to identify individual resins in a mixture (Serpico 2006, 444). However with the widespread use of GC-MS, it has become possible not only to determine if a material is resinous, but also in many instances to establish the botanical source for these resins (ibid). These are based primarily on the isolation and identification of compounds called terpenes and terpenoids (ibid) (see Fig.15.0). Found in most resins, these compounds are based on 6 carbon rings, shown in hexagonal configuration, with attached hydrogen atoms (ibid). When carbon and hydrogen are the only atoms present, the compound is identified as a terpene (ibid). However when oxygen is also bonded to the carbon rings, these compounds are known as terpenoids (ibid). These terpenoids can further be divided into two groups (ibid):

Lower terpenoids:

- Monoteroenoids: Compounds with 10 carbon atoms
- Sesquiterpenoids: Compounds with 20 carbon atoms

Higher terpenoids:

- Diterpenoids: Compounds with 20 carbon atoms
- Triterpenoids: Compounds with 30 carbon atoms

It is this a latter group that is more likely to remain detectable in ancient samples, as the larger carbon structures make these compounds more stable (Serpico 2006, 445). It is through the detection of these compounds in particular that we can begin to identify the particular botanical origins of some of the resinous materials used in the embalming process. Some of these in particular have been researched in particular detail, and will be discussed further below.

Diterpenoids	**Terpenoids**		**Triterpenoids**	
Pistacia	*Pine (Monoterpenoids)*	*Cedar (Sesquiterpenoids)*	*Frankincense*	*Myrrh*
7-oxodehydroabietic acid	α-pinene, β-pinene	azulenes, atlantones	β-boswellic acid	α-amyrin, β-amyrin

Fig. 16.0: A selection of identifying biochemical compounds in resinous materials, created by the author, using information from (Serpico 2006, 443-450)

Coniferous Resins:

The widespread use of plant oils in Egyptian mummification suggests that embalmers were aware of the preservative potential of coniferous resins (Abdel-Maksoud and El-Amin 2011, 134). The polymerisation of these unsaturated oils would have stabilised otherwise fragile tissues and wrappings, by producing a physio-chemical barrier that impedes the activities of microorganisms (Buckley and Evershed 2001, 837-841). These resins were typically derived from coniferous trees, especially cedars (*Cedrus libani*), junipers (*Juniperus phoenicia*) (*Juniperus drupacea*), pines (*Pinus halepensis*) (*Pinus pinea*), Cilician Fir (*Abies

Cilicia) and Oriental Spruce (*Picea orientalis*) (Klys et al 1999, 217-228) (Lucas 1999, 310-325). All of these grow naturally in cooler regions to the north of Egypt such as Syria-Palestine and Asia Minor (Abdel-Maksoud and El-Amin 2011, 135-137) (Lucas 1999, 310-325). Biochemical investigations from Buckley and Evershard, of the mid-dynastic to late Roman period, show an increase in the prominence of these resins in mummified remains as Egyptian history progressed (Buckley and Evershed 2001, 837-841).

Pistacia Resins:

Other resins used in mummification from non-coniferous sources come from the genus *Pistacia*, particularly *Pistacia palaestina* and *Pistacia lentiscus* (Lucas 1999, 321). *P. palaestina* and *P. lentiscus* both produce an extractable clear resin, known as turpentine and mastic respectively (Lucas 1999, 321). Pistacia are a species of flowering plant in the cashew family, with the species seen in Egyptian mummification native throughout the Eastern Mediterranean. Biochemical analyses from Buckley et al of Pharoanic human and animal mummies both reveal the presence of pistacia resins within the embalming mixtures (Buckley and Evershard 2001, 837-841) (Buckley et al 2004, 294-298). This indicates a common usage in both practices (ibid).

Myrrh:

Myrrh is a gum resin extracted from the *Commiphora* species of small, thorny trees (Maksoud and El-Amin 2011, 138). Use of myrrh as a pungent aroma, and ointment in Ancient Egypt, is widely recorded in contemporary accounts from Pliny, Theoprastus and Plutarch (Lucas 1999, 93). These resins were imported to Egypt from the natural habitat of the *Commisphora* (known as Punt) in the Horn of Africa, modern day Somalia, Eritrea, Ethiopia, and southern Arabia (Maksoud and El-Amin 2011, 138). This import of myrrh was an important economic practice. This can be seen from large-scale expeditions sent to Punt in the Middle Kingdom, such as those seen in the carvings at Deir el-Bahari (Bryan 2002, 239). Analyses of mummified remains have identified the presence of gum resins in both human and animal Pharaonic mummies, however these have not been identified conclusively as belonging to a specific *Commisphora* species (Buckley and Evershard 2001, 837) (Buckley et al 2004, 295). Hamm et al made use of Headspace SPME (Solid-Phase Microextraction), coupled with GC-MS, to identify the characteristic biomarkers of myrrh. This perhaps allows for a new method of conclusive identification of myrrh in embalming mixtures (Hamm et al 2003. 73-83).

Cassia and Cinnamon:

Cassia (*Cinnamomun cassia*) and cinnamon (*Cinnamomun zeylanicum*) are similar substances to one another. Both are pungent herbs made from the dried bark of certain varieties of laurel, grown in what is now India, China and Sri Lanka (Lucas 1999, 308). Ikram and Dodson suggest that due to natural antibacterial properties, pungent smells, vibrant colours and high cost, these herbs likely provided an important practical and symbolic purpose (Ikram and Dodson 1998). Furthermore, the use of the spice in mummification is mentioned in the writings of Herodotus (de Sélincourt 2007, 114). However, GC-MS analyses in recent academic research as yet have failed to identify the presence of these ingredients (Buckley and Evershard 2001, 837-841) (Buckley et al 2004, 294-298) (Maksoud and El-Amin 2011, 138). This makes the suggestion of their use in literary sources problematic. However, biochemical analyses of mummified remains have been limited to small numbers of specimens, and a considerably more expansive study would be needed to make such claims conclusively.

Natural Petroleum:

Natural petroleum, also known as asphalt or bitumen, is a sticky, black and highly viscous liquid or semi-solid form of petroleum, occurring in hydrothermal veins. In the Ancient Eastern Mediterranean, a prominent bitumen source was the hypersaline Dead Sea, where the substance is known to float up to the surface from deep petroleum seeps (Bein and Amit 2007, 439-447). It should be noted however that recent geochemical research has suggested some of the bitumen we see in mummification may have been sourced from the oil seeps at Gebel el Zeit, in the Gulf of Suez, Egypt (Barakat et al 2005, 211-228). The role of bitumen is interpreted primarily as a preservative agent, employed by Egyptian embalmers to ward off biological decay as a biocide, an external shield to insects, and as a mechanical binder for aromatic cedar oils in a mixture (Nissenbaum and Buckley 2013, 566-567). Early research into mummification materials suggest that bitumen was employed extensively in the preservation of the dead, based on the accounts of Diodorus and Strabo (Lucas 1999, 303). Natural petroleum compounds are identified in GC-MS studies of Pharoanic mummified animal remains, perhaps suggesting use in animal mummification in this period (Buckley and Evershed 2001, 837). Furthermore, Aufderheiede suggests from GC-MS analyses of four mummified human remains, that bitumen use increased in the later Ptolemaic and Roman stages of Egyptian history (Aufderheide 2003, 255). The importance of bitumen is apparent from the accounts of Diodorus Siculus, who recounts the attempts by Antigonus I of Phyrgia (one of the successors of Alexander the Great) to conquer the Nabateans of the Dead Sea region to control trade of natural petroleum (Nissenbaum and Buckley 2013, 567). On the Nabateans, Diodorus writes:

'The barbarians who enjoy this source of income take it to Egypt and sell it for the embalming of the dead; for unless this is mixed with the other aromatic ingredients, the preservation of the bodies cannot be permanent' (ibid)

These accounts, alongside the biochemical analyses, suggest bitumen played an important role both in mummification in Later Ancient Egypt, and in the geopolitics of Egyptian-Levantine relations. However, more recent use of petroleum solvents and GC-MS has suggested that bitumen is not present in mummified remains as consistently as previously supposed (Buckley and Evershed 2001) (Lucas 1999, 303-308). It is suggested that the confusion comes as a result of the change seen in embalming mixtures, in which components change to a similar black colour to bitumen due to oxidisation (Buckley and Evershed 2001, 837). Therefore, a more extensive use of GC-MS analyses across more numerous mummified samples, could help to infer the degree to which particular biochemical compounds were utilised in embalming agents, including natural petroleum.

Although chemically distinct from fresh resin, bitumen does contain hydrocarbon triterpenes and triterpenoids with molecular structures similar to botanical resins (Serpico 2006, 455). With the increased use of GC-MS, more conclusive indicators for the presence of naturally occurring asphalt have been identified (Serpico 2006, 456). In more recent analytical studies, the identification of bitumen has relied on the use of the isolation of particular solvent soluble compounds (ibid). These principally include long-chain hydrocarbons such as pristane (C_{19}) and phytane (C_{20}), and cyclic compounds such as hopanes, moretanes, steranes and phytosteroles (ibid). Additionally, the identification of aromatics such as naphthalene have also been undertaken (ibid). However the chemistry of these compounds remains very complex, and as such any results must be treated with a degree of caution (ibid).

The Value of GC-MS Analysis

It should be noted that in identifying the botanical origin of an embalming ingredient, one does not necessarily determine a geographic origin. Examples such as the Gebel el Zeit bitumen deposits can show the potential of the identification of new sources for ingredients (Barakat et al 2005, 211-228). Furthermore some exotics may be returned to Egypt and produced locally; as in the case of the *Burseraceae* tree's found at Hatshepsut's tomb (Bryan 2000, 239). In spite of such limitations, GC-MS analyses remain the best available method in which to identify the use of imported ingredients in the embalming process. It is for this reason that this thesis will rely on the use GC-MS results, in order to inform a discussion of the relative use and significance of imported embalming agents in the mummification of animals in later Ancient Egypt.

Chapter 5: Methodology

Testing the Thesis Hypothesis

After reflecting on the available archaeological, textual and biochemical evidence from the existing academic literature, there appears to be evidence for some form of relationship between long-distance trade and the mummification of animals in Ancient Egypt. As a result, this thesis aims to quantify this relationship through the review of biochemical analyses. This will be done in order to determine the extent to which exotic embalming ingredients are used in the anthropogenic preservation of mummies, and utilised in the creation of embalming agents. This therefore aims to provide quantifiable scientific data in support of the connectivity of religious and economic practice in later Ancient Egypt, and thus potentially illuminate the complicated nature of Egyptian cultural dynamics and socio-economic interactions.

Contextual Information

One important element of this research question is to consider the context of the mummified remains analysed by Buckley & Tunney and Buckley & Fletcher. Such a contextual framework will be based on the information provided by the aforementioned contributors. Namely, these include the date in which the specimen was produced, the collection the specimen was sourced from, the site of discovery (provenance) and the species of the mummified specimen. In the results provided by Buckley & Tunney and Buckley & Fletcher, these form the four columns on the left hand side of the data provided (see Appendix 1-3). This contextual information can allow for the identification of any potential correlations between these factors and the use of imported embalming ingredients. This in turn can be used to potentially reveal more as to how the use and import of exotic goods in animal mummification may have occurred alongside other socio-economic trends.

Sample Collection

From the sample provided, 27 mummified specimens were examined. These embalmed remains have been sourced from six separate collections from across the UK, Europe and US. Such an approach helps to limit the risk of an observational bias, as they are less likely to have been recovered from a single excavation or site. Subsequently, this should provide a more representative sample with which to assess the role of imported ingredients in animal mummification. However there are serious issues in using collections such as these, steming from a number of different sources. Most notable amongst these is the role of antiquarian archaeological approaches. Mummified animal remains were often removed and shipped to collections without an accurate recording of their context, making any subsequent contextual dating difficult. Furthermore, this means that many of the specimens in this study have spent a long period in their respective collections, making ascertaining any contextual information (such as dating) complicated, with records often poorly kept. These collections also have an increased risk of contamination during long-term storage, potentially affecting the accuracy of biochemical analyses, including GC-MS. Furthermore we must be aware of the regular production of pseudo-mummies, which often contain little to none of the species represented (Ikram 2005, 14). This means that any relationships identified between imported biochemical agents and the species of the mummified specimen may have to be treated with a degree of caution. In spite of these limitations, the use of museums collections such as these remains the best source of mummified animals for such a study.

Dating

Serious issues are present in regards to the dating of the specimens in this study. Of the 27 mummified remains considered in this thesis, 30% lacked any form of suggested dating. Accordingly, this means that those samples that have been provided with a date are attributed to large chronological phases, across more than one period. This limits the extent to which we can date the mummified remains in this study accurately. However, in spite of these issues, some useful results can be drawn from the remaining specimens with provided dating information. Based on those dates provided, the greatest majority of the dated specimens (55%) are attributed to the 3rd Intermediate and Late Period (1069-332 B.C), a period in which we see the last native Egyptian Dynasties subjected to great foreign influence from the Nubians, Assyrians and the Achamenid Persian Empire (see Fig. 16.0). While this period is one of two distinct phases with very different political and economic climates (see Chapter 2), the overlap in the dates provided from the museum catalogues for the specimens analysed in this study necessitates grouping these chronological phases together. The remaining 15% of the mummified specimens are attributed to the Greco-Roman Period (see Fig. 16.0). During this period, Egypt came under the control of the Ptolemaic Dynasty of Macedonian Greek pharaohs, followed by the annexation of the region as a province of the Roman Empire (30 B.C.-395 A.D.). In the range of dates identified in the sample provided by Buckley & Tunney and Buckley & Fletcher, we also see a predominant use of imported ingredients; with more than 60% of the specimens for each period containing inferred exotic biochemical agents, as will be discussed later

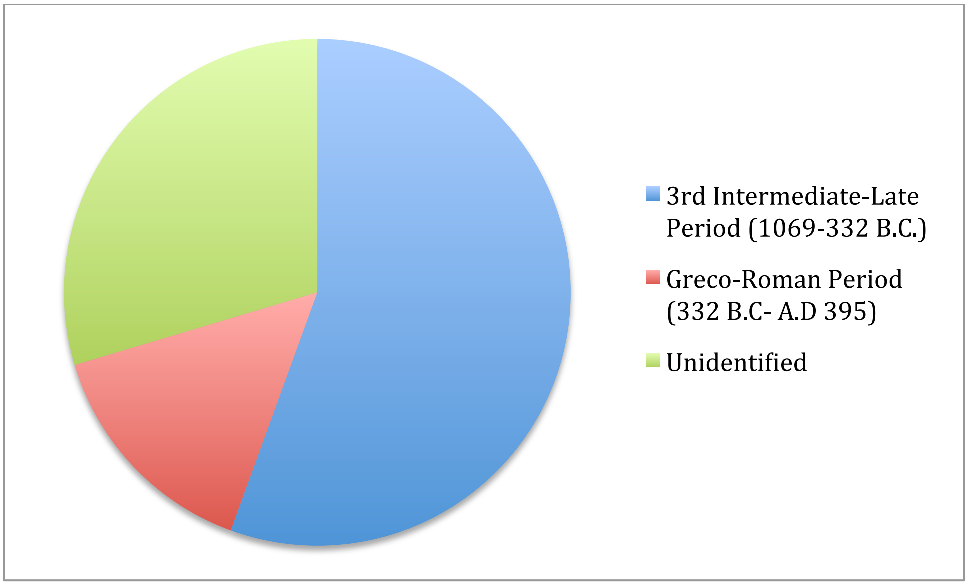

Fig. 17.0: Distribution of mummified specimens provided by Buckley & Tunney and Buckley & Fletcher, by date, produced by author (see Appendix 1,2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

Provenance

The information provided for the site of discovery of these mummified specimens suffers from the same serious issues discussed earlier. However, the provenance of the specimens analysed by Buckley & Tunney and Buckley & Fletcher reveal some interesting trends in regards to the relationship between animal mummification and long-distance trade. From the 27 specimens considered, 10 (37%) are provided with some information relating to the site of excavation (Fig.17.0, 18.0). Of these, 7 are linked to sites in close proximity (within 50km) of the ancient capital at Memphis:

Kafr Ammar/Tarkhan (21st Nome of Upper Egypt): A necropolis 50km south of Cairo, Tarkhan was excavated over the course of two seasons by W.M Flinders-Petrie in 1912-1914 (Cornelius et al 2012, 133). An earlier study, involving the CT scans of 5 mummified animals by Cornelius et al, included two specimens from the later cemeteries at Tarkhan (Kafr Ammar) (Cornelius et al 2012, 129-148).

Saqqara (1st Nome of Lower Egypt): A necropolis adjacent the city of Memphis, Saqqara was a gigantic cemetery site located 30km south of Cairo. The site was in use from Predynastic times, through to the Roman occupation. North Saqqara is well-known for its sacred animal necropolis, with species-specific catacombs containing hundreds of thousands of mummified remains (Nicholson 2005, 44-71). Along with the Serapeum (associated with the deification of the Apis Bulls), catacombs containing the remains of cats, dogs, ibis, baboons and raptors have been identified (Nicholson 2005, 44-71). Additionally, archaeological evidence has suggested a complex socio-economic network in support of these animal cults, assisting the associated production of mummified animal remains as votive offerings (see Chapter 3).

Memphis (1st Nome of Lower Egypt): Egypt's first capital, which played an important role for over 3,000 years of Egyptian history. Memphis was the capital of Lower Egypt for almost all of the Dynastic period (Snape 2014, 170). Located at the apex of the delta, 20km south of modern Giza, Memphis remained an important cultural and economic population centre (Snape 2014, 177). This is in spite of the movement of the capital briefly to Amarna in the 18th Dynasty, and then to Alexandria under the Ptolemaic Pharaohs (ibid). This is suggested to be due to the importance of the site in embodying traditional Egyptian culture and belief systems (Snape 2014, 177). This city is associated predominantly with the Apis Bull, one of the prominent bull cults in Ancient Egypt (Dodson 2005, 72-74).

Hawara (20th Nome of Upper Egypt): Located in the marshy wetlands of the Fayum Depression, the site of Hawara is known for the presence of a Middle Kingdom royal pyramid complex associated with Amenhemat III (Snape 2014, 169). Along with a number of other sites in the region (such as Medinet Maadi and Shedet), Hawara is associated from the Middle Kingdom onwards with the cult of the crocodilian deity Sobek, perhaps due to the presence of these creatures in the wetland environment (Bresciani 2005, 199-205). Sites in this region, including Hawara (named Crocodilopolis by Greek speakers), became intensely exploited in the Ptolemaic Period (Snape 2014, 169)

The remaining 3 identified specimens are associated with the large cemetery sites beyond the Memphite region:

Asyut (13th Nome of Upper Egypt): This site functioned as an important centre for the trade of goods from the Western Desert Oases (Snape 2014, 28). Archaeological evidence suggests the burial of numerous animal species such as ibis, birds of prey, cats, cattle, baboons and canids (Kitigawa 2013, 344). The identification of dog remains is particularly pertinent, as evidence suggests the chief deities for the city were Wepwawet and Anubis, both represented as canines (ibid). Accounts from as early as the 18th century report canid burials and mummies, while large volumes of mummified remains have been uncovered from two large tombs (ibid). While research into these tombs has been interrupted by mudslides, caused by heavy rain and the presence of a military base, many dog remains appeared at the surface (ibid). However, excavations in 2008-2010 allowed further survey of the zooarchaeological material (Kitigawa

2013, 344-354). Analysis of the 'Tomb of the Dogs' is hampered by the disturbed condition of the tomb itself, providing evidence of consistent grave-robbery (ibid). Greco-Roman pottery fragments and Ptolemaic Demotic inscriptions, and the disordered remains of both soft tissue and bones with linen wrappings, were discovered (ibid). Of the collected animal remains, 93% were attributed to canid species, although differentiating between these species is difficult (ibid). Such findings mirror those remains uncovered from the area around the tomb, with 98% of the animal remains from indeterminate dog species (ibid).

Beni Hasan (16th Nome of Upper Egypt): A large cemetery site 20km south of the modern city of Minya in Middle Egypt, Beni Hasan served as the cemetery complex for the nearby nome capital at Menat-Khufu (Snape 2014, 115). This site is also associated with the remains of 80,000 mummified cats and kittens from excavations in 1888 (Ikram 2005, 1-14).

One issue with the information provided is the lack of more precise association with specific temple sites in all cases. This is particularly relevant with the crocodile specimen from Memphis, as this only identifies where the specimen was obtained from, and not necessarily the location the remains were deposited. Furthermore, a review of existing literature on animal mummification has failed to identify the presence of any embalmed crocodile remains uncovered from sites in the vicinity of Memphis. Such an issue again stems from the limitations of antiquarian archaeological survey, which results in a lack of detailed information. Without such information any more precise detail is difficult. In spite of these limitations, we can still identify the role of the Memphite region as a significant hub of animal cult practice in later Ancient Egypt.

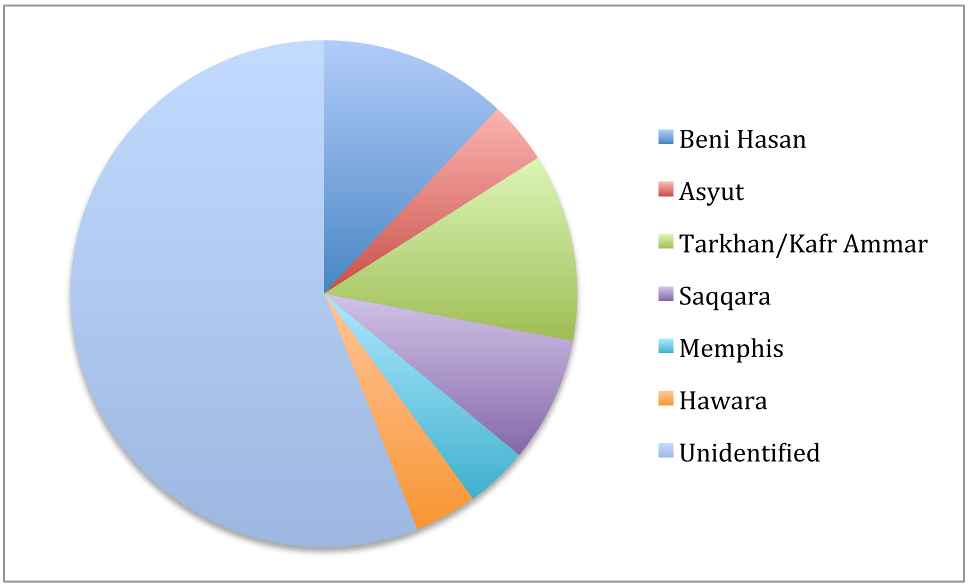

Fig. 18.0: Distribution of mummified specimens provided by Buckley & Tunney and Buckley & Fletcher, by provenance, produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

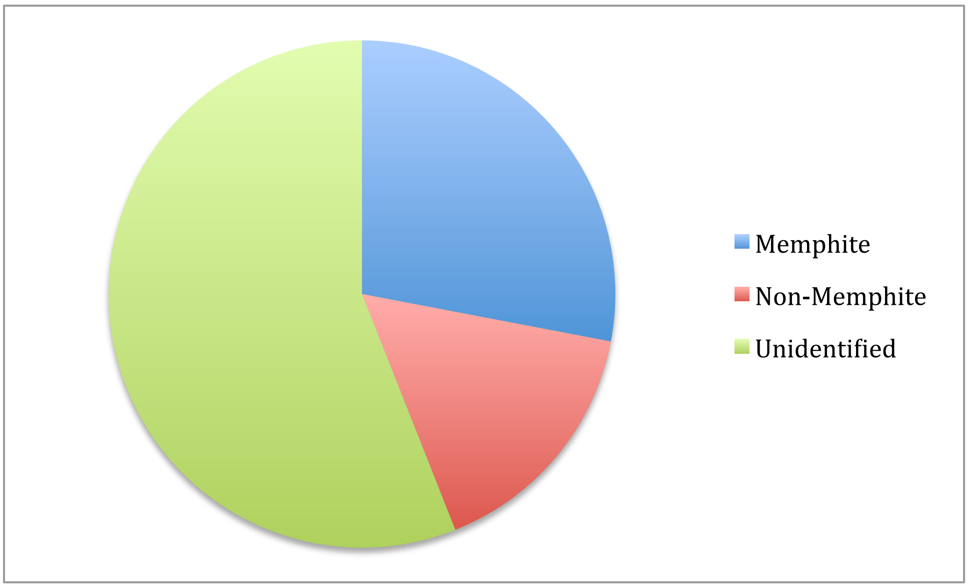

Fig. 19.0: Comparison of Memphite and Non-Memphite mummified remains in sample, produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

Species

From the interpretation of the analyses of Buckley and Tunney, we can identify at least 12 individual species from the mummified remains associated with this study. Of the 27 mummified remains considered, 12 (44%) are attributed to several different species of birds (ibis, hawk and falcon), 10 (37%) from mammalian species (cat, dog, mongoose, baboon and shrew), 3 (11%) crocodilian and fish species respectively, and 1 (4%) unidentified egg (Fig. 19.0, 20.0). Of these remains, those of cats, ibis and several bird of prey species are by a large margin the most common. Of the 27 specimens, 18 are attributed to these three groups, with 6 identified as cats (22%), 7 as birds of prey (26%) and 5 as ibis (18%). From identifying the individual species mummified, this thesis will consider whether the use of imported exotic ingredients in animal mummification is particularly prevalent in particular species.

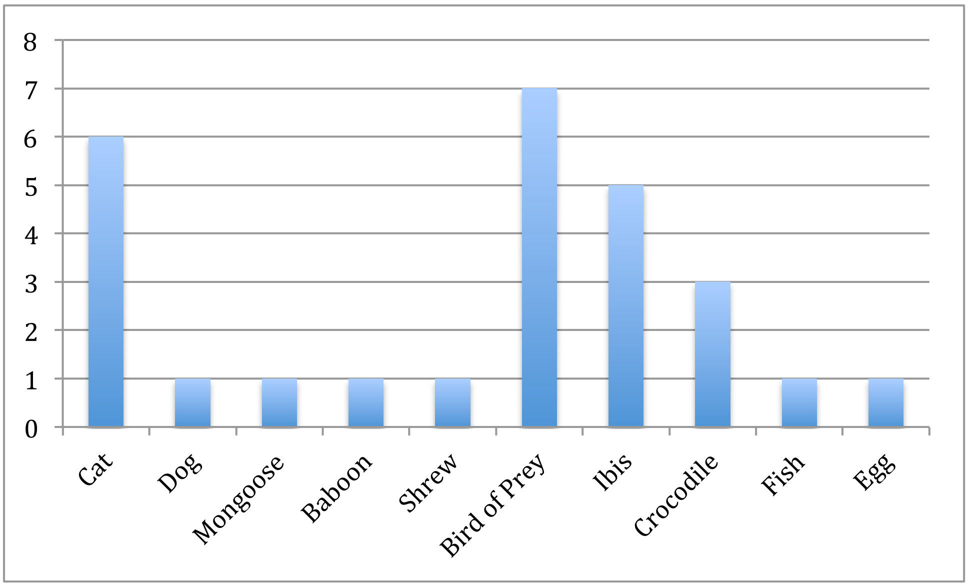

Fig. 20.0: Distribution of mummified specimens provided by Buckley & Tunney and Buckley & Fletcher, by species, produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

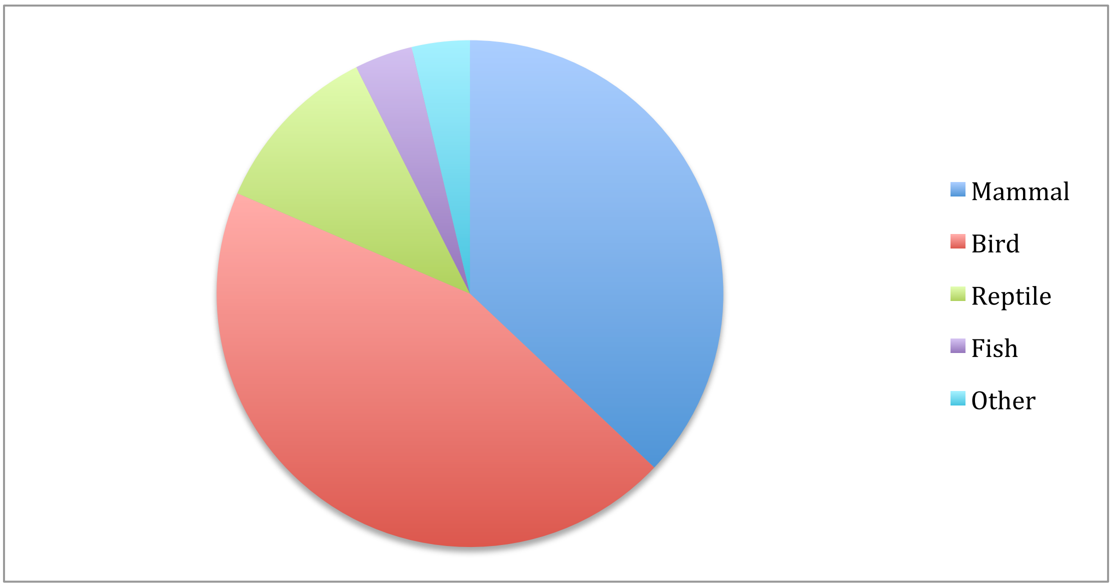

Fig. 21.0: Comparison of distribution between primary taxonomic groups in mummified specimens examined, produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

Sampling Issues in Mummified Animal Remains:

The primary sampling issue prevalent when considering the dating and provenance of mummified animal remains is the problems caused by antiquarian archaeological methodologies. As previously stated, many hundreds of thousands of mummified were transported back to Europe and North America. While many were destroyed for use as fertiliser, many more ended up in private collections, and later museums. The issue with using these museum collections is that often, the museums will have no record or context of individual mummified remains. This is likely due to the fact that they are donated by private collections, who frequently bought them from grave robbers or antique dealers. Consequently, these specimens are unable to be placed in the context of their site of deposit or age. This makes them far less valuable in terms of inferring the socio-economic use of imported ingredients in the embalming process for mummified animals. Therefore, it is important to be aware of the potential implications of such an issue before considering the results of the GC-MS data provided by Buckley & Tunney and Buckley & Fletcher.

GC-MS Results

Existing literature has made clear the advantages of using GC-MS in the analysis of the components of Egyptian embalming agents. Subsequently, this provided the best method for potentially quantifying the role of exotic imports in the mummification of animals in Ancient Egypt. For that reason, this thesis interprets the findings of unpublished GC-MS analyses conducted by Dr. Stephen Buckley, Prof. Joann Fletcher and Ms. Deborah Tunney of the University of York, of 27 mummified animal remains (see Appendix 1-3). The study of these results will allow for the potential identification of imported ingredients, and a consideration of how these can be related to the nature of the Egyptian import economy.

Where are the Samples Taken?

An important factor in considering the quality of the results provided by Buckley & Tunney and Buckley & Fletcher, is where the samples analysed have been taken from the mummified remains. In some cases, these samples have been taken from fragmented resinous pieces, loose debris and pieces of packaging, for example in Ibis 471 from the Elgin Museum (see Appendix 1). Such samples are potentially in a poorer condition, and subject to possible degradation and contamination. This could potentially lower the quality of the results from these samples. As such, when considering the interpretation of the results collated, we must be aware of any potential limitations, and treat our conclusions with caution.

GC-MS Methodology

The following review of the experimental procedures used is provided by the primary authors of the GC-MS analyses reviewed in this thesis, and is considered standard practice in the biochemical analysis of Egyptian embalming agents. The organic residues within these mixtures were chemically characterized and identified using a dual approach of conventional GC-MS and Sequential Thermal Desorption-Gas Chromatography-Mass Spectrometry (TD-GC-MS) and Pyrolosis-Gas Chromatography-Mass Spectrometry (Py-GC-MS). This allows for the chemical analysis of both the free and bound polymerized biomarkers likely to he present in the embalming mixtures. Samples for GC and GC-MS were initially ground into a fine powder. These samples were then extracted with an appropriate volume of chloroform-methanol solution. After centrifusion, the solvent was removed from the residue and placed in a vial. The solvent was then reduced by rotary evaporation. Following transfer of the extract to screw-capped vials, the remaining solvent was removed by evaporation under a gentle stream of nitrogen at 40°C. The residue was then reweighed to give the total lipid extracts (TLE). The TLE's were subsequently trimethylislylated using *N, O*-bis (trimethylsilyl)trifluoroacetamide. Excess BSTFA was then removed under a gentle steam of nitrogen and the derivatized sample redissolved in dichloromethane and analyzed by GC and GC-MS. The identification of compounds was achieved on the basis of both their mass spectra and retention times, and the analysis of reference samples. The samples for sequential TD-GC-MS and Py-GC-MS were initially ground into a fine powder prior to analysis. A weighed amount of these ground samples was taken and these samples loaded into quartz tubes before being inserted into the pyrolosis probe for TD/Py-GC-MS. The samples were thermally desorbed at 310°C, followed by pyrolosis at 610°C. Identification of the compounds was achieved on the basis of both their mass spectra and retention times, and the analysis of reference samples. The weights of samples analysed are included in the appendices provided (see Appendix 2-3).

Issues With GC-MS

There are numerous issues that have to be considered in the methodology of this study. Primarily among these is the difficulty in accessing samples and conducting primary data analysis. GC-MS is in an expensive and destructive analytical process, with initial costs of between $50,000 and $200,000, and 5% instrument costs annually (Sneddon et al 2007, 1003-1012). These issues with funding and accessibility to museum collections limit the possibility of primary data analysis. While primary data analysis would have been ideal in order to support this thesis, the restrictions imposed through the financial and time limitations of a one-year MA thesis made this impossible. This made the use of secondary data in support of the thesis hypothesis a necessity. Furthermore, some of the original data from Ms. Tunney was removed from the University of York archives, and therefore inaccessible. Consequently, this meant that out of a possible 27 specimens examined, only 14 can be provided with complete chromatographic data (see Appendix 2-3). Appendix 1 identifies all of the specimens examined in the analyses provided, while Appendix 2 and 3 include those with supporting chromatographic data. The results from all 27 specimens will be discussed, however those without supporting chromatographs and sample weights should be treated with caution. Even with these issues however, GC-MS can allow for the identification of exotic imports in the embalming agents of the mummified specimens in this study. Used in combination with existing literature on animal mummification, Egyptian religion, social structures, economics, and politics, we can build a picture of the interconnectivity of religion and socio-economics during this period. In turn, this can be used to hopefully reveal trends and inform future research strategies.

Chapter 6: Results

From the collated results from the GC-MS analyses conducted by Buckley & Tunney and Buckley & Fletcher, 53 samples were taken from the 27 mummified animal remains previously discussed. In total, 20 of the 27 mummified animals in the study provided (74%) contained inferred exotic embalming ingredients. Furthermore, 40 of the 53 samples tested (75%) contained inferred ingredients of an imported exotic nature (see Fig 21.0, 22.0, 23.0). These findings suggest the common use of these imported ingredients within the mummification process in Ancient Egypt, between 1069 B.C. and A.D. 395. Broadly, these can be sub-divided into three regional bands, Levantine, East African and North African. These geographic distinctions allow for correlations to be drawn between the ingredients identified in the embalming agents of these mummified specimens, and the common routes of trade and exchange discussed earlier. Although the term 'balsam' is often used to denote resinous material in general, the balsam identified by Buckley & Tunney and Buckley & Fletcher refers collectively to aromatic and phenolic acids. These can derive from balsamic resins, with examples including storax (*Liquidamber* orientalis), styrax (although extant sources in the Near East may no longer produce resin), *Umbeaserae*, the roots of plants including cereals and sedges (C*eperaceae*). Therefore, these 'balsams' do not provide a specific biochemical or geographic source. In contrast however, other materials identified through the GC-MS analyses can suggest the origin and nature of the ingredients utilised in the embalming process.

Native

Lipids

Plant Oils and Animal Fats:

From the 208 biochemical compounds identified by Buckley & Tunney and Buckley & Fletcher, 53 have been identified as plant oils and animal fats, accounting for 24.5% of the total sample (see Appendix 1-3). Naturally hydrophobic, these ingredients are useful in limiting potentially enzymatic decay. As previously discussed, it is difficult in GC-MS to identify the exact source of oils and fats, given their similar chemical morphology. This is seen in the results examined here, where the majority are identified broadly as plant oils/animal fats (see Appendix 1-3). However of these oils and fats, only castor oil is easily identified, in 1% of the total sample (see Appendix 1-3). This is due to the identification of the inferred presence of ricinoleic acid (see Appendix 2-3)

Wax and Beeswax:

The presence of biochemical compounds inferred as coming from wax and beeswax has been identified in 35 of the 208 samples, accounting for 17% of the total. The use of waxes, beeswax in particular, has been inferred through the identification of long-chain alcohols, acids and hydroxyacids, for example ω-dicarboxylic acid (see Appendix 2-3).

Imported

The Levant

Conifer Resins:

Of the 88 identified ingredients of a non-Egyptian origin, 78 (89%) are associated with the region that now encompasses, Jordan, Israel, Palestine, Syrian and Lebanon. The majority of these (36/78, 46%) can be attributed to the resinous material of numerous species of the taxonomic class *Pinophyta* (Coniferous Plants). Materials identified through GC-MS as Conifer Resin (10/78, 13%), Conifer oil (2/78, 3%) and Conifer Pitch (3/78, 4%) are all derived from the resin of Levantine coniferous trees. Although, identifying the sources amongst a number of possible species is difficult. However, other coniferous plant materials have been identified in the mummified remains in this study with a greater degree of accuracy. These include the identification of 21 samples of resinous material from two sub-divisions of the family *Pinaceae*. These consist of the identification of resinous material from the genus *Cedrus* (Cedars) and *Pinus* (Pines), with 3 (4%) and 18 (23%) respectively. While trees in the group *Pinophyta* are common throughout a myriad of ecosystems across the world, numerous species such as *Cedrus libani* are native to the region directly to Egypt's north in the Levant (Gardener 2013). Trade routes in this region are well attested in Ancient Egypt, and are an important stimulus for many political and military interactions throughout Egyptian history. Compounds in the pine resins (B-thujene, α-pinene, β-pinene and bornyl acetate) have shown antibacterial and antifungal properties (Hong et al 2004, 863-866), while cedar oils (α-pinene, β-myrcene, limonene, terpinolene, α-terpinene and γ-terpinene) are still commonly used in pet care products as an insect repellent (Craiga et al 2004, 217-224). Results from Buckley & Tunney and Buckley & Fletcher infer the presence of these compounds through the identification of aromatic hydrocarbons such as retene, and the diterpenoid dehydrobietic acid (see Appendix 2-3).

Pistacia:

Other materials of a Levantine non-coniferous source have also been identified through the GC-MS analyses of Buckley and Tunney. These predominantly consist of the identification of 18 (23%) instances of resinous material from the genus *Pistacia*. All of the numerous *Pistacia* species are native to the Middle East and Central Asia, placing them within the recognised range of the Levantine trade routes discussed previously (Al-Saghir and Porter 2012, 12-32). The yellowish, transparent, resinous material exuded from plants of the genus *Pistacia* is known commonly as Mastic. Mastic has been previously identified in both analyses of mummified remains, and on bowls discovered from the site at Amarna. (Stern et al 2003, 457-469). Biochemical elements of mastic (verbenone, α-terpineol, linalool and pentacyclic triterpenes) are known for both antiseptic and anti-microbial effects (Connan et al 1999, 35-50; Doi et al 2009, 135-142). *Pistacia* has been identified in the GC-MS analyses conducted through the identification of 7-oxodehydroabietic acid and oleanonic acid (see Appendix 2-3).

Bitumen:

In addition to those plant-based inferred ingredients, the GC-MS analyses also identified 3 samples (3%) of Bitumen within the mummified specimens. As previously discussed, Bitumen is a naturally occurring hydrocarbon mixture formed from petroleum impregnating porous rocks such as sandstone or limestone (Abdel-Maksoud and El-Amin 2011, 139). While bitumen sources are known from across the world, the bitumen used in Egyptian mummification is traditionally associated with the Dead Sea in Palestine (Barakat et al 2005, 211-228). However, a closer source at Gebel Zeit in Egypt's Gulf of Suez, has been suggested in recent years (ibid). Biochemical analyses through GC-MS appear to indicate both the Dead Sea and Gebel Zeit as sources of bitumen in mummification. Both of these regions are well within the trade areas in both the Old Kingdom and New Kingdom, suggesting both sources are well established (Abdel-Maksoud and El-Amin 2011, 139) (Barakat et al 2005, 211-228). Therefore, both are possible sources for the bitumen presence inferred in the mummified animal remains in this study (Maurer et al 2002, 751-762; Harrel and Lewen 2002, 285-293). It has been suggested that bitumen comes into extensive use in the Third Intermediate, Ptolemaic and Roman Period, perhaps due to the expansion of trade routes during this period (Clark et al 2016, 12). Bitumen's use in mummification comes from its antibacterial properties, and its black colouration (ibid). This represents the black silt of the fertile Nile floods, and in turn, concepts such as regeneration and rebirth (Nissenbaum and Buckley 2013, 563-568) (Clark et al 2016, 12). Unfortunately those specimens associated with inferred bitumen use do not have associated chromatographic data, due to the sampling issues previously stated (see Appendix 2-3).

East Africa and Arabia (Punt)

Burseraceae:

A much smaller number of identified ingredients (22/88, 25%) can be attributed to an East African or Southern Arabian provenance, in the regions the Egyptians called Punt. These are described in the analyses as plant/sugar gum resins, with Myrrh suggested as a possible source in some cases. Determining the precise species that these samples came from, however, is difficult. Gum resins typically can be attributed to thorny bushes of the genus *Boswellia* and *Commiphora*. These are common in modern Eritrea, Somalia, Djibouti, Ethiopia and Yemen (Lucas and Harris 1999, 91). *Boswellia* and *Commiphora* species produce the resinous materials frankincense and myrrh, which are famous for their uses as aromatic incenses (ibid). Historical sources suggest the role of frankincense and myrrh in the mummification process, while GC-MS analyses of mummified human remains infer the presence of myrrh (Hamm et al 2003, 73-83). Some of the core biochemical components of myrrh (α-pinene, sesquiterpene hydrocarbons, δ-elemene, β-bourbonene, furanosesquiterpenes and germacrene type compounds) are used as insecticides and insect repellants, while also possessing antiseptic properties (Tipton et al 2006). Both *Buseracea* and *Pistacia-Mastic* resins belong to the group known as the triterpenoid resins: mixtures of triterpenoid molecules with mainly pentacyclic tetracyclic skeletons (Colombini and Modugno 2009, 16-17). 7 out of 109 imported ingredients inferred (6%) from the analyses specimens were identified as belonging to triterpenoid resins, although identifying the source plant species (and by proxy the geographic source) is difficult. *Buseracea* gum resins indicate the importation of goods from the region the Egyptians identified as Punt, supported by archaeological evidence. Buckley & Tunney and Buckley & Fletcher have identified Sugar/plant gums, through the inferred presence of threitol and pentitol (see Appendix 3).

North Africa

Sandarac:

From the GC-MS analyses, we can also identify the presence of exotic plant materials native to North Western Africa. Specifically, 3 samples taken from a Greco-Roman mummified crocodile from Memphis (1.1983.95, Bolton Museum) have been inferred as being sandarac, making up 3% of the total samples of an imported nature identified (see Appendix 1-3). This has been identified biochemically through the inferred presence of 12-acetoxysandaracopimaric acid (see Appendix 2). Sandarac is a translucent yellow resinous substance, biochemically consisting predominantly of labdane compounds (70%), along with sandaracopimaric acid, 12-acetoxysanaracopimaric acid, and phenols such as totarol (Colombini and Modugno 2009, 15). The resin is extracted from the small cypress-like tree *Tetraclinus articula* (Kononenko et al 2016, 2). While also native to Malta and Spain, *T. articula* is most prevalent in the Atlas Mountains of North Africa, in modern Algeria, Morocco and Tunisia (Sanchez Gomez et al 2011). While the presence of sandarac has not been attested in mummified remains outside the GC-MS analyses considered, sandarac is well-known for its use as a varnish. For example, accounts of its use to protect paintings come as early as the writings of Leonardo Da Vinci. (Kononenko et al 2016, 1-3). Additionally, sandarac belongs to the group of materials identified as diterpenoid resins. This is the family to which the pine and conifer resins, previously discussed, also belong (Colombini and Modugno 2009, 14-16). Therefore, it can be assumed sandarac resin provide a similar preservative function to the other diterpenoid resins considered in this thesis.

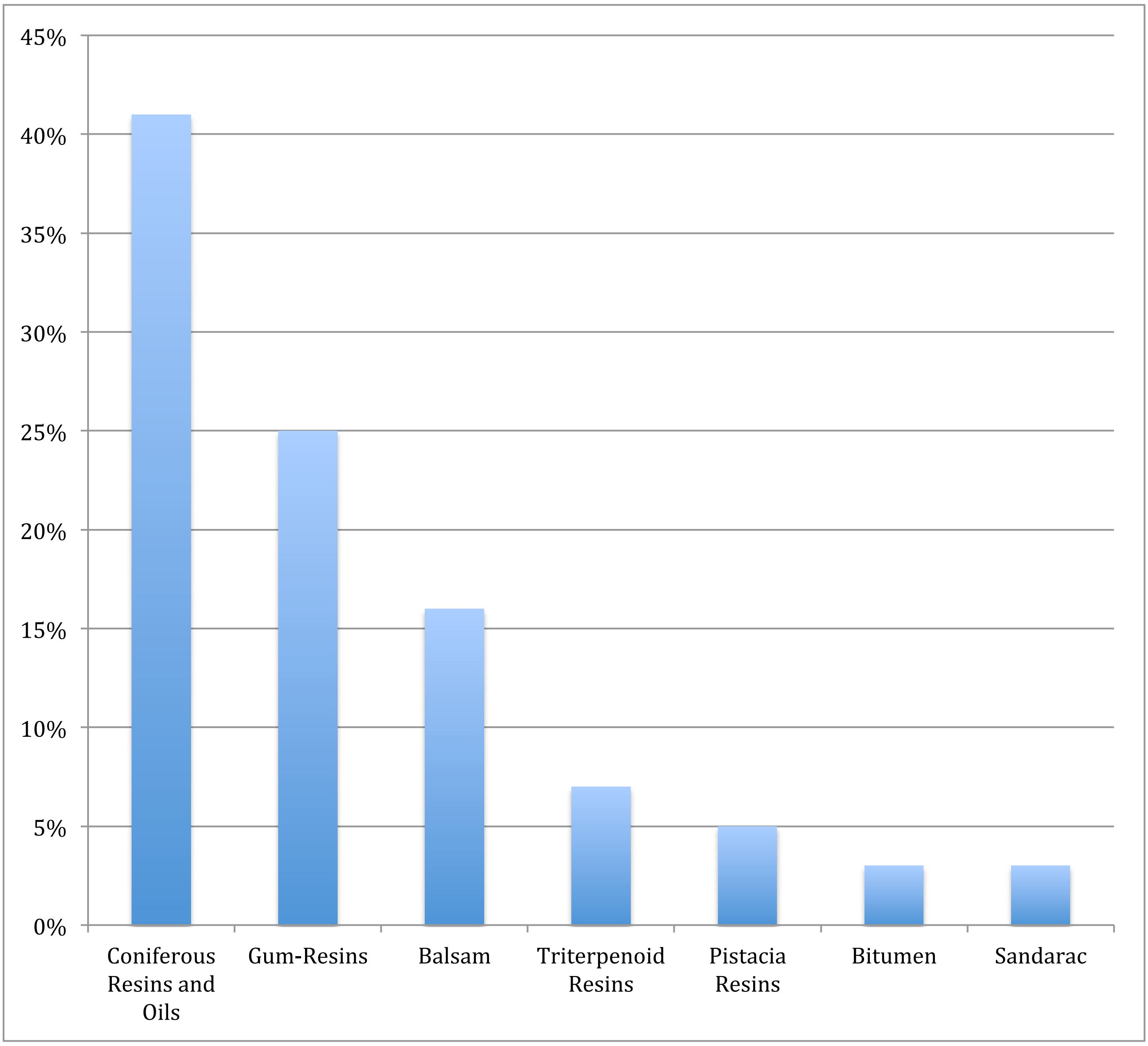

Fig. 22.0: Proportions of inferred non-Egyptian embalming ingredients, identified through GC-MS, produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

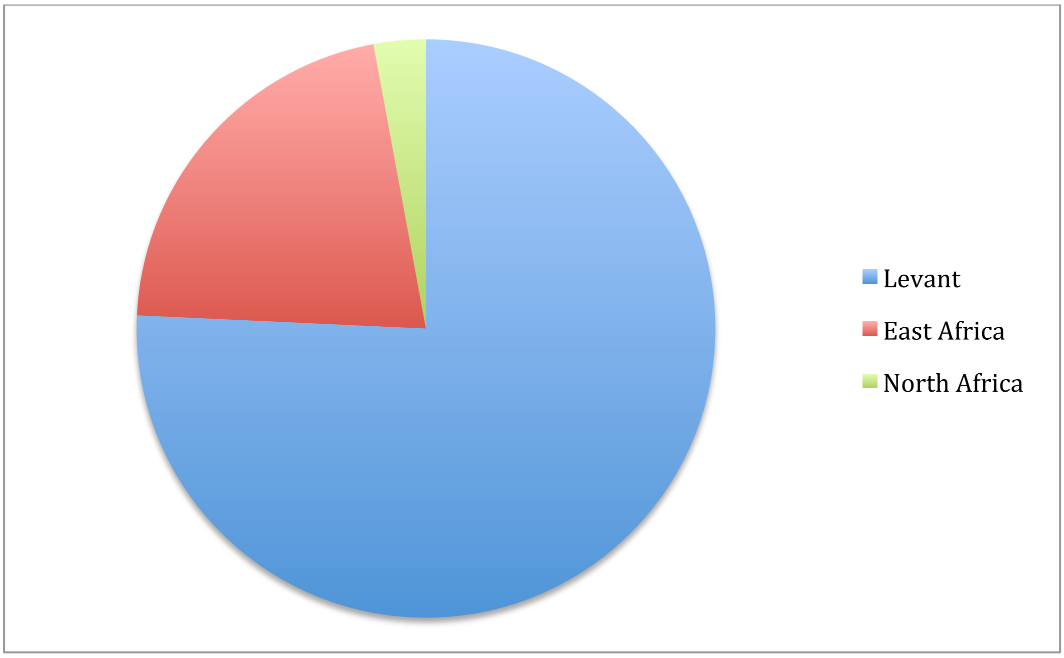

Fig. 23.0: Comparison of distribution of inferred imported ingredients, by geographic origin, produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

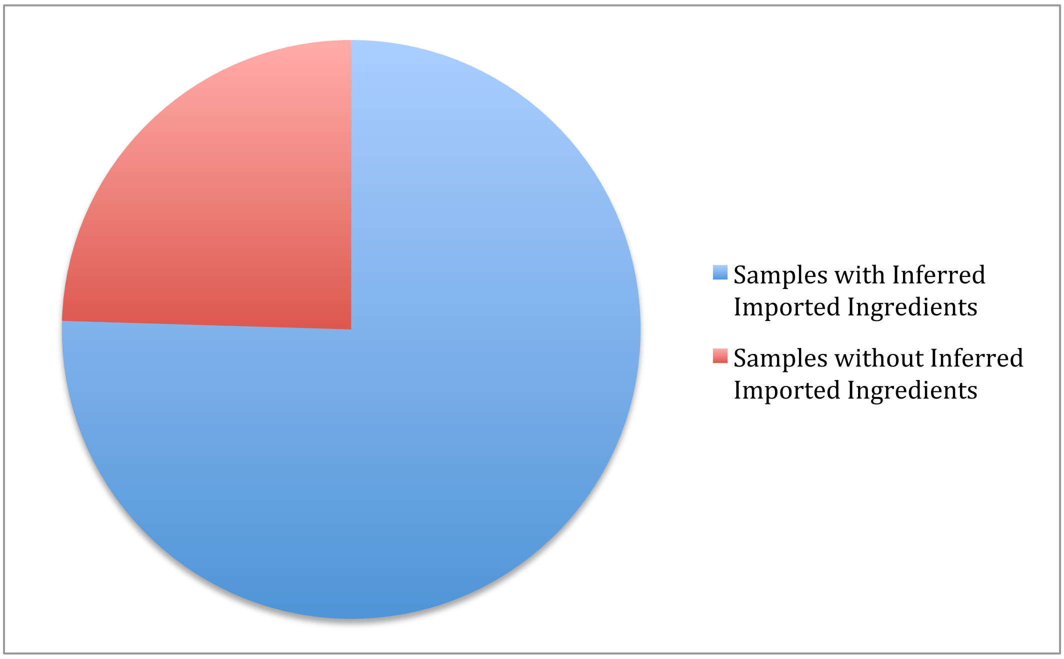

Fig. 24.0: Proportion of sample (subjected to GC-MS) suggested to contain inferred imported ingredients, produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

Identification of Imported Embalming Agents by Species

An examination from the data collated from the GC-MS studies of Buckley & Tunney and Buckley & Fletcher suggests that embalming recipes are relatively similar across the different species of mummies identified, and mirror the findings more generally. Waxes, Plant Oils and Animal Fats are the most commonly occurring ingredients, while Levantine coniferous and pistacia resins are typically more utilised than East African gum-resins (see Fig. 25.0-29.0). Additionally we see the occasional use of bitumen, castor oil and sandarac, mirror the results more generally (see Fig 25.0-27.0). While there are differences in the percentages of use of different embalming agents between species, this more likely than not an effect of the small sample size, rather than any suggestion of a preferred use of certain ingredients amongst certain species. The exception appears to be with crocodilians, as they are the only species associated with the use of sandarac. However, it should be noted that this derives from only one specimen in this study, and therefore more data would be necessary to suggest any definitive correlation.

Identification of Imported Embalming Agents by Provenance

As with the identification of embalming agents in difference species, the data provided by Buckley & Tunney and Buckley & Fletcher suggests that embalming recipes are relatively similar across Ancient Egypt. Once again Waxes, Plant Oils and Animal Fats are the most common, with Levantine imported conifer and pistacia resins utilised more than East African gum-resins (see Fig. 25.0-29.0). This appears to be the case in both the Memphite and Non-Memphite specimens, suggesting that recipes are relatively uniform across the later Ancient Egyptian state (see Fig 0.0). However with so many of the specimens not having any identified origin, any conclusions regarding such a trend should be treated cautiously.

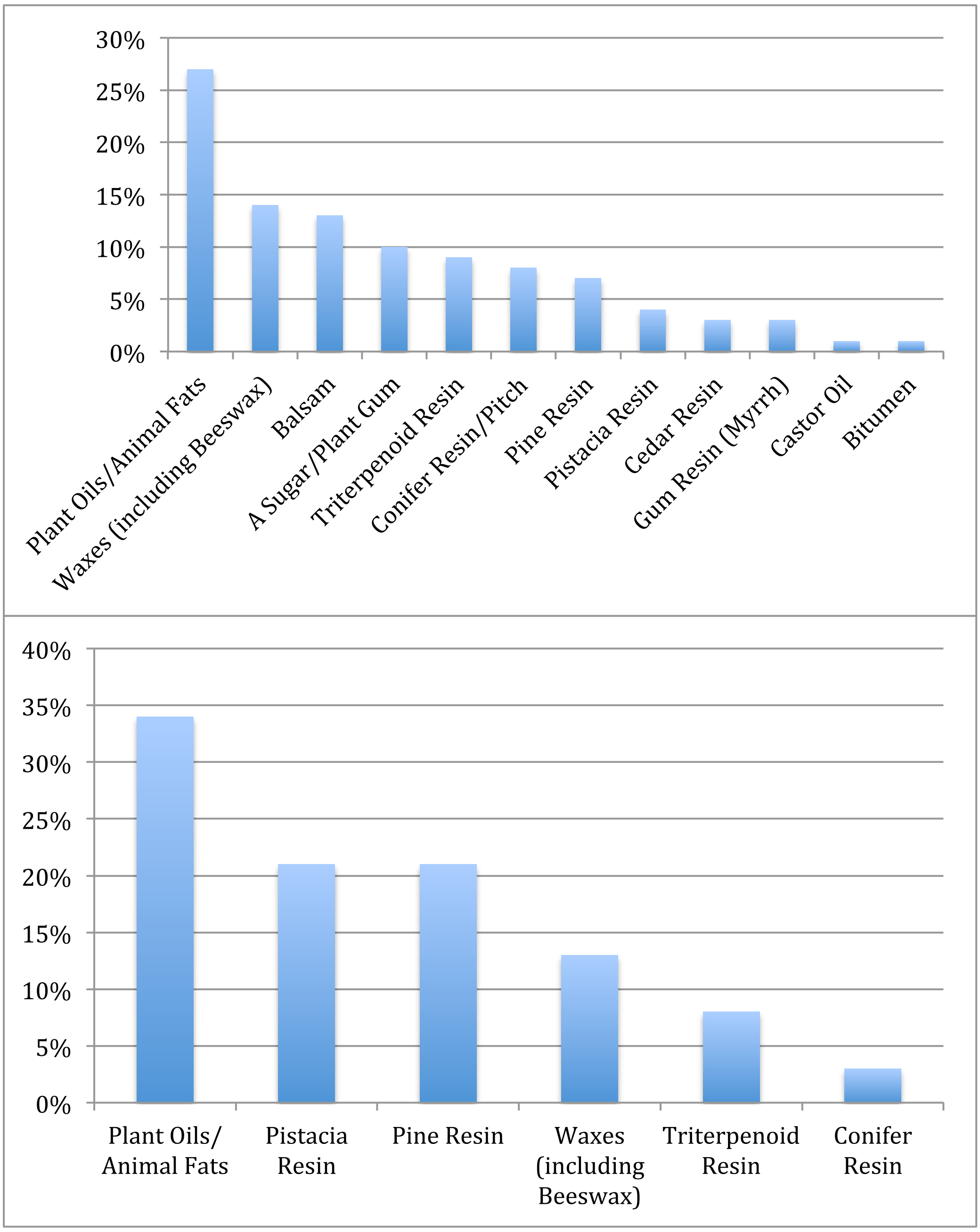

Fig. 25.0: Identified biochemical compounds in mummified cats (above) and birds of prey (below), produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

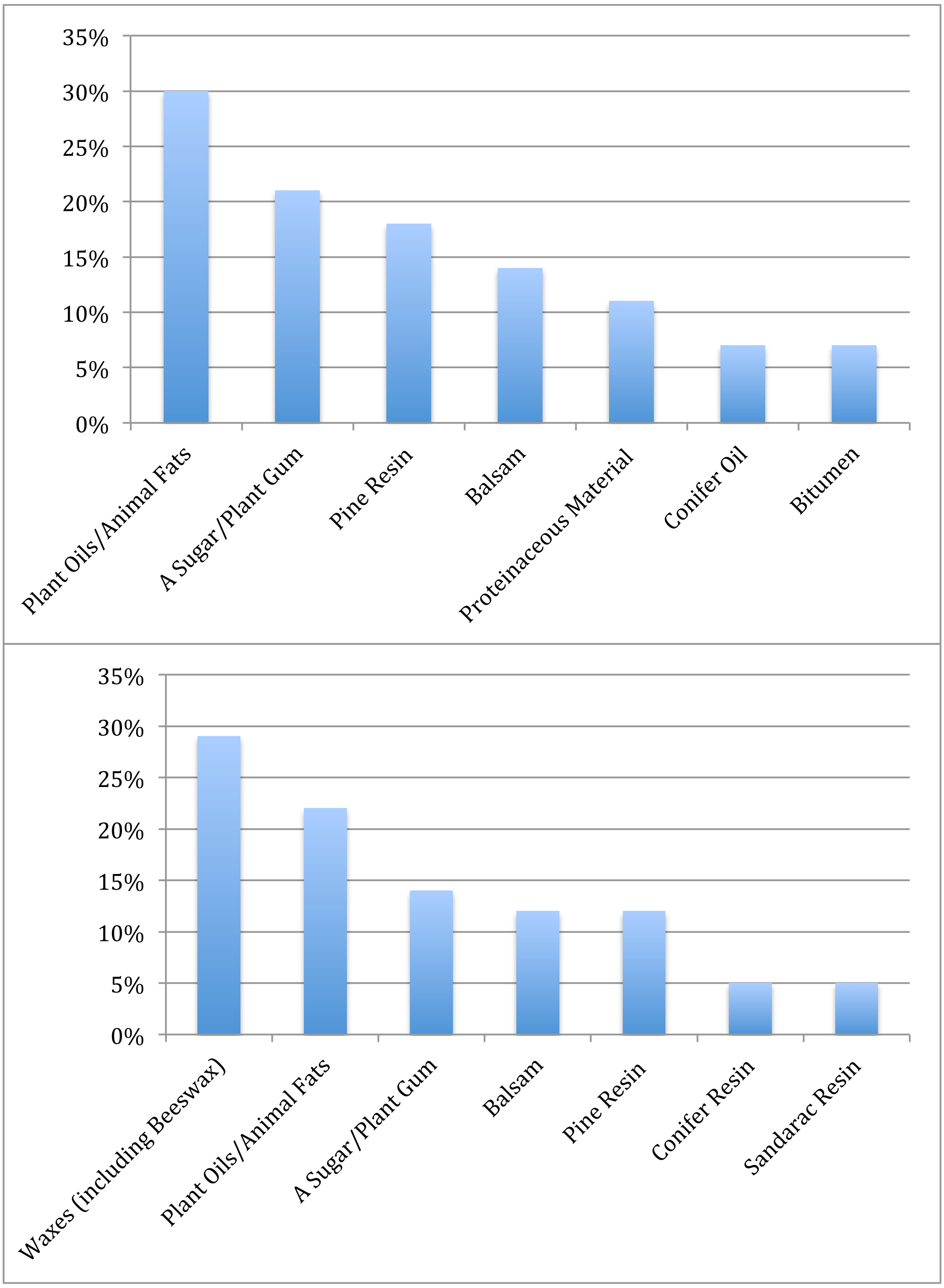

Fig. 26.0: Identified biochemical compounds in mummified ibis (above) and crocodiles (below), produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

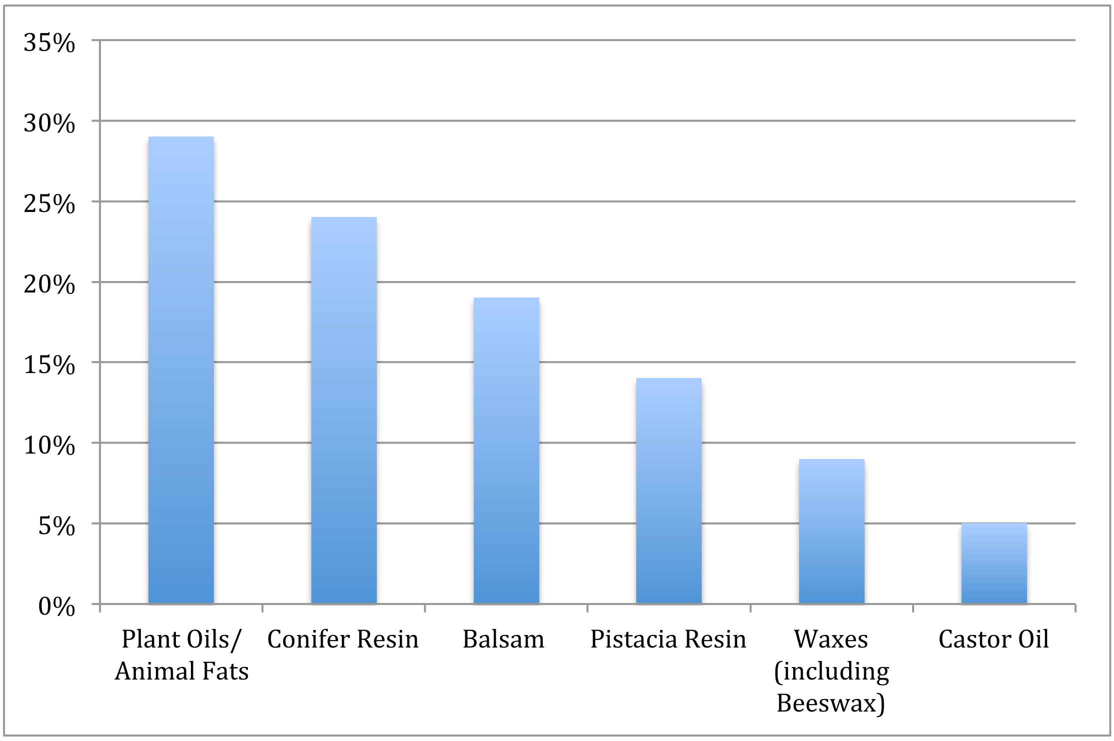

Fig. 27.0: Identified biochemical compounds in mummified remains from other identified species, produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

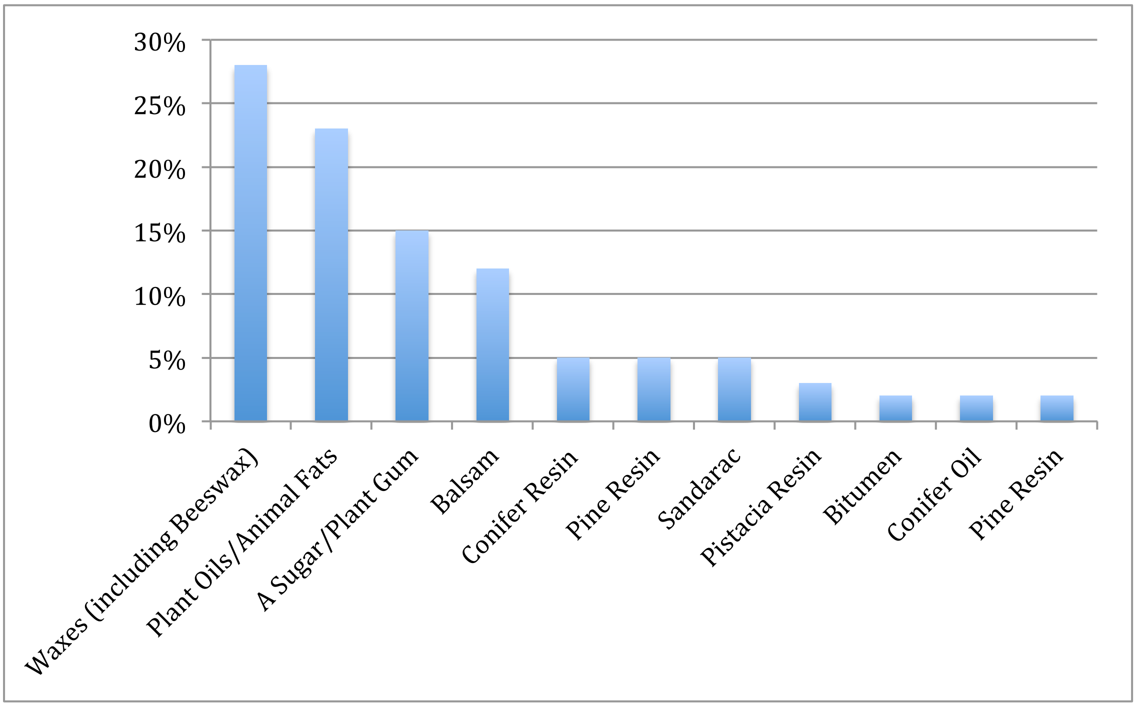

Fig. 28.0: Identified biochemical compounds in mummified remains of a Memphite provenance, produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

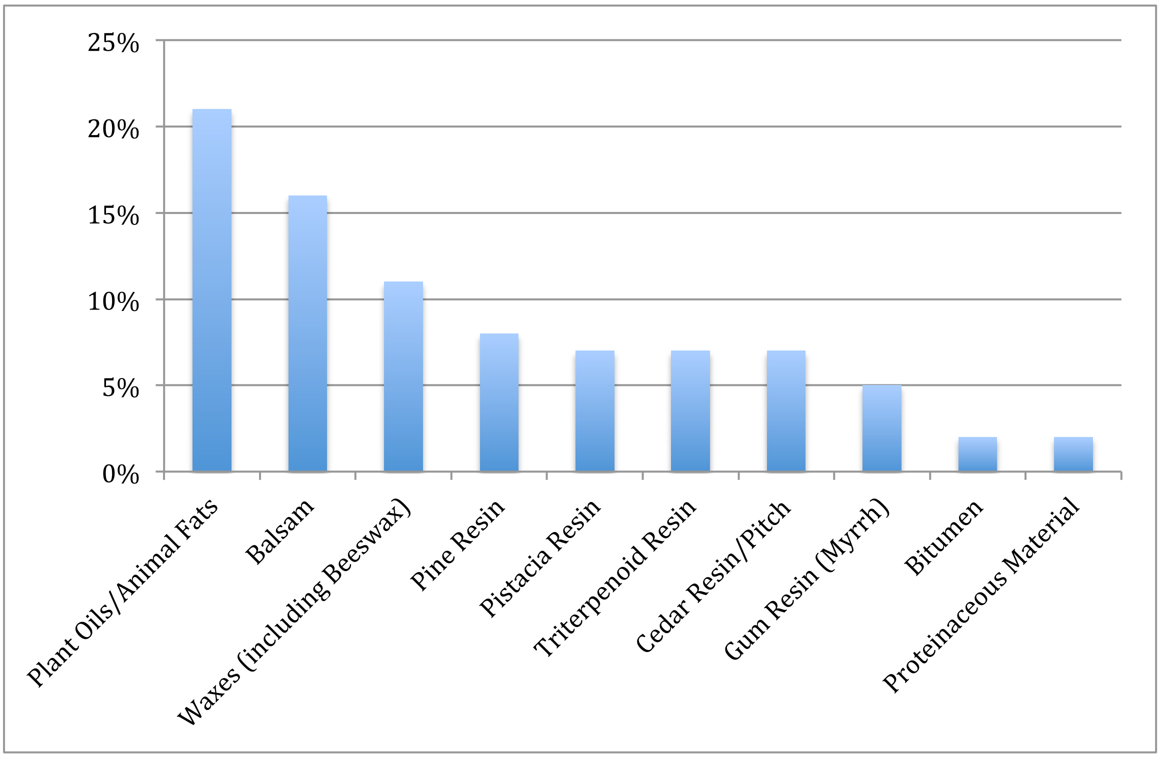

Fig. 29.0: Identified biochemical compounds in mummified remains of a non-Memphite provenance, produced by author (see Appendix 1, 2) (Buckley and Tunney 2016) (Buckley and Fletcher 2016).

Interpretations of GC-MS Analyses of Mummified Animal Remains

From the results considered from the GC-MS analyses provided by Buckley & Tunney and Buckley & Fletcher, we can begin to identify trends and correlations between the imported ingredients identified through biochemical analyses, and other contextual information such as the species, date and provenance of the mummified specimens. Results gathered in support of this thesis suggest the importance of mass animal embalming for votive mummies in later Ancient Egyptian society, in terms of their social and economic significance. They also reveal a relatively common use of ingredients from beyond the borders of Egypt in the embalming process. This common use of these non-native embalming agents has been suggested to be influenced by the political upheaval from at least 800 B.C. Successive influence from foreign governing authorities could have allowed a greater volume of trade of these necessary imported ingredients into Egypt, due to the associated cultural homogeny and expanded trade routes. This would have allowed for significant expansion of the sites of animal cult worship, as well as the increased mass production of votive mummies. This was in order to meet the religious demands of the native Egyptian population, as well as the increased revenue and support for the non-Egyptian ruling class. Furthermore, the mummified remains considered in this thesis allow us to consider the use of GC-MS analyses in understanding the relationship between long-distance trade and animal mummification. Subsequently, these findings can be used to assess the potential implications for future research methodologies in this area.

Chapter 7: Discussion

The most effective methodology at present used to consider the impact of long-distance trade, and the importation of goods, on the mummification of animals, comes through GC-MS analyses. This study will draw on the collated results of the analyses by Buckley & Tunney and Buckley & Fletcher (see Appendix 1-3) (Buckley and Tunney 2016) (Buckley and Fletcher 2016), in order to identify the inferred presence of imported exotic ingredients in the embalming agents of individual mummified specimens. In addition, this study will interpret this secondary data, in correlation with information such as provenance, dating and species. This is in order to discuss more implicitly the socio-economic role and interaction between religious practice and long-distance trade in Ancient Egypt. Furthermore, this study will refer back to the archeological context discussed in earlier chapters when considering the results of biochemical analyses (see Chapter 2-4). By utilising a combination of these analyses, in conjunction with a wider context of Egyptian animal mummification and long-distance trade, we can begin to consider how these two may link. From this, we can determine how this link can reveal socio-economic trends in Ancient Egyptian culture.

Conifer Resins and Levantine Trade:

From the findings of the GC-MS analyses in this thesis, 17% of those identified ingredients belong to the species in the group *Pinophyta*. These species are typically associated with the Levantine region analogous with the modern states of Lebanon, Jordan, Israel, Palestine and Syria. Therefore, the findings of this study mirror our wider knowledge of the Ancient Egyptian import economy. Archaeological and textual evidence suggests the importance of the import and use of cedar for timber, resin and oil, throughout much of Egyptian history. This seems to include its use in the embalming process, as both an aromatic and a hydrophobic/antibacterial preservative. An interesting finding from these analyses is the predominance of these conifer resins in mummified remains dated to the 3rd Intermediate and Late Period. This seems to contradict the findings in previous research more, which seem to attribute the use of *Pinophyta* resins becoming more common in Greco-Roman Egypt (Buckley and Evershed 2001, 837-840). Moreover, the increased number of mummified animals from this period in this study more generally conflicts with the assumption that animal mummification becomes more prevalent from the Ptolemaic Period onwards, as a direct result of political influence. It is quite possible that in the case of this study this simply represents an observational bias, with a greater number of specimens in this relatively small study from an earlier chronological phase. What is clear however is the importance of *Pinophyta* resinous ingredients in the embalming process, having been identified in over 40% of the specimens. This is supported by similar findings from GC-MS analyses of human and animal mummies from a similar chronological phase (see Chapter 4). Given the huge number of mummified animals produced in this period, and its regular use in embalming, massive volumes of this material would have to imported, predominantly through maritime trade with port cities such as Byblos, in order to meet production demands. Given the textual evidence for the Ptolemaic government and temple authorities guaranteeing of Levantine resin imports, such findings support the influence of the ruling in elite in the financing and supply of goods for the embalming process.

Comparisons between Pistacia and Conifer Usage:

From the same geographic origin as the genus *Pinophyta*, resinous material from the pistacia plant accounts for 9% of the total compounds identified. Given regionality, it can be inferred that both ingredients probably follow similar routes of import into Egypt. Furthermore the use of these resinous materials is unsurprising, given the antimicrobial and antiseptic properties of the substance, and the evidence its use in previous studies. What is interesting however is that *Pistacia* resin usage seems to be far less frequent than that of Levantine conifers from the same region. One possible reason for this is the alternative uses for these cedars in Egyptian society. Archaeological and textual evidence suggests the regular import of Levantine cedar timbers, with these hardwoods particularly valued for in Egyptian shipbuilding. Therefore, there is a significant possibility that both *Pinophyta* resins, oils and hardwoods part of the same acquisition and production process. Subsequently, this could essentially make the production and trade of cedar resins and oils a byproduct of timber industry. This could reduce the overall cost of utilizing this material, making conifer resins a cheaper alternative to pistacia resins. Furthermore conifer trees are much larger than pistacia plants, allowing far more resin to be extracted per plant. This could further account for the discrepancy seen between *Pinophyta* and *Pistacia* usage in the mummified remains analysed in this thesis.

Difference in Usage of Bitumen Compared to Plant Resins:

Buckley & Tunney and Buckley & Fletcher's analyses have also revealed the presence of bitumen, accounting for 1.5% of the biochemical compounds identified. A naturally occurring hydrocarbon, bitumen is suggested to have antimicrobial properties that would aid the embalming process. Furthermore, the dark colour of the material is suggested to have a cosmological association with the afterlife. In spite of this association, the evidence in both this thesis and previous literature suggests that the use of bitumen in mummification is relatively infrequent. While clearly in use, bitumen appears to be far less prolific in embalming practice than suggested in early literary sources. Although the use of local Egyptian bitumen sources has been suggested at Gebel el Zeit, contemporaneous literary accounts seem to infer that the majority of bitumen is can still be traced to the Dead Sea. Therefore, this material is more likely than not transmitted by the same routes of import as the conifer and pistacia resins identified in this thesis. However, the use of bitumen seems to be far less frequent. There could be a number of possible causes for this discrepancy. The most likely of these is the difficulty in accessing bitumen sources. As previously stated, bitumen floats to the surface of hyper-saline water bodies, namely Dead Sea, and is collected. Subsequently, this makes bitumen harder to acquire, and probably makes the collection and import of the material more costly. This would make the process of bitumen use in embalming more expensive, and potentially means the material is used in smaller quantities.

Growing Use of East African (Puntite) Gum-Resins:

Embalming agents of an inferred East African origin make up 11% of those ingredients identified. These are attributed the genus *Boswellia*, from which the species that produce myrrh and frankincense gum resins belong. These ingredients have been recognized to have similar antimicrobial and hydrophobic properties as the Levantine resinous materials identified in this study. It interesting therefore that these materials are used in a far lower frequency than those ingredients native to the Levant. Given the similar biochemical action, this distinction in usage is more likely than not determined by geographic factors. As previously stated, these materials are associated with the region known to the Egyptian's as Punt, roughly analogous with modern Eritrea, Somalia, Ethiopia and Yemen. This region lies a far greater distance from Egypt than the Levant, and appears to have less direct political influence from the later Ancient Egyptian state, given this region never fell under the direct control of the Persian, Ptolemaic or Roman Empires. This could be seen as increasing the cost of the acquisition and transport of these gum resins, and could account for the lesser use in the mummification process. However we must also consider the possibility that some gum-resins may have been procured from locally from imported and cultivated plants, as is seen in the Deir el-Bahari reliefs, as a possible means of circumventing the need to import the resinous material into Egypt. This is less likely though, given the scale of the use of this material in the embalming process.

Atlas Mountain Sandarac: Evidence for North African Trade Links?

While the majority of the imported ingredients identified through GC-MS are of a Levantine or Puntite origin, 3 samples present in the Greco-Roman period mummified crocodile specimen 58.911 (Bolton Museum) have been attributed to the biochemical compound sandarac. These samples account for 4% of the imported ingredients identified throughout the analyses conducted by Buckley & Tunney and Buckley & Fletcher. This specimen represents a very interesting outlier, as sandarac is exclusively native to the Atlas Mountains in modern day

Morocco, Algeria and Tunisia (North Africa). Hypothetically, the use of sandarac as part of an embalming recipe is not surprising. This is because of its biochemical qualities as an antibiotic and hydrophobic agent, evident through its recorded use in preserving oil paintings.

The presence of sandarac in this study is interesting, as it does not fit with existing archaeological and textual evidence for typical routes of long-distance trade and exchange throughout Ancient Egyptian history. However, with the associated mummified animal of a Greco-Roman origin, it potentially presents some interesting implications. From around 30 B.C., both Egypt and the Atlas Mountain region were under the political administration of the Roman Empire. Based on the suggestion that the same political and cultural control facilitates long-distance trade through shared administrative systems and cultural homogeny, the Roman period may have seen periodic import and use of sandarac into Egypt from North West Africa. Furthermore, an examination of primate skeletal material, from the Ptolemaic Baboon Catacomb at North Saqqara, identifies 21 Barbary Macaques (*Macaca sylvanus*) (Goudsmit and Brandon-Jones 1999, 45-53). This species in native to North West Africa, with this habitat overlapping that of *Tetraclinis articulata*, from which sandarac is sourced (ibid). These findings could support a trade of both live animals, and embalming ingredients, from a region not traditionally associated with Ancient Egyptian trade. However, with only 1 of the 27 mummified specimens in this study obtaining sandarac in the embalming agent, this poses an issue. This makes it difficult to identify whether this study represents an outlier, or whether it is part of a larger trend for the use of sandarac in animal mummification, in the limited scope of this study. In spite of these limitations, the presence of North West African sandarac in specimen 1.1983.95 (Bolton Museum) provides an insight into how trade from this region may have influenced the mummification of animals.

What can these findings tell us about the mechanics of mummification and trade?

The Importance of the Royal Authority in Administering the Supply of Ingredients?

From the results considered from the GC-MS analyses provided by Buckley & Tunney and Buckley & Fletcher, we can begin to identify trends and correlations between the imported ingredients identified through biochemical analyses, and other contextual information such as the species, date and provenance of the mummified specimens. Results gathered in support of this thesis suggest the importance of mass animal embalming for votive mummies in later Ancient Egyptian society, in terms of their social and economic significance. They also reveal a relatively common use of ingredients from beyond the borders of Egypt in the embalming process. This common use of these non-native embalming agents has been suggested to be influenced by the political upheaval from at least 800 B.C. Successive influence from foreign governing authorities could have allowed a greater volume of trade of these necessary imported ingredients into Egypt. With around 70 million mummified animals suggested to have been produced in the latter 800 years of Ancient Egyptian history, this would potentially have required tens of thousands of amphorae containing imported resins to have been imported on an annual basis, significant trade systems would be needed to support such a demand. Cultural homogeny between Egypt and the rest of the Near East under the Achamenid, Ptolemaic and Roman Empires allows for goods to be transported, administered and taxed under a single authority, easing their movement (see Chapter 2). Meanwhile the growth of shipping ports in controlled by the Phoenicians (such as Byblos and Tyre), the foundation of Greek merchant Colonia such as Naucratis, and infrastructure projects such as major roads and canal systems in the Roman Period, allows exotic resins to be imported in far greater quantities at a reduced cost (see Chapter 2). This would have allowed for significant expansion of the sites of animal cult worship, as well as the increased mass production of votive mummies. This was in order to meet the religious demands of the native Egyptian population, as well as the increased revenue and support for the non-Egyptian ruling class. Furthermore, the mummified remains considered in this thesis allow us to consider the use of GC-MS analyses in understanding the relationship between long-distance trade and animal mummification. Subsequently, these findings can be used to assess the potential implications for future research methodologies in this area.

Evidence from this thesis suggests the importance of the elite ruling authority in the control of the import of embalming agents in animal mummification, and by proxy the temple economy itself. Mummified remains from this latter phase of Egyptian history have been found in huge numbers. If the samples from this study are considered representative, then the use of imported ingredients was relatively common. This would therefore have required huge quantities of embalming agents, including those imported from abroad, in order to support the quantity of mummified remains produced. Acquiring these goods would have therefore required significant resources to fund this, particularly given the costs associated with the long-distance import of goods. Ptolemaic sources in particular suggest the importance of the ruling elite in providing the funds and administrative bureaucracy to provide these goods. This includes the presence of an apparent government monopoly on the import of Levantine 'turpentine', likely to be cedar and pistacia resins, under the direct control of the ruling system. Given the evidence for the use similar embalming recipes across the last eight hundred years of Ancient Egyptian history, it is likely such a system of state control existed in a similar fashion across this chronological phase. Such an association of religious practice with the political authority has a precedent throughout dynastic Egyptian history. This supports the use of resources and administration from the government elite to support the mass production of mummified animal remains. Furthermore, this supports the theory presented by Salima Ikram on why we see the growth of animal mummification in later Ancient Egypt. She suggests that in order to placate a restless native population, foreign rulers would enable the proliferation of Egyptian religious practice and cults. This includes the ability to produce large numbers of low cost mummified animal remains for sale to pilgrims as votive offerings. To an extent the findings of this thesis support this statement. In controlling the supply of imported embalming ingredients, the ruling elite (particularly the Ptolemaic Dynasty) could potentially control a restless native population through a dominant role in everyday religious practice (by controlling the supply of votive offerings) , and limit the resistance to foreign rule (see Chapter 3). We can therefore possibly see a change in religious and cultural behavior of the Ancient Egyptian population, directly as the result of political and economic policy. The greater percentage of imported ingredients in the Greco-Roman period than the 3rd Intermediate and Late Period, mirrors the suggested use of the adoption of Egyptian religious practice as a political ploy. With a larger sample of better-sourced data, perhaps this relationship can be examined more extensively.

The influence of the control of the elite on the import of embalming agents can be seen to have a consequence on the wider archaeological landscape. Evidence from the archaeological record of these sites suggests the need for economic systems in support of the embalming of votive mummies. This evidence is particularly prevalent from the investigations of North Saqqara. Investigations of the Ibis catacombs suggest the presence of residential worker communities. This is in addition to evidence for other forms of economic activity, such as vendors for votive statuettes. This community of workers would act in support of the religious class (responsible for embalming the votive mummies), and visiting pilgrims who purchased these offerings. Such an economic system mirrors the model presented by Carol A. Smith (1971), for the impact of high-value trade in urban development in Early Medieval Emporia (Smith 1976, 51). It could be argued that, by controlling the production of votive mummies as a high-value resource, the priestly class (Katachoi) could demand resources and support from the general population. The presence of residential worker communities at North Saqqara could therefore be seen as the growth of a population to provide the necessary resources for this group. Subsequently, the control of the imported ingredients could be seen to directly influence the growth of economic communities at sites associated with animal mummification, such as North Saqqara. The predominance of mummified animal remains at large necropolises, in both this sample and the wider archaeological record, supports the importance of these sites in the production of votive offerings.

Why do we see the Choice of these Materials?

While this thesis has examined only a small number of mummified specimens, we can still begin to consider why Egyptian embalmers may have utilised some of the different ingredients identified through GC-MS. From a biochemical point of view, all of the identified agents identified show properties that would aid the embalming process. This includes those that have been imported. However, the relative frequencies of these individual components reveal a number of possible trends. From the dated specimens analysed, we see an increased use of imported ingredients in embalming mixtures, up from 53% to 61%. This could be the case of embalmers becoming more aware over time of the antimicrobial and hydrophobic properties of conifer and gum resins, in addition to symbolic use (Buckley and Evershard 2001). However such increased use had economic consequences. If this is taken as being a representative sample, it suggests an increased accessibility of foreign goods in the embalming process in the Greco-Roman Period (332 B.C- A.D. 395) than in the 3rd Intermediate and Late Period (1069-332 B.C). These goods are most commonly associated with two regions, the Levant and East Africa. Therefore this sample can be seen to identify that the use of exotic embalming agents mirrors the wider pattern of Ancient Egyptian long-distance trade networks. More importantly though the results seem to mirror the socio-economic progression and events throughout this latter phase of Ancient Egyptian history. An average increase in use of imported ingredients between the two phases of 8% is significant, and once again mirrors the events we can identify in the archaeological and historical record. Evidence for the government financing the import of conifer resins in the Ptolemaic Period, for example the increase in port building and maritime connections to Punt, can possibly account for this increase. This is particularly interesting, given that the use of East African materials is seen to increase by a 2% margin in the Greco Roman samples analysed, although this small a margin could simply be the result of sampling issues. It is also interesting to note the lessening use of animal fats and plant oils, including castor, from 28% to 17%. Oils and fats are naturally hydrophobic, while castor oil has been shown to have antibacterial qualities. These are also materials widely considered to be sourced locally, either as a byproduct of the meat industry or agricultural processes. Therefore, these are likely to be far more inexpensive than imported materials. The drop in percentage use of these materials and increase percentage use of imported resins and other materials suggests an increased accessibility of foreign goods. As to why these are chosen over native plant oils and animal fats, there are a number of possible reasons. With the natural aroma and preservative qualities, it can be argued that conifer, pistacia and gum resins could be considered a superior material. Therefore, when the availability of these exotic ingredients increases with an expansion of the import economy, and the increased commercial accessibility of these goods. However while the use of East African ingredients increases in the Greco-Roman Period, throughout the specimens the use of Levantine conifer resins is by far the most common of the ingredients seen, imported or otherwise. As previously iterated, this is likely due to economic, political and geographic circumstance. The Levant is far less distance for merchants to travel, decreasing the expense of transporting goods. This makes the use of Levantine imports cheaper than those from East and North Africa. Subsequently, this could allow for greater quantities of embalming material to be acquired at a lesser cost to the administrative authority required to finance it. The region also has significant historical ties to Egypt, with regular political and economic influence. This is particularly pronounced in the chronological phase analysed in this study, with Egypt and the Levant constituent parts of the Achamenid Persian, Ptolemaic and Roman Empires. As previously discussed, this shared political administration, and cultural and linguistic hegemony is considered to aid the long-distance trade of goods. This could subsequently facilitate the import of goods from the Levantine region, and make the acquisition of embalming materials from this region less costly than alternatives from East Africa in particular.

The Relationship Between Trade and Animal Mummification:

From the results considered from the GC-MS analyses provided by Buckley & Tunney and Buckley & Fletcher, we can begin to identify trends and correlations between the imported ingredients identified through biochemical analyses, and other contextual information such as the species, date and provenance of the mummified specimens. Results gathered in support of this thesis suggest the importance of mass animal embalming for votive mummies in later Ancient Egyptian society, in terms of their social and economic significance. They also reveal a relatively common use of ingredients from beyond the borders of Egypt in the embalming process. This common use of these non-native embalming agents has been suggested to be influenced by the political upheaval from at least 800 B.C. Successive influence from foreign governing authorities could have allowed a greater volume of trade of these necessary imported ingredients into Egypt, due to the associated cultural homogeny and expanded trade routes. This would have allowed for significant expansion of the sites of animal cult worship, as well as the increased mass production of votive mummies. This was in order to meet the religious demands of the native Egyptian population, as well as the increased revenue and support for the non-Egyptian ruling class. Furthermore, the mummified remains considered in this thesis allow us to consider the use of GC-MS analyses in understanding the relationship between long-distance trade and animal mummification. Subsequently, these findings can be used to assess the potential implications for future research methodologies in this area.

Chapter 8: Future Directions

From a consideration of the results of this study, the aims of this thesis appear to have been reasonably successful in identifying trends between long-distance trade and animal mummification in Ancient Egypt. However, the findings of this thesis suggest scope for improvement in any future research hypotheses in this field. Such considerations are important if future research is to consider the use of mummified animals as part of an archaeological methodology in which to assess social, cultural and economic trends in Ancient Egyptian society.

Use of Selective Sampling in Support of Future Research Methodologies?

There are numerous issues prevalent with the sample considered in this study. The foremost of these is the lack of complete chromatographic data. With only 14 of the 27 specimens provided this information. This limits the degree to which these findings of this thesis can be used to interpret the role imported exotic goods in the embalming process, and clearly highlights the benefits of primary data analysis. Furthermore there are significant contextual issues, with 30% of the specimens having not been dated, and only 46% provided with any information in regards to the site of excavation. Again, the most effective means of correcting this in any future research methodology would be to collect a far larger and better-sourced sample. To that effect, the best probable approach would be to identify and select specimens, of a known origin, from either a single large collection (such as the British Museum) or multiple smaller collections. We can then select an equal number of remains for each period (3rd Intermediate Period, Late Period, Ptolemaic Period and Roman Period), in order to produce as representative a sample as possible. While such an approach would reduce the risk of having specimens with unidentified dating or provenance, utilising large museum collections causes issues in terms of accessibility, given the destructive nature of GC-MS analyses. Furthermore, this approach would not allow for the identification of trends in terms of the number of specimens mummified in each chronological phase. In spite of these issues, considering a much larger sample of specimens, with accurate contextual information, would allow for the trends suggested in this thesis to be stated more conclusively. In turn, this could hopefully allow for a far greater understanding of the role of long-distance trade in later Egyptian animal mummification.

Considering the Hypothetical Use of AMS Radiocarbon Dating in Future Research?

While providing some degree of contextual dating in support of the conclusions of this thesis, the use of this methodology has issues. An assessment of results provided by Buckley & Tunney and Buckley & Fletcher show that the dates provided have large ranges and cover multiple phases of Egyptian history. One possible alternative to consider is to make use of a scientific dating methodology. For example, one possibility is to make use of radiocarbon dating in order to produce quantifiable data as to the age of mummified samples. Traditional radiocarbon dating of biological remains generally makes use of residual collagen extracted from bones, or from dental enamel (Bonk Ramsey et al 2004, 155-163). Such sampling is typically too invasive and destructive for the study of mummified remains in museum collections, even when making use of more advanced techniques such as Accelerator Mass Spectrometry (AMS) radiocarbon dating (Richardin et al 2013, 345-352). In order to conduct radiocarbon dating on 26 mummified human remains, Richardin et al developed a new protocol for the pretreatment of small hair samples, based on the selective extraction of the keratin cortex (Richardin et al 2011, 379-384). This experimental methodology requires less than 30g of raw material, allowing for small enough samples of hair to be taken so that the mummified remains are not excessively damaged (Richardin et al 2013, 345-352).

While the results of this research appear to have provided valuable data on the ages of the 26 mummified human remains, such a technique has issues if hypothetically applied to mummified animal remains. While such analyses would be applicable to the mummified mammal remain, those species without hair (reptiles, birds and fish) would require a different methodological approach in circumventing destructive sampling issues. However, previous attempts have been made to radiocarbon date fish scales and bird feathers, so perhaps with further development of these techniques, it would be possible to date these samples in a less destructive manner (James et al 2010, 1084-1089) (Richardin and Gandolfo 2013, 1810-1818).

Even with such developments, radiocarbon dating still remains a destructive process, which potentially limits the degree of accessibility of samples in museum collections. Perhaps an even greater issue is the relative economic cost of conducting AMS radiocarbon dating, which makes combined analyses of mummified specimens using AMS radiocarbon dating and GC-MS analyses both logistically difficult and prohibitively expensive. This means utilising samples with some form of contextual data (particularly provenance) still remains the most effective means of dating mummified animal remains, despite issues of large dating ranges. Furthermore, this still remains the most viable path in terms of any future research methodologies in this area, given the clear issues in regards to mummified animals in European and American collections. Such issues may be partly mitigated through a larger sample size or remains of better contextual recording. The use of a greater sample size could hypothetically reduce the margin of error introduced by antiquarian archaeological methodologies, and allow for the suggestions made in this thesis to be corroborated.

Oxygen Isotope Analyses and Punt Trade?

Perhaps the most interesting potential future direction this thesis raises in relation to the species utilised in mummification is the potential correlation between imported live baboons and exotic embalming agents. These are suggested to have moved along the same routes of long-distance exchange from the Punt. One potential direction this research could taken is to conduct further oxygen isotope analyses on a greater sample of mummified baboons, in order to consider the ratio of baboons bred in Egypt, as opposed to those imported live from East Africa. To this effect, one direction any potential research could take is to expand upon the work of Dominy et al. This study conducted compared the isotopic signatures of oxygen and strontium isotopes in two mummified baboons (influenced by weather patterns and regional topography) from the British Museum (Dominey et al 2015, 122-23). O^{18} and S^{86} and S^{88} isotopic ratios were compared to those of extant primates, and used by Dominey et al to place the mummified baboon investigated in a region of origin consisting of modern Somalia, Eritrea and Ethiopia (ibid). The use of a similar methodology to that of Dominey et al, used in conjunction with GC-MS analyses of the same mummified remains, could be used to produce a more considered study of the potential relationship between the trade of live animals and Punt ingredients. Subsequently, these scientific analyses could be used alongside period textual and artistic references, such as the Deir el-Bahari wall reliefs. Research into this area could then hypothetically succeed in improving our understanding of long-distance trade and the socio-economic relationship between Egypt and Punt, which at this stage is still relatively unknown. However, financial and access limitations would be an issue with future research into this area, due to the expense of two forms of destructive biochemical analyses. Therefore, such issues must be considered before constructing any future methodological process as described above.

Use of Headspace SPME in Differentiating Gum-Resins?

One issue, in the use of GC-MS in assessing the use of imported ingredients, is the inability to distinguish different biochemical compounds from one another. The analyses provided by Buckley & Tunney and Buckley & Fletcher attribute 20% of the biochemical compounds identified as either ‘gum-resins’, or ‘sugar/plant gums’. While these have been inferred as being from either *Commiphora* or *Boswellia* (species native to East Africa and the Arabian Peninsula), GC-MS is unable to distinguish individual species and reins (such as frankincense and myrrh) from one another. Additionally, while not critical in identifying patterns of use of different regional ingredients, it does limit our understanding of the exact patterns of ingredients in embalming mixtures. One potential way of responding to this issue is presented by the work of Hamm et al (2004). In this study, Hamm et al suggests the relative merits of utilising Headspace SPME (Solid Phase Microextraction) in identifying the presence of resinous material in the embalming agents of mummified remains (Hamm et al 2004, 235-243. This process allows a solvent-free sample preparation technique, which involves introducing a fused silica fiber, coated with a thin layer of a selective liquid or solid coating (Zhang and Pawliszyn 1993, 1843). This is used to extract organic compounds directly from aqueous samples, for further instrumental analysis through GC-MS (ibid). This allows for the extraction of organic volatile compounds from a complex matrix, while being relatively non-destructive due to requiring only small amounts of the sample matrix (Hamm et al 2004, 235-243).

Such a technique shows promise when paired with GC-MS in identifying individual biochemical compounds in embalming mixtures. Hamm et al have had some success in identifying ingredients such as myrrh, frankincense and pine resin in embalming mixtures associated with human mummification (ibid). Given the suggested similarity in the embalming agents utilised in human and animal mummification, it can be inferred that this Headspace SPME and GC-MS could be applicable to embalmed animal remains as seen in this thesis. While this technique could be highly beneficial in increasing the accuracy of identifying ingredients in animal mummification, we must consider the limitations. While reasonably non-invasive and non-destructive, Headspace SPME brings additional operating costs and need for expensive sampling equipment. In combination with GC-MS, this could become a financial liability, unless it had substantial funding and support.

Testing for the Extent of Sandarac Use in Animal Mummification?

From a consideration of the GC-MS results provided by Buckley & Tunney and Buckley & Fletcher, the findings clearly support the thesis hypothesis for an observable trend between the embalming agents used to mummify animals in later Ancient Egypt, and the long-distance trade of these ingredients into Egypt. However, there is still scope to expand upon and improve the analyses conducted in this thesis. Generally, a repeat of the methodology used in this study with a larger sample size would aid in confirming the conclusions of this thesis. Such an approach would be particularly pertinent when considering the inferred presence of sandarac from the mummified crocodile 1.1983.96 (Bolton Museum). Given the lack of sandarac identified in any previous GC-MS analyses of mummified remains, this is an area that definitely needs to be examined in more detail. Due to the limited numbers of samples in most GC-MS studies of mummified animal remains (including this thesis), it is difficult to distinguish between two factors: whether such a result is an outlier, that does not correlated with existing trends in imported embalming agents, or whether it is part of an unidentified import of sandarac for mummification. Conducting a similar methodological approach to the one utilised in this thesis, but on a larger scale, could help solve this issue with a greater degree of certainty. Indeed, such a study could involve using remains sourced from the Fayum Delta, where large numbers of mummified crocodilians have been recovered, potentially providing further specimens showing sandarac use. This could in turn suggest the import of sandarac into Egypt on a large-scale. If such a trade of sandarac were then to become apparent, future research methodologies could then consider where this system of trade from the Atlas Mountains can be placed within the wider network of Egyptian long-distance trade.

Chapter 9: Conclusions

Overall, this study has been successful in answering the thesis hypothesis. The interpretation of the GC-MS data provided by Stephen Buckley, Deborah Tunney and Joann Fletcher allows us to identify the regular presence of imported exotic ingredients in the embalming agents of mummified animal remains. With 74% of the mummified animals in the data provided by Buckley & Tunney and Buckley & Fletcher containing inferred imported ingredients, the use of these materials seems to be relatively common across the latter phases of Ancient Egyptian history. This is true across multiple chronological periods in the latter 1500 years of Egyptian history, and a wider variety of sites and species. Such findings suggest that the use of imported exotic ingredients from outside Egypt was an important element of the embalming process, mirroring the hypothesised trends suggested in previous archaeological and textual research.

A review of the Ancient Egyptian economic system has identified a predominance of trade from the regions directly adjacent to the Nile Delta and Valley. This import of exotic goods seems to have been heavily influenced by the political establishment, both in terms the demand for foreign materials, but also in providing the resources and administrative systems to support such trade. Such a system for elite control on the supply exotic goods seems to expand with the arrival of foreign rulers from the 3rd Intermediary Period onwards. The growth of the animal cults and mass animal mummification seems to follow a similar chronological trend. Huge numbers of mummified animals appear to be produced from around 800 BC onwards, along with massive sites dedicated to creating these votive offerings on an industrial scale. An overview of existing literature also reveals the regular use of imported ingredients in human and animal mummified remains from this same chronology. Furthermore they provide some evidence for how GC-MS can be used to infer the relationship between animal mummification and trade, which formed the core premise of this thesis.

While the interpretation of the GC-MS data provided suffered as a result of serious sampling issues, we could still identify some interesting trends. The use of imported exotic materials seems to be relatively common. While attributed to both the predominant regions of exchanged discussed, the majority are attributed to the region encompassing modern Syria, Palestine, Lebanon, Israel and Jordan. Such trends mirror much of our understanding of how the Egyptian trade economy functions, and supports the suggestion of the importance of the ruling elite in the Egyptian trade economy. In turn, this can be used to argue for the use of exotic import control and votive mummification as a means of subduing a restless native population in the latter stages of Ancient Egyptian history. Furthermore some findings from the data provided open up potential avenues for future research, particularly in relation to the inferred use of sandarac and possible trade routes from North Africa. These findings can therefore be used as a possible pilot study for future research into the correlation between animal mummification and international trade.

While this study has had success in addressing the hypotheses, we must be aware of both the issues of the cost and destructive nature of GC-MS, and the serious and unavoidable sampling issues that are prevalent in mummified animal remains in museums collections in the UK, Europe and North America. Overall, in spite of these issues, the use of the analytical techniques considered in this study have some merit in regards to approaching any future research into this topic. However, future research must make use of a much larger and selectively chosen sample of mummified remains, in order to limit these issues as best as possible. Such a project (given cost and accessibility issues) would need significant academic and financial support to succeed. If given this support, such a study could provide a fascinating insight into how animal mummification can be placed into the wider social and economic framework of Egyptian society, and consequently is worth pursuing.

Appendix 1

Mummy	Date	Provenance	Sample location and description[1]	Inferred components of embalming agents
Cat c2372/3 (Turin Museum)	712-332 BC (XXV – XXXI dynasty)	Unknown	1. 'resin'-impregnated linen	Castor oil, animal fat, conifer resin, pistacia resin, 'balsam', beeswax
Cat 56.22.224 (Liverpool Museum)	664-343 BC (XXVI – XXX dynasty)	Beni Hassan	1. Blackened wrapping from base of mummy 2. Detached 'resin'-soaked wrapping (location 1) 3. Detached 'resin'-soaked wrapping (location 2) 4. Red material in right ear	Animal fat, cedar resin(?), pistacia resin, gum resin (myrrh?), 'balsam', beeswax Animal fat, cedar resin(?), pistacia resin, gum resin (myrrh?), 'balsam', beeswax, bitumen (tr.) Animal fat, cedar resin(?), pistacia resin, gum resin (myrrh?), 'balsam', beeswax Plant oil, a sugar/plant gum, beeswax
Cat with painted head – 1920.29.39.4 (Pitt Rivers Museum)	664-332 BC (XXVI – XXXI dynasty)	Beni Hassan	1 – Darkened wrapping from right side of neck 2 – Darkened wrapping 2 from right side of neck 3 – Blackened resinous material from neck area	Plant oil/animal fat, conifer pitch (a strongly heated resin), 'balsam' Plant oil/animal fat, conifer pitch (a strongly heated resin), a sugar/plant gum Plant oil/animal fat, pine resin, triterpenoid resin, a sugar/plant gum, wax

			6 – Blackened wrapping/'resin' from inside neck	'balsam', beeswax(?)
Cat 144 (Nottingham Castle Museum)	?	Unknown	1. Degraded linen and mixed debris – loose in box	Plant oil/**animal fat**
Cat 191 (Bristol Museum)	?	Unknown	1. Linen and mixed debris from head region – sweepings	Plant oil/**animal fat**, wax (beeswax?)
Cat 595 (Harrow School)	?	Unknown	1. Residue-coated linen from neck region – loose in tissue paper	Plant oil/**animal fat**
Dog c2347/2 (Turin Museum)	712-332 BC (XXV – XXXI dynasty)	Unknown	1. 'resin'-impregnated linen	Animal fat, conifer resin, 'balsam'
Ichneumon (mongoose) S8191 (Turin Museum)	712-332 BC (XXV – XXXI dynasty)	Asiut?	1. 'resin'-impregnated linen	Plant oil, conifer resin, pistacia resin, 'balsam'
Baboon 2345/1 (Turin Museum)	712-332 BC (XXV – XXXI dynasty)	Unknown	2. resin-impregnated linen	Animal fat, pistacia resin, beeswax

Shrew (package of) 1920-89 (Plymouth Museum)	664-332 BC (XXVI – XXXI dynasty)	Unknown	1. blackened linen wrapping	Castor oil, animal fat, conifer resin, pistacia resin

Hawk 52.55.46 (Liverpool Museum)	818-664 BC (XXIII – XXV dynasty)	Tarkhan	1. 'Resin' on wrapping underneath jaw/mandible 2. 'Resin' on back, base of neck (head of spine) 3. 'Resin' on wrapping covering right breast	Plant oil/animal fat, wax (beeswax?) Plant oil/animal fat, wax (beeswax?) Plant oil/animal fat, wax (beeswax?)
Hawk 52.55.47 (Liverpool Museum)	818-664 BC (XXIII – XXV dynasty)	Tarkhan	1. 'Resin'-soaked linen above right eye	Plant oil/animal fat, wax
Hawk 1983.727 (Plymouth Museum)	664-332 BC (XXVI – XXXI dynasty)	Unknown	5. 'resin'-impregnated loose linen wrappings	Animal fat, conifer resin, pistacia resin, beeswax
Hawk (Accipiter) 384 (Museum of Fine Arts, Boston)	?	Unknown	1. Residue-coated feathers – left shoulder/wing 2. Residue-coated feathers – left shoulder/wing 3. Residue-coated feathers – left shoulder/wing	Plant oil/animal fat, pine resin, triterpenoid resin, wax Plant oil/animal fat, pine resin, triterpenoid resin, wax Plant oil/animal fat, pine resin, triterpenoid resin, wax
Falcon 027 (Garstang Museum, University of Liverpool)	?	Unknown	1. Dark-stained linen – debris within tissue paper	Plant oil/animal fat, pine resin, pistacia resin, beeswax

Bird of prey 475 (New Walk Museum, Leicester)	?	Kafr Ammar	1. Stained, residue-coated tail feathers – exposed layers 2. Stained, residue-coated tail feathers – exposed layers	Pistacia resin, wax (beeswax?) Pistacia resin, wax (beeswax?)
Bird of prey 004 (Kirklees Museum, Batley)	?	Unknown	1. Residue-coated linen portion – loose in bag and on bundle 2. Residue-coated linen portion – loose in bag and on bundle 3. Residue-coated linen portion – loose in bag and on bundle 4. Residue-coated linen portion – loose in bag and on bundle	Plant oil/**animal fat**, pine resin, pistacia resin Plant oil/**animal fat**, pine resin, pistacia resin Plant oil/**animal fat**, pine resin, pistacia resin Plant oil/**animal fat**, pine resin, pistacia resin
Ibis 1969.112.42	664-343 BC (XXVI – XXX dynasty)	Sakkara	1. 'Resin'-soaked wrapping, covering right breast 2. 'Resin'-soaked wrapping, covering left breast	Plant oil (tr.), a sugar/plant gum, wax (tr.) Plant oil (tr.), a sugar/plant gum, wax (tr.)
Ibis 1.1983.137 (Bolton Museum) Ex-Wellcome Collection	664-332 BC (XXVI – XXXI dynasty)?	Beni Hassan	1 – 'Resin'-impregnated linen from leg 2 – Darkened tissue from leg	Plant oil/animal fat, pine resin, 'balsam', a sugar/plant gum Plant oil/animal fat, pine resin, 'balsam', a sugar/plant gum (tr.) proteinaceous material

Ibis 165 (Oriental Museum, Durham)	332 – 30 BC (Ptolemaic period)	Sakkara	1. Reed fragments and mixed debris – removed from packaging	Plant oil/animal fat, conifer oil, bitumen
Ibis 162 (Oriental Museum, Durham)	30 BC – AD 395 (Roman Period)	Unknown	1. Resinous fragment 2. Resinous fragment	Pistacia resin Pistacia resin
Ibis? 471 (Elgin Museum)	?	?	1. Mixed debris from base – loose after photography	Plant oil/animal fat, conifer (pine?) oil, pine resin, bitumen
Crocodile 1908.64.6 (Pitt Rivers Museum) Ex-Wellcome collection	664-332 BC (XXVI – XXXI dynasty)	Unknown	1 – Darkened wrappings – threads on underside (belly) 2 – Small blackened thread from left eye 3 – Linen threads from underside of tail	Plant oil/animal fat, a sugar/plant gum, wax Plant oil/animal fat, wax Plant oil/animal fat, a sugar/plant gum, wax

Crocodile 1.1983.95 (Bolton Museum) Ex-Wellcome collection	332 BC – AD 395 (Graeco-Roman period)?	Memphis	1 – ‘Resin’-impregnated linen wrapping (external) – middle of mummy 2 – ‘Resin’/tissue/bone from head 3 – ‘Resin’-impregnated linen wrapping (external) – tail of mummy 4 – Wrapping ‘resin’ impregnated	Plant oil (inc. castor)/animal fat, pine resin, sandarac resin, ‘balsam’, a sugar/plant gum, wax(?), beeswax Plant oil/animal fat, pine resin, ‘balsam’, a sugar/plant gum, wax(?), beeswax (tr.) Plant oil/animal fat, pine resin, sandarac resin, ‘balsam’, a sugar/plant gum (tr.), beeswax (tr.) Plant oil (inc. castor)/animal fat, pine resin, sandarac resin, ‘balsam’, a sugar/plant gum (tr.), beeswax (tr.)
Crocodile – ‘fake’ 58.1911 (Bolton Museum)	332 BC – AD 395 (Graeco-Roman period)	Hawara	1 – Darkened linen wrappings from head (under chin) 2 – Darkened linen wrappings from middle of mummy 3 – Darkened linen wrapping from tail	Plant oil/animal fat, conifer resin (tr.),‘balsam’, a sugar/plant gum, wax, beeswax Plant oil/animal fat, conifer resin (tr.),‘balsam’, a sugar/plant gum, beeswax (tr.) Plant oil/animal fat, conifer resin (tr.),‘balsam’, a sugar/plant gum, wax, beeswax (tr.)
Fish c2396/1 (Turin Museum)	712-332 BC (XXV – XXXI dynasty)	Unknown	1. ‘resin’-impregnated linen	Animal fat, conifer resin, ‘balsam’
Egg A128-1968 (Bolton Museum)	664-332 BC (XXVI – XXXI dynasty)?	Unknown	1. ‘resin’-impregnated linen	Animal fat, conifer resin, ‘balsam’, a sugar/plant gum, beeswax

Total number of samples = 53; Samples containing imported ingredients = 40 (75%)
Total number of mummies = 27; Mummies containing imported ingredients = 20 (74%)

Appendix 2

Dr Stephen Buckley and Ms Deborah Tunney

Mummy	Date	Provenance	Sample location and description[1]	Inferred components of embalming agents
Cat with painted head - 1920.29.39.4 (Pitt Rivers Museum)	664-332 BC (XXVIth - XXXth dynasty)	Beni Hassan	1 - Darkened wrapping from right side of neck 10.26mg - extract 3.78mg (37%) 2 - Darkened wrapping 2 from right side of neck 13.07 - extract 5.87mg (45%) 3 - Blackened resinous material from neck area 0.59mg - extract -0.6mg (100%) 4 - Woolly packing/tissue from neck area 6.46mg - extract 1.40mg (22%) 5 - Darkened wrapping from neck area 14.14mg - extract 2.60mg (18%) 6 - Blackened wrapping/'resin' from inside neck 7.85 - extract 4.52mg (58%)	Plant oil/animal fat, conifer pitch (a strongly heated resin), 'balsam' Plant oil/animal fat, conifer pitch (a strongly heated resin), a sugar/plant gum Plant oil/animal fat, pine resin, triterpenoid resin, a sugar/plant gum, wax Plant oil/animal fat, pine resin, triterpenoid resin, 'balsam', a sugar/plant gum, wax Plant oil/animal fat, conifer pitch (a strongly heated resin), triterpenoid resin, 'balsam', a sugar/plant gum, wax Plant oil/animal fat, pine resin, triterpenoid resin, 'balsam', beeswax(?)
Ibis 1.1983.137	664-332 BC (XXVIth - XXXth dynasty)	Beni Hassan	1 - 'Resin' impregnated linen from leg 1.89mg - 0.38mg (20%)	Plant oil/animal fat, pine resin, 'balsam', a sugar/plant gum

(Bolton Museum)			2 - Darkened tissue from leg 4.90mg - 1.47mg (30%)	Plant oil/animal fat, pine resin, 'balsam', a sugar/plant gum (tr.) proteinaceous material
Crocodile 1908.64.6	664-332 BC (XXVIth - XXXth dynasty)	Unknown	1 - Darkened wrappings - threads on underside (belly) 1.45mg - 1.11mg (77%)	Plant oil/animal fat, a sugar/plant gum, wax

(Pitt Rivers Museum) Ex Wellcome collection			2 - Small blackened thread from left eye <0.1mg 3 - Linen threads from underside of tail 0.89mg - 0.68mg (76%)	Plant oil/animal fat, wax Plant oil/animal fat, a sugar/plant gum, wax
Crocodile 1.1983.95 (Bolton Museum) Ex Wellcome collection	664-332 BC (XXVIth-XXXthdynasty)	Memphis	1 - 'Resin' impregnated linen wrapping (external) - middle of mummy 1.56mg 2 - 'Resin'/tissue/bone from head 0.89mg 3 - 'Resin' impregnated linen wrapping (external) - tail of mummy 1.02mg 4 - Wrapping 'resin' impregnated 7.95mg	Plant oil (inc. castor)/animal fat, pine resin, sandarac resin, 'balsam', a sugar/plant gum, wax(?), beeswax Plant oil/animal fat, pine resin, 'balsam', a sugar/plant gum, wax(?), beeswax (tr.) Plant oil/animal fat, pine resin, sandarac resin, 'balsam', a sugar/plant gum (tr.), beeswax (tr.) Plant oil (inc. castor)/animal fat, pine resin, sandarac resin, 'balsam', a sugar/plant gum (tr.), beeswax (tr.)
Crocodile - fake 58.1911 (Bolton Museum)	664-332 BC (XXVIth-XXXthdynasty)	Hawara	1 - Darkened linen wrappings from head (under chin) 4.22mg 2 - Darkened linen wrappings from middle of mummy 6.18mg 3 - Darkened linen wrapping from tail 9.91mg	Plant oil/animal fat, conifer resin (tr.),'balsam', a sugar/plant gum, wax, beeswax Plant oil/animal fat, conifer resin (tr.),'balsam', a sugar/plant gum, beeswax (tr.) Plant oil/animal fat, conifer resin (tr.),'balsam', a sugar/plant gum, wax, beeswax (tr.)

Table 1.
[1] The term 'resin' denotes physical appearance and does <u>not</u> presuppose any chemical composition or biological origin.
[2] Compositions do not necessarily reflect the original formulations due to possible chemical changes over time.

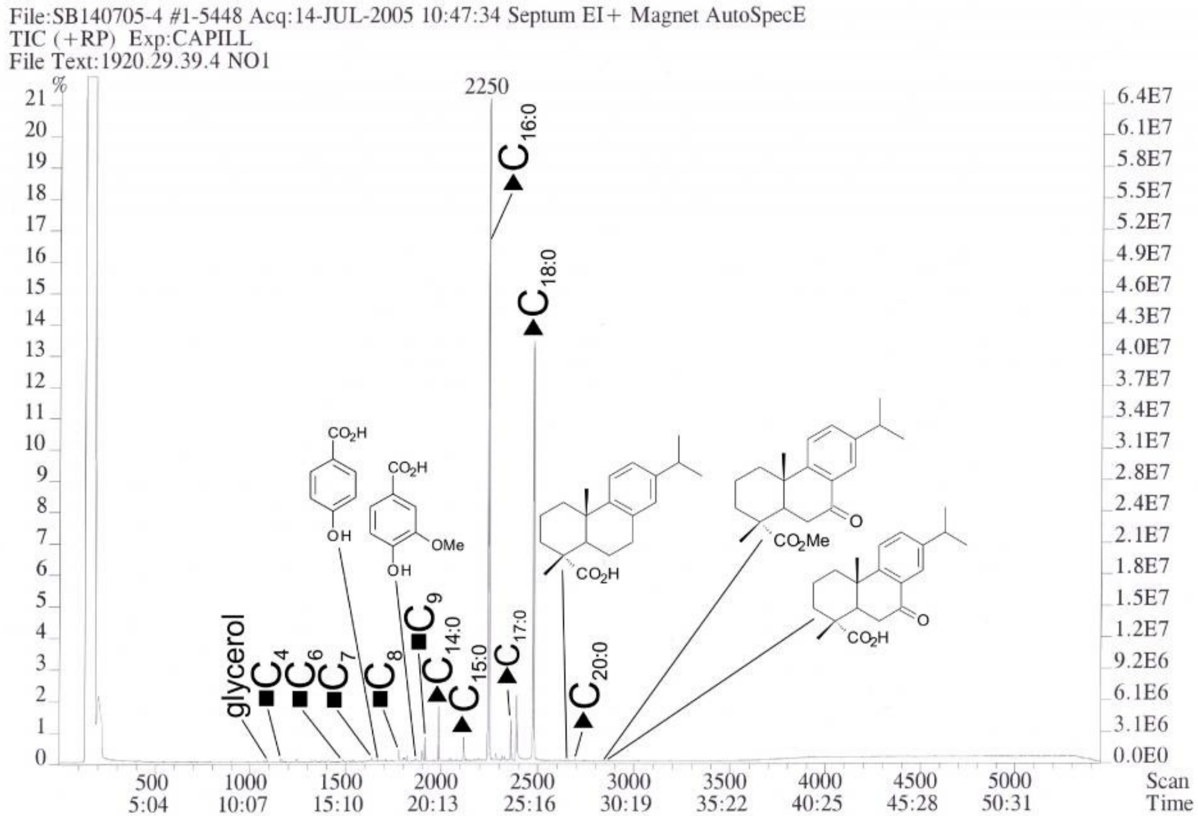

Figure 1 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Cat head 1920.29.39.4, 664-332 BC (XXVIth – XXXIst dynasty) 1. darkened wrapping from right side of neck (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles. Also shown are the

structures of two aromatic acids identified: 4-hydroxybenzoic acid and vanillic acid; three diterpenoids identified: dehydroabietic acid, methyl 7-oxodehydroabietate and 7-oxodehydroabietic acid. Additionally, glycerol is also labelled.

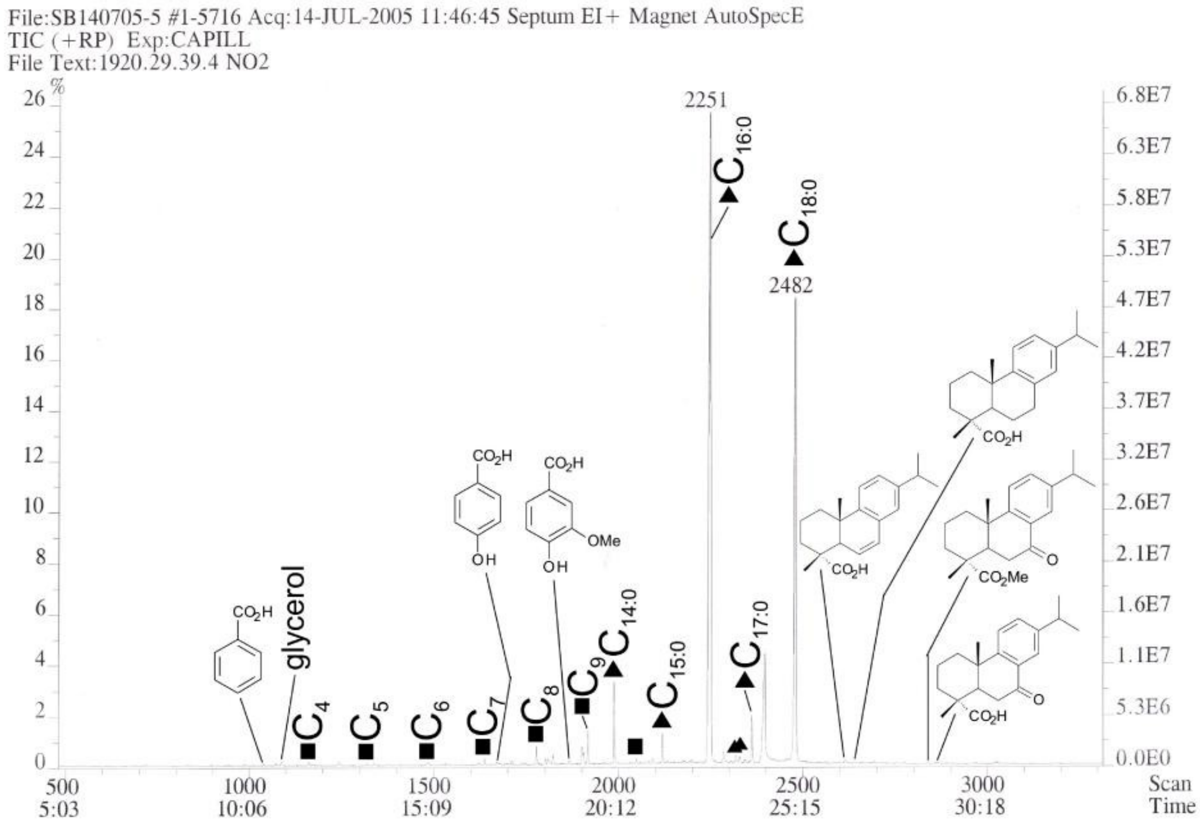

Figure 2 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Cat head 1920.29.39.4, 664-332 BC (XXVI[th] – XXXI[st] dynasty) 2. darkened wrapping 2 from right side of neck (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles. Also shown

are the structures of three aromatic acids identified: benzoic acid, 4-hydroxybenzoic acid and vanillic acid; four diterpenoids identified: 6-dehydrodehydroabietate, dehydroabietic acid, methyl 7-oxodehydroabietate and 7-oxodehydroabietic acid. Additionally, glycerol is also labelled.

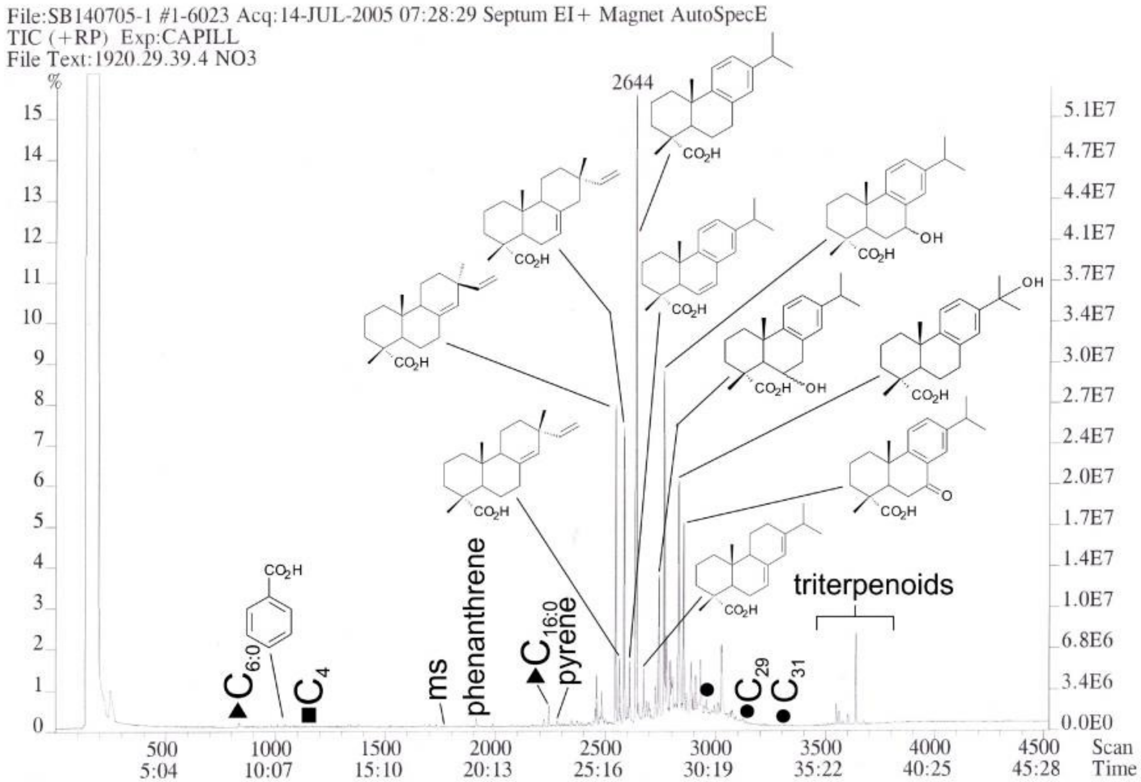

Figure 3 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Cat head 1920.29.39.4, 664-332 BC (XXVIth - XXXIst dynasty) 3. blackened resinous material from neck area (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles, C_x indicates *n*- alkanes. Also shown are the structures of an aromatic acid identified: 4-hydroxybenzoic acid; ten diterpenoids identified: pimaricacid,

sandaracopimaric acid, isopimaric acid, methyl 6-dehydrodehydroabietate, dehydroabietic acid, abietic acid, 6-hydroxydehydroabietic acid, 7-hydroxydehydroabietic acid, 15-hydroxydehydroabietic acid and 7-oxodehydroabietic acid. Additionally, ms indicates monosaccharides and phenanthrene, pyrene and a number of triterpenoids are also labelled.

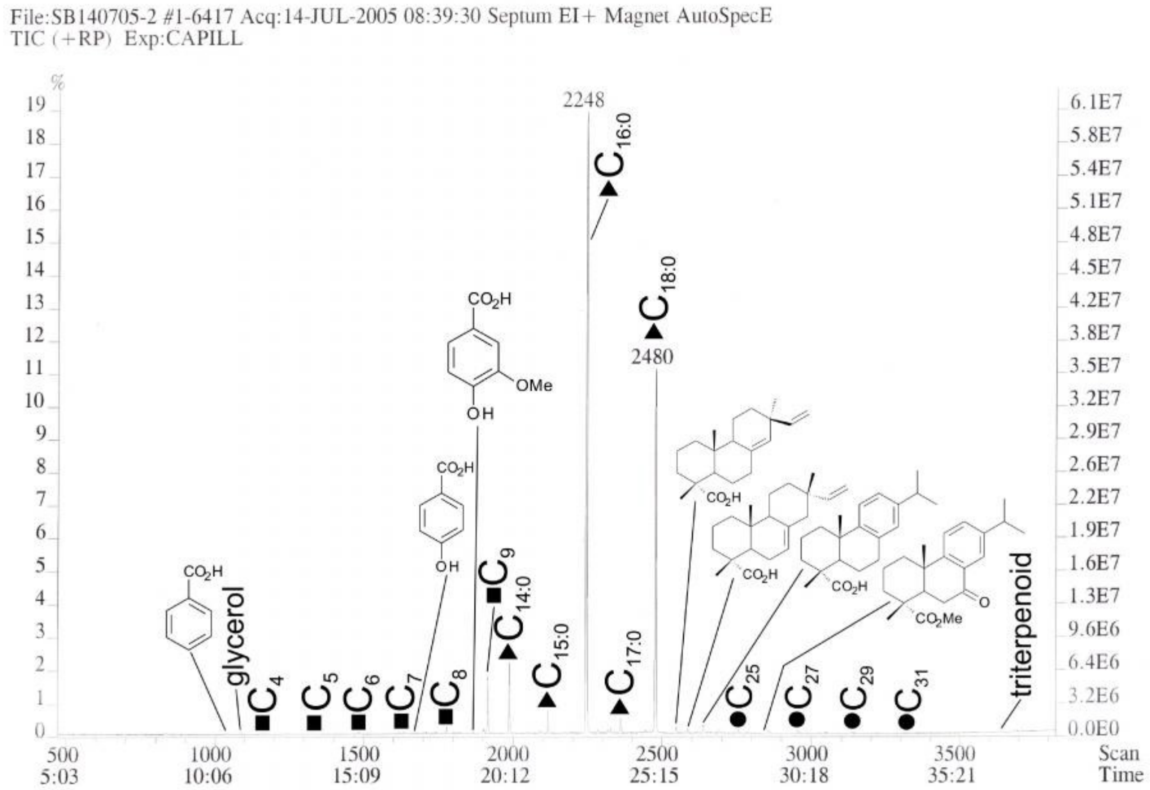

Figure 4 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Cat head 1920.29.39.4, 664-332 BC (XXVIth – XXXIst dynasty) 4. woolly packing/tissue from neck area (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles; C_x indicates *n*-alkanes.

Also shown are the structures of three aromatic acids identified: benzoic acid, 4-hydroxybenzoic acid and vanillic acid; four diterpenoids identified: pimaric acid, isopimaric acid, dehydroabietic acid and methyl 7-oxodehydroabietate. Additionally, glycerol and an unidentified triterpenoid is also labelled.

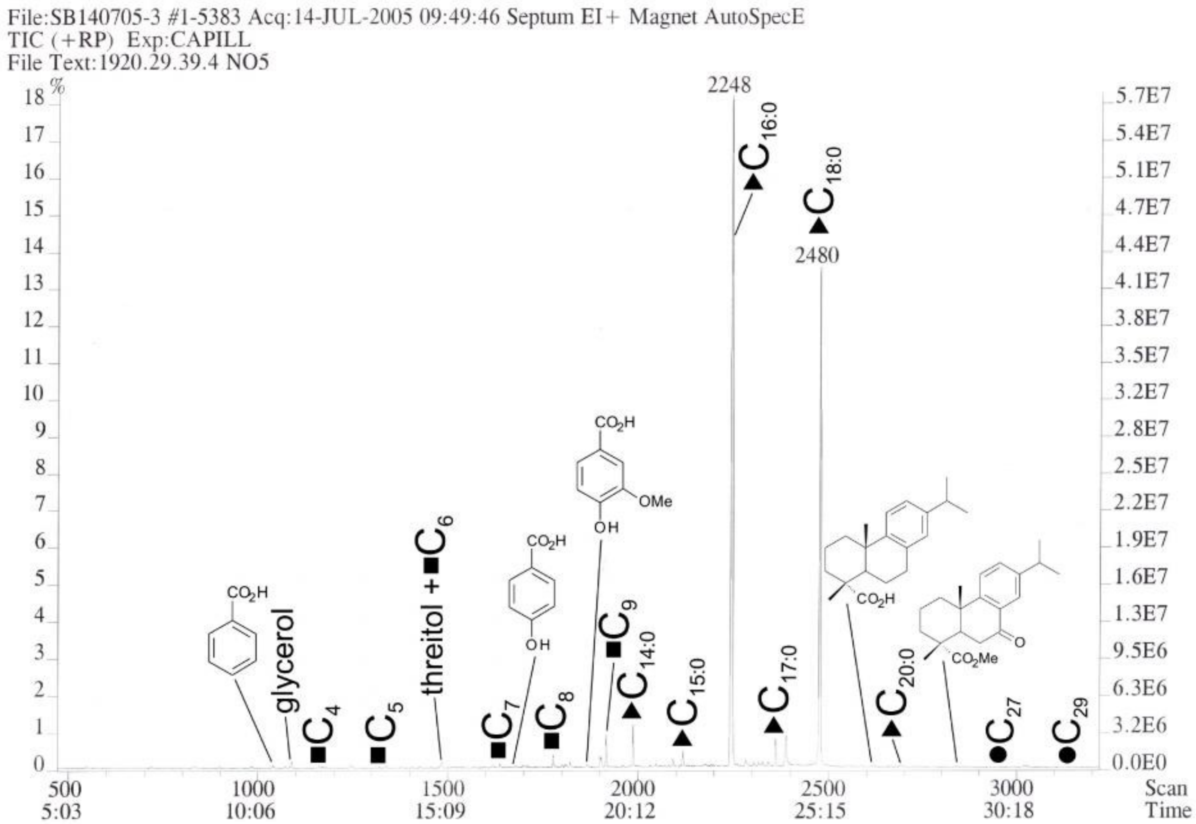

Figure 5 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Cat head 1920.29.39.4, 664-332 BC (XXVIth – XXXIst dynasty) 5. darkened wrapping neck area (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles; C_x indicates *n*-alkanes.

Also shown are the structures of three aromatic acids identified: benzoic acid, 4-hydroxybenzoic acid and vanillic acid; two diterpenoids identified: 6-dehydrodehydroabietic acid and methyl 7-oxodehydroabietate. Additionally, glycerol and threitol is also labelled.

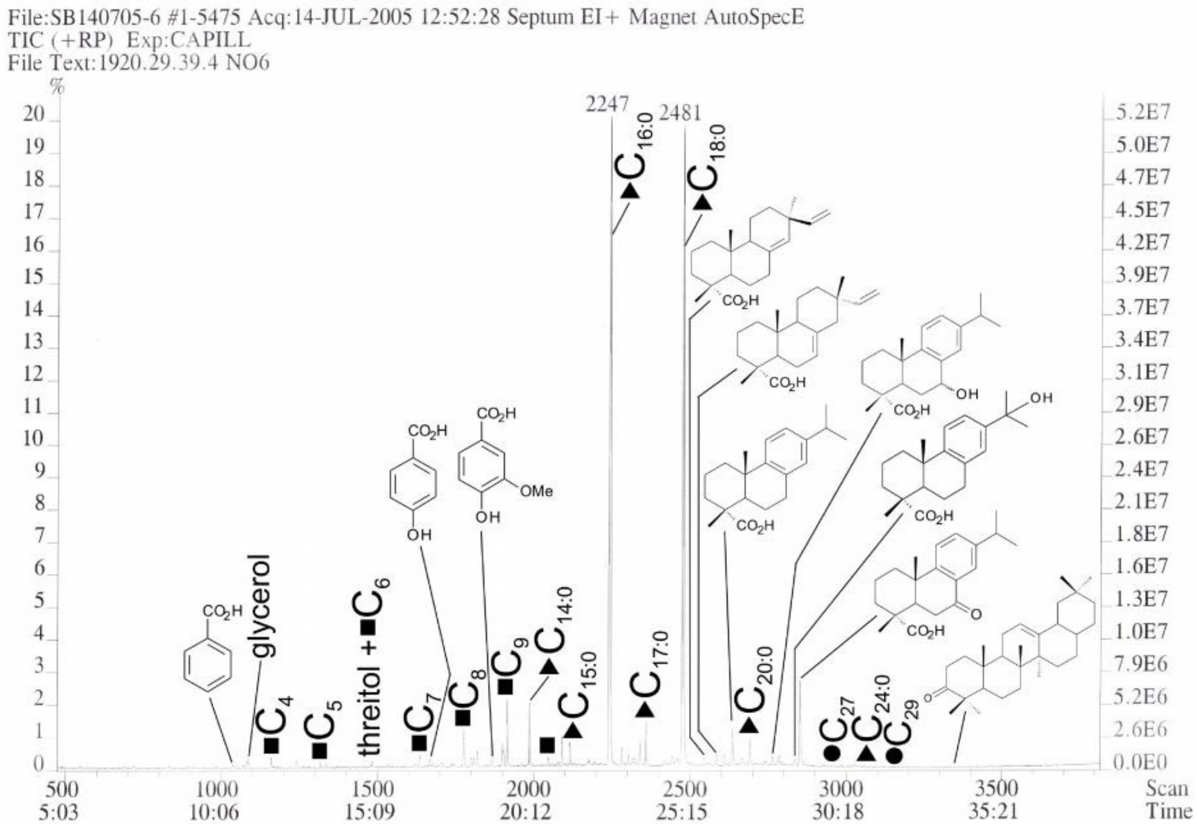

Figure 6 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Cat head 1920.29.39.4, 664-332 BC (XXVI[th] – XXXI[st] dynasty) 6. blackened wrapping/'resin' from inside neck (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles; C_x indicates *n*- alkanes. Also shown are the structures of three aromatic acids identified: benzoic acid, 4-hydroxybenzoic acid and vanillic acid; six diterpenoids

identified: pimaric acid, isopimaric acid, dehydroabietic acid, 7-hydroxydehydroabietic acid, 15-hydroxydehydroabietic acid and 7-oxodehydroabietic acid; a triterpenoid identified: nor-j3-amyrone. Additionally, glycerol and threitol are also labelled.

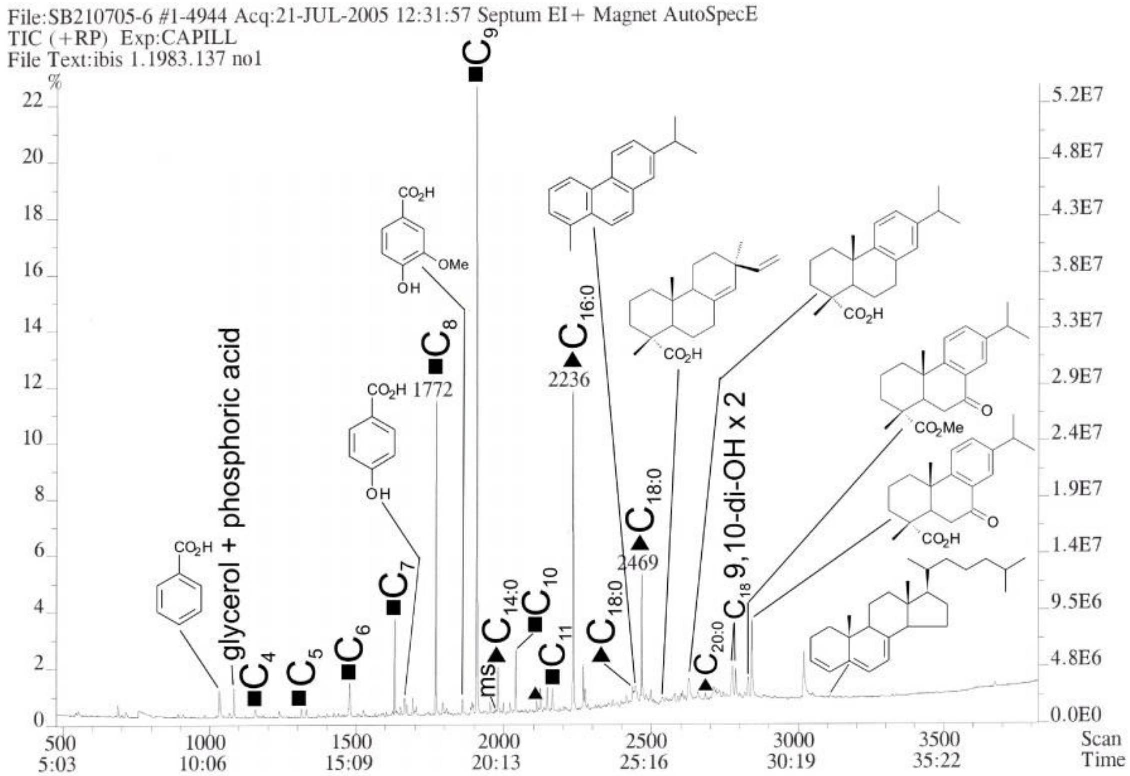

Figure 7 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Ibis 1.1983.137, 664-332 BC (XXVI[th] – XXXI[st] dynasty) 1. 'resin'-impregnated linen from leg (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids. Also shown are the structures of three aromatic acids identified: benzoic acid, 4-hydroxybenzoic acid and vanillic acid; five diterpenoids identified: retene, pimaric acid, dehydroabietic acid, methyl 7-oxodehydroabietate and 7-oxodehydroabietic acid; a sterol: cholesta-3,5,7-triene. $C_{18:0}$ 9,10-di-OH indicates 9,10-

dihydroxyoctadecanoic acid (*threo* and *erythro* isomers); ms indicates a monosaccharide. Additionally, glycerol and phosphoric acid are also labelled.

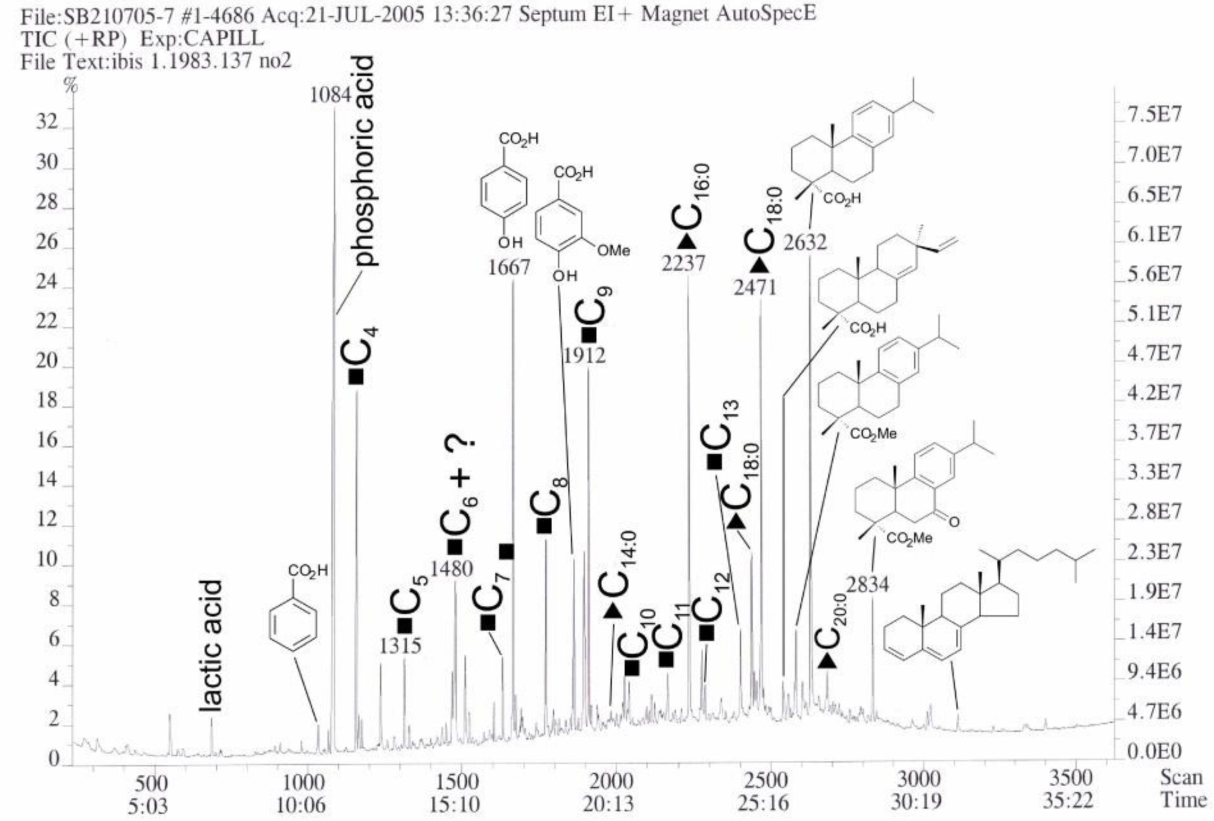

Figure 8 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Ibis 1.1983.137, 664-332 BC (XXVIth – XXXIst dynasty) 2. darkened tissue from leg (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids. Also shown are the structures of three aromatic acids identified: benzoic acid, 4-hydroxybenzoic acid and vanillic acid; four diterpenoids identified: pimaric acid, methyl dehydroabietate,

dehydroabietic acid and methyl 7-oxodehydroabietate; a sterol: cholesta-3,5,7-triene. Additionally, lactic acid and phosphoric acid are also labelled.

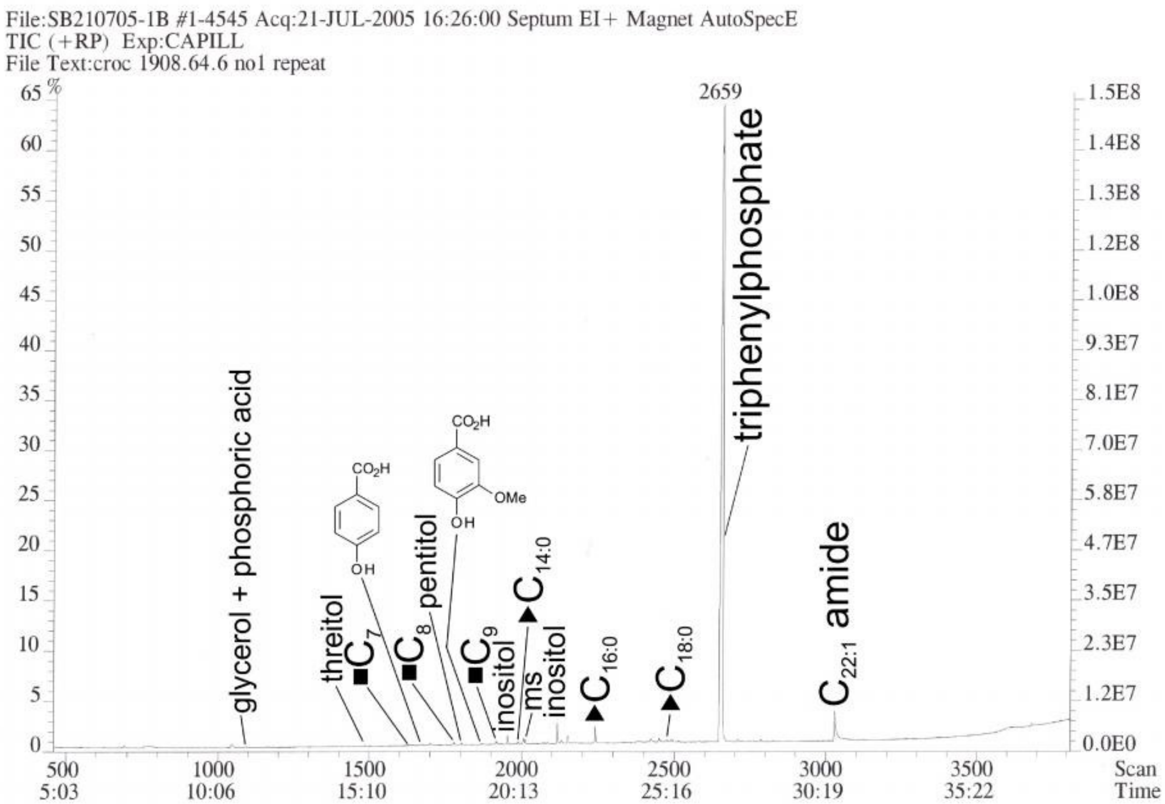

Figure 9 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Crocodile 1908.64.6, 664-332 BC (XXVI[th] – XXXI[st] dynasty) 1. darkened wrappings – threads on underside (belly) (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids. Also shown are the structures of two aromatic acids identified: 4-hydroxybenzoic acid and vanillic acid; ms indicates monosaccharides. $C_{22:1}$ amide indicates

docosenamide (erucamide). Additionally, glycerol, phosphoric acid, triphenylphosphate and the sugar/gum markers threitol, a pentitol and two inositols are also labelled.

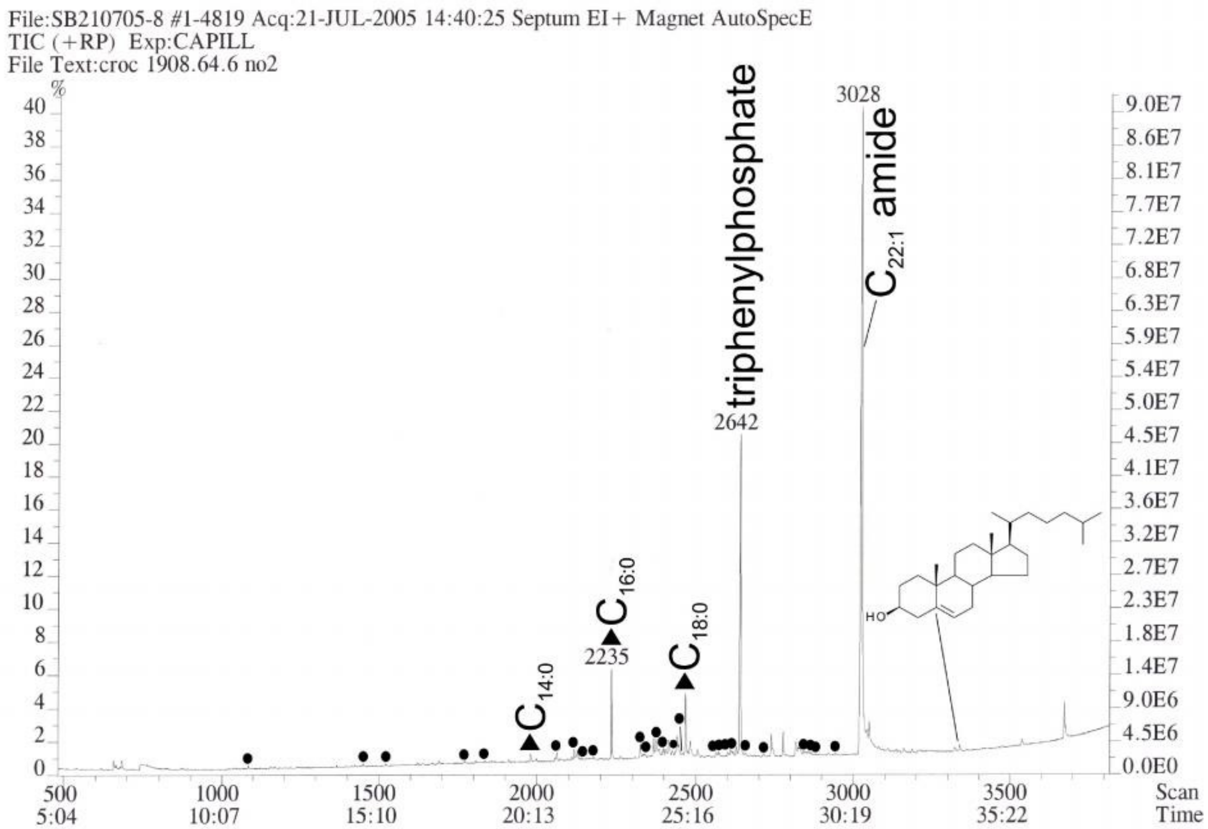

Figure 10 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Crocodile 1908.64.6, 664-332 BC (XXVI[th] - XXXI[st] dynasty) 2. small blackened thread from left eye (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled circles; C_x indicates *n*-alkanes. Also shown is the structure of a sterol identified: cholesterol. $C_{22:1}$ amide indicates docosenamide (erucamide). Additionally, triphenylphosphate is also labelled.

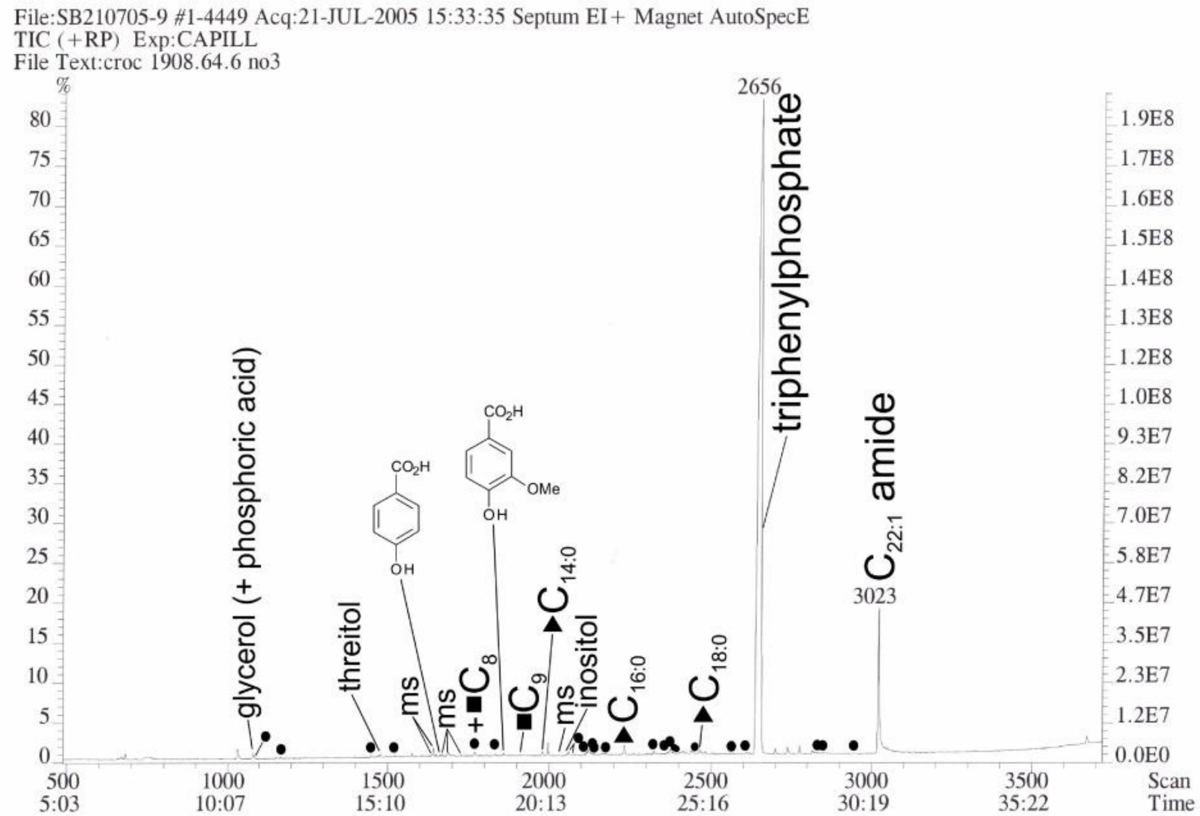

Figure 11 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Crocodile 1908.64.6, 664-332 BC (XXVI[th] - XXXI[st] dynasty) 3. linen threads from underside of tail (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles; C_x indicates *n*-alkanes. Also shown are the structures of two aromatic acids identified: 4-hydroxybenzoic acid and vanillic acid; ms indicates monosaccharides. $C_{22:1}$

amide indicates docosenamide (erucamide). Additionally, glycerol, phosphoric acid, triphenylphosphate and the sugar/gum marker, an inositol, are also labelled.

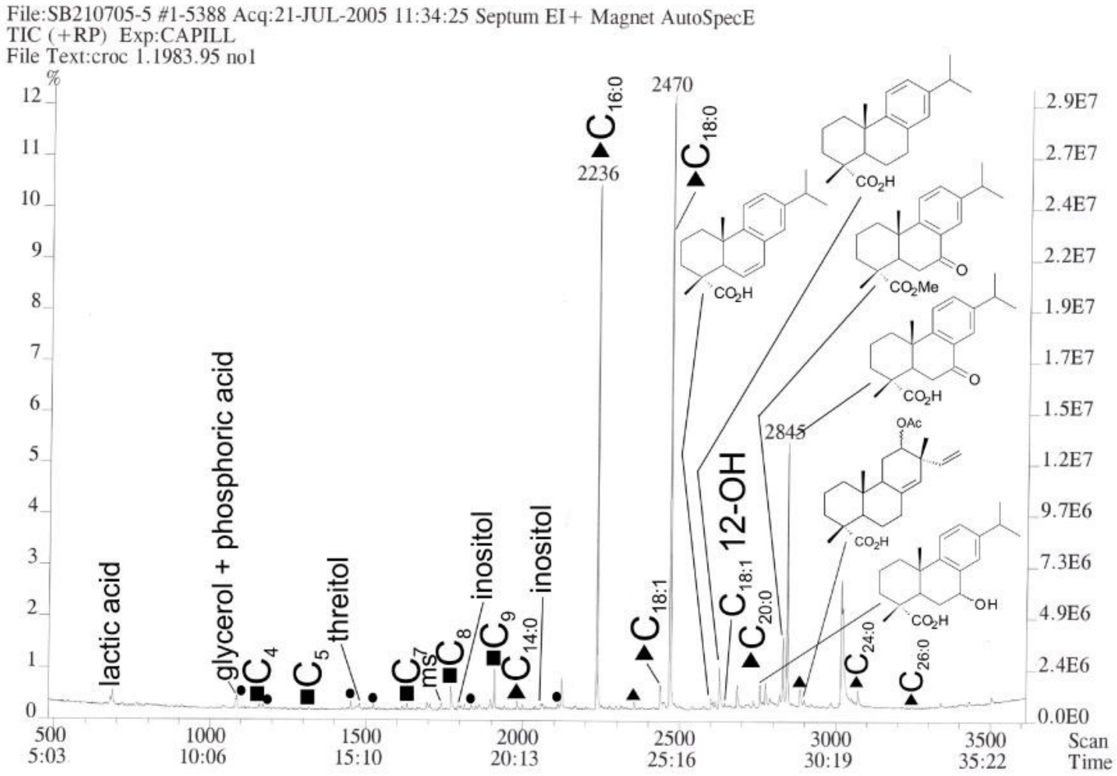

Figure 12 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Crocodile 1.1983.95, 664-332 BC (XXVI[th] – XXXI[st] dynasty) 1. 'resin'-impregnated linen wrapping (external) – middle of mummy (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles; C_x indicates *n*-alkanes. Also shown are the structures of six diterpenoids identified: 6-dehydrodehydroabietic acid, dehydroabietic acid, 7-hydroxydehydroabietic acid, methyl 7-oxodehydroabietate, 7-oxodehydroabietic acid and 12-acetoxysandaracopimaric acid; msindicates

monosaccharide; $C_{18:1}$ 12-OH indicates ricinoleic acid. Additionally, lactic acid, glycerol, phosphoric acid and the sugar/gum markers threitol and two inositols are also labelled.

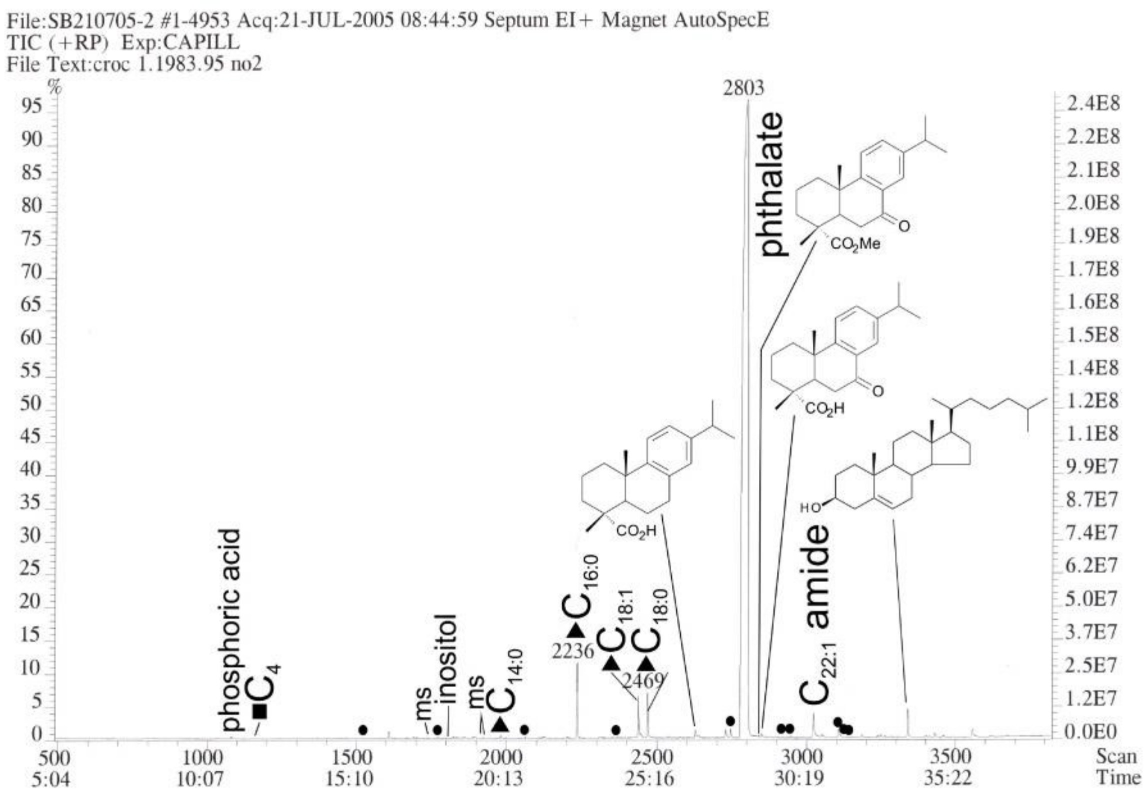

Figure 13 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Crocodile 1.1983.95, 664-332 BC (XXVI[th] - XXXI[st] dynasty) 2. 'resin'/tissue/bone from head (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles; C_x indicates *n*-alkanes.

Also shown are the structures of three diterpenoids identified: dehydroabietic acid, methyl 7-oxodehydroabietate and 7-oxodehydroabietic acid; a sterol: cholesterol; ms indicates monosaccharides. Additionally, phosphoric acid and two inositols are also labelled.

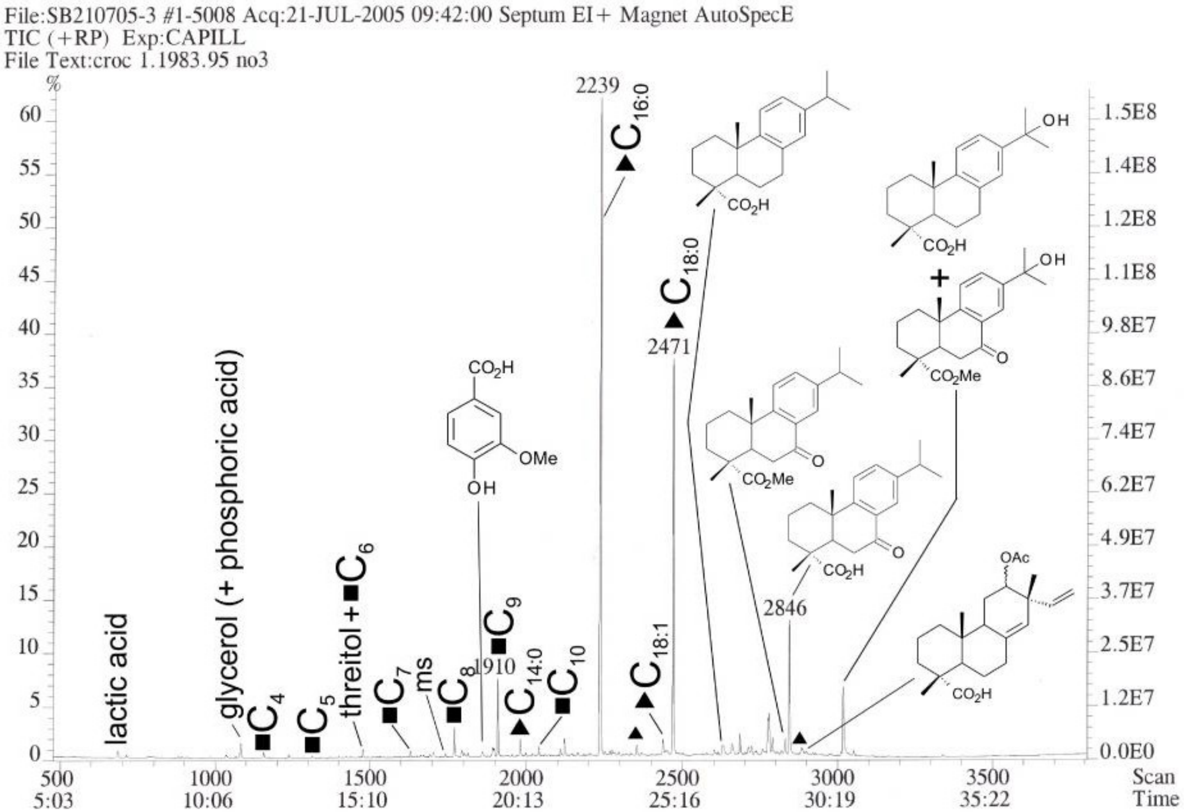

Figure 14 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Crocodile 1.1983.95, 664-332 BC (XXVIth - XXXIst dynasty) 3. 'resin'-impregnated linen wrapping (external) – tail of mummy (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids. Also shown is

the structure of one aromatic acid identified:vanillic acid; six diterpenoids identified: dehydroabietic acid, methyl 7-oxodehydroabietate, 7-oxodehydroabietic acid, 15-hydroxy-7-oxodehydroabietic acid, methyl 15-hydroxy-7-oxodehydroabietate and 12-acetoxysandaracopimaric acid; ms indicates monosaccharide. Additionally, lactic acid, glycerol, phosphoric acid and threitol are also labelled.

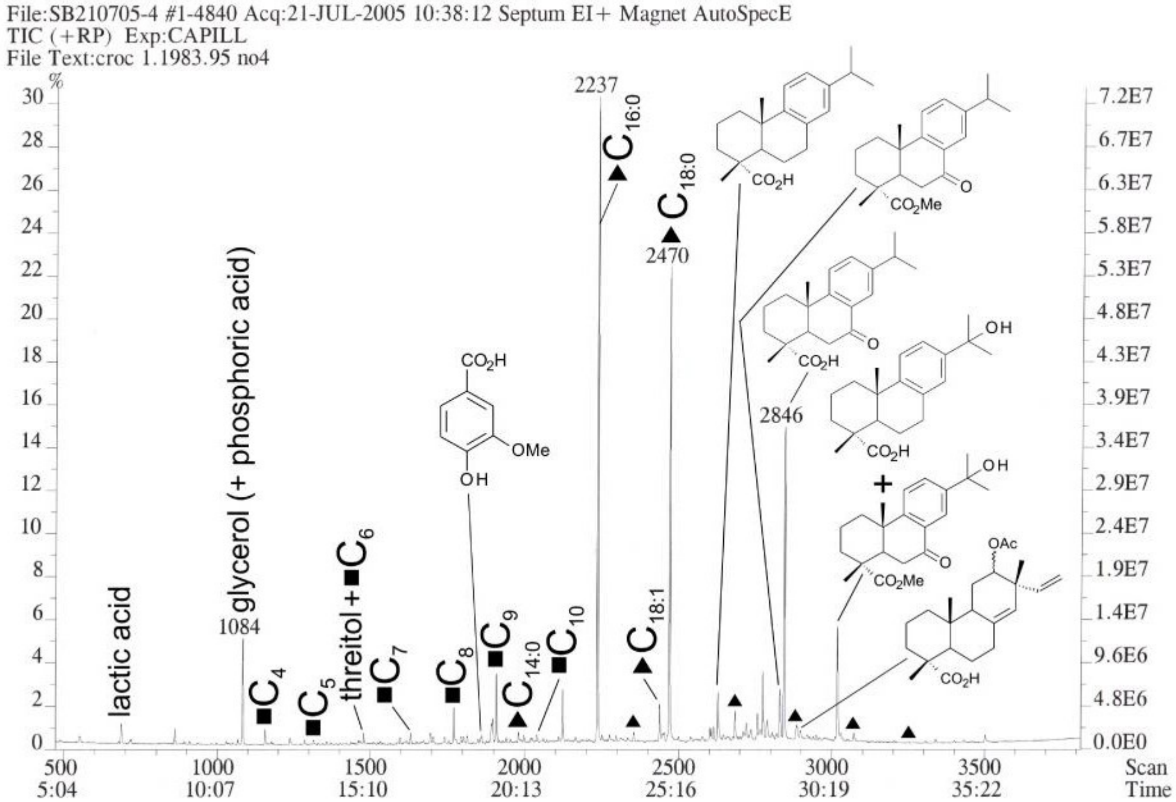

Figure 15 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Crocodile 1.1983.95, 664-332 BC (XXVI[th] – XXXI[st] dynasty) 4. wrapping 'resin'-impregnated (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids. Also shown is the structure of one

aromatic acid identified:vanillic acid; six diterpenoids identified: dehydroabietic acid, methyl 7-oxodehydroabietate, 7-oxodehydroabietic acid, 15-hydroxy-7-oxodehydroabietic acid, methyl 15-hydroxy-7-oxodehydroabietate and 12-acetoxysandaracopimaric acid. Additionally, lactic acid, glycerol, phosphoric acid and threitol are also labelled.

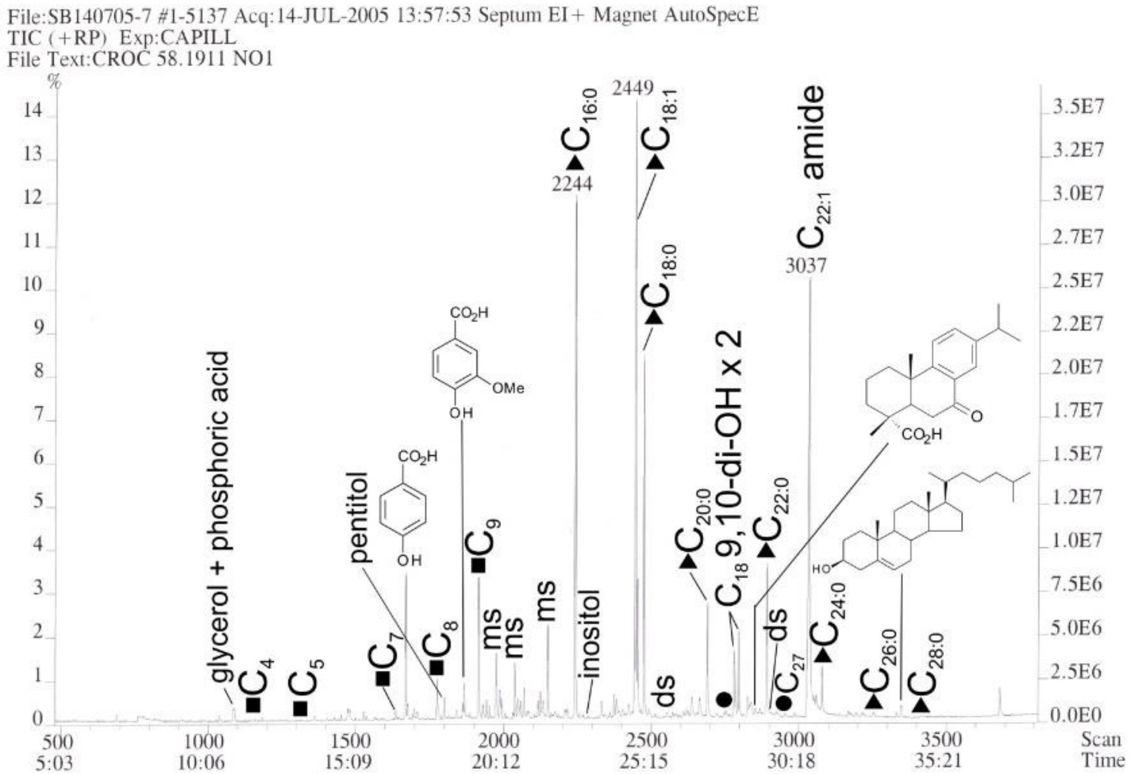

Figure 16 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Crocodile ('fake') 58.1911, 664-332 BC (XXVIth – XXXIst dynasty) 1. darkened linen wrappings from head (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles; C_x indicates *n*-alkanes. Also shown is the structure of two aromatic acids identified:4-hydroxybenzoic acid and vanillic acid; one diterpenoid identified: 7-

oxodehydroabietic acid; one sterol identified: cholesterol; ms indicates monosaccharides; ds indicates disaccharides; $C_{18:0}$ 9,10-di-OH indicates 9,10-dihydroxyoctadecanoic acid (*threo* and *erythro* isomers); $C_{22:1}$ amide indicates docosenamide (erucamide). Additionally, glycerol, phosphoric acid and the sugar/gum markers a pentitol and two inositols are also labelled.

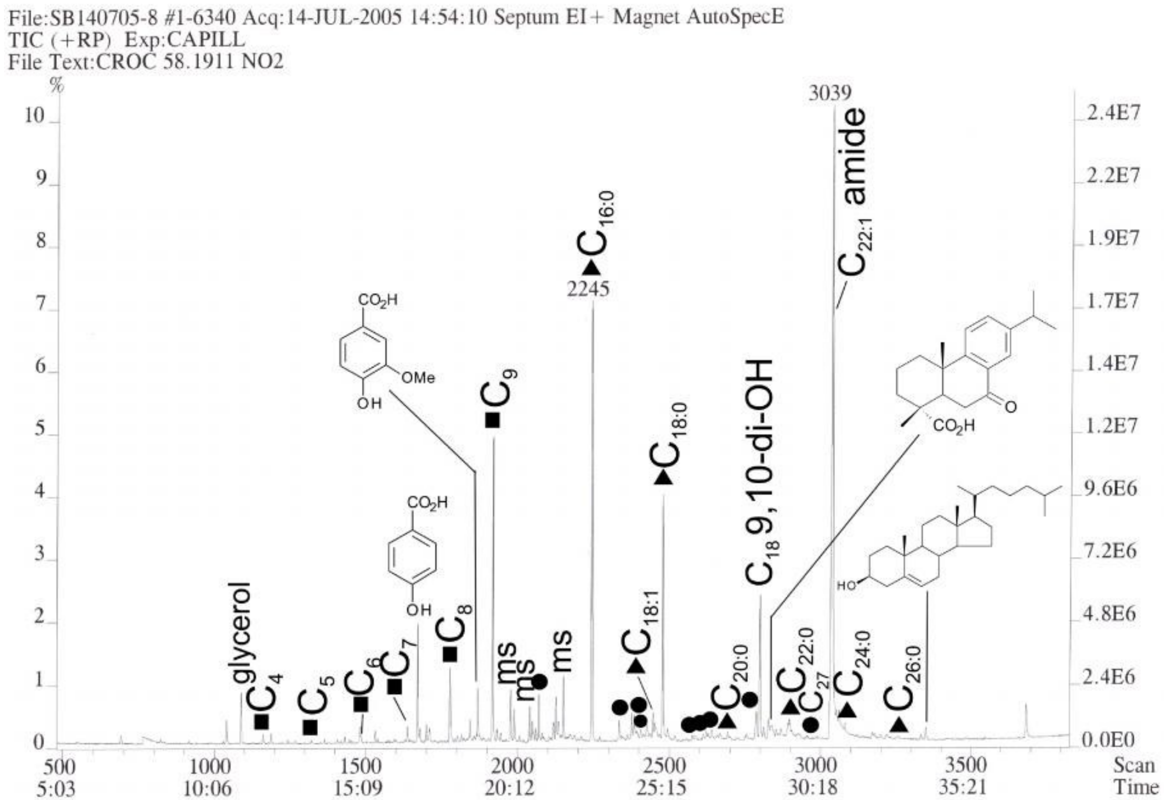

Figure 17 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Crocodile ('fake') 58.1911, 664-332 BC (XXVI[th] – XXXI[st] dynasty) 2. darkened linen wrappings from middle of mummy (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles; C_x

indicates *n*-alkanes. Also shown is the structure of two aromatic acids identified:4-hydroxybenzoic acid and vanillic acid; one diterpenoid identified: 7-oxodehydroabietic acid; one sterol identified: cholesterol; ms indicates monosaccharides; $C_{18:0}$ 9,10-di-OH indicates 9,10-dihydroxyoctadecanoic acid (*erythro* isomer); $C_{22:1}$ amide indicates docosenamide (erucamide). Additionally, glycerol is also labelled.

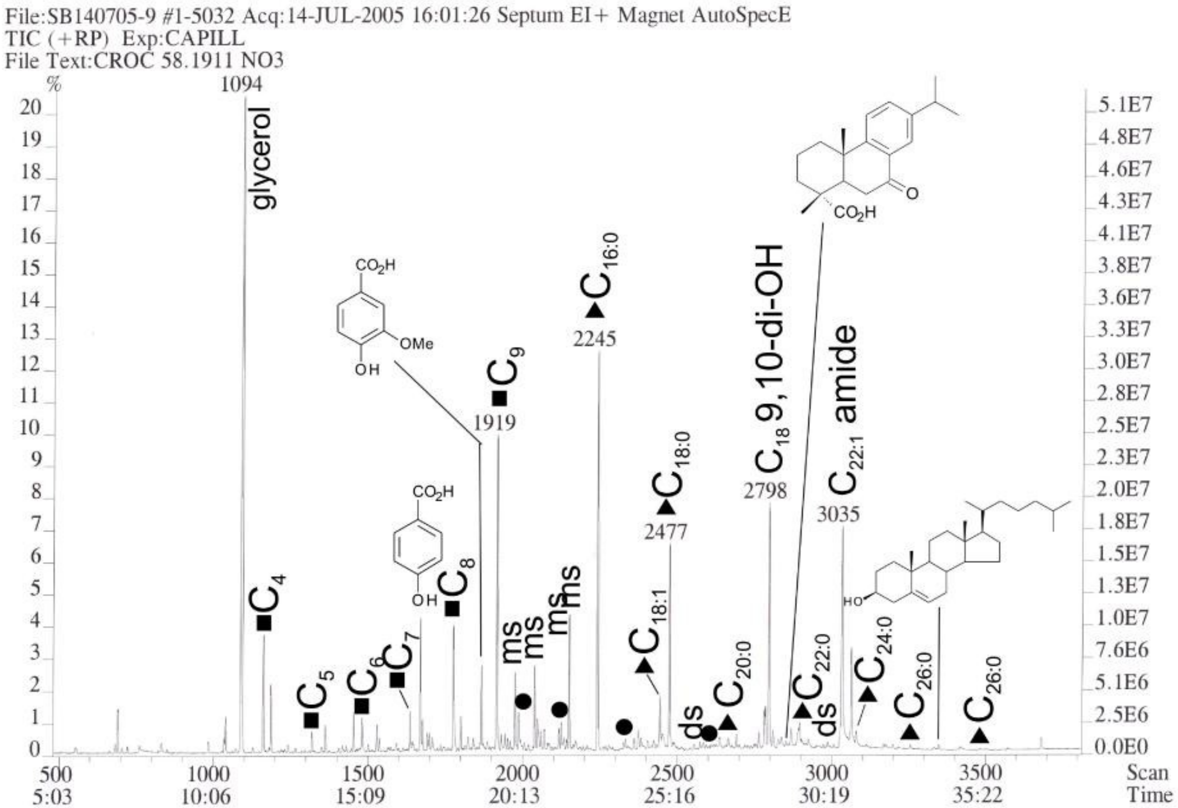

Figure 18 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Crocodile ('fake') 58.1911, 664-332 BC (XXVIth – XXXIst dynasty) 3. darkened linen wrapping from tail (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates a,w-dicarboxylic acids; filled circles; C_x indicates *n*-

alkanes. Also shown is the structure of two aromatic acids identified:4-hydroxybenzoic acid and vanillic acid; one diterpenoid identified: 7-oxodehydroabietic acid; one sterol identified: cholesterol; ms indicates monosaccharides; ds indicates disaccharides; $C_{18:0}$ 9,10-di-OH indicates 9,10-dihydroxyoctadecanoic acid (*erythro* isomer); $C_{22:1}$ amide indicates docosenamide (erucamide). Additionally, glycerol is also labelled.

Appendix 3

Dr Stephen Buckley and Professor Joann Fletcher

Mummy	Date	Provenance	Sample location and description[1]	Inferred components of embalming agents
Cat c2372/3 (Turin Museum)	712-332 BC (XXVth – XXXIst dynasty)	Unknown	1. ‘resin’-impregnated linen 5.76mg – 0.43mg (7%)	Castor oil, animal fat, conifer resin, pistacia resin, ‘balsam’, beeswax
Dog c2347/2 (Turin Museum)	712-332 BC (XXVth – XXXIst dynasty)	Unknown	1. ‘resin’-impregnated linen 16.22mg – 0.60mg (4%)	Animal fat, conifer resin, ‘balsam’
Ichneumon (mongoose) S8191 (Turin Museum)	712-332 BC (XXVth – XXXIst dynasty)	Asiut?	1. ‘resin’-impregnated linen 0.65mg – 0.03mg (5%)	Plant oil, conifer resin, pistacia resin, ‘balsam’
Baboon 2345/1 (Turin Museum)	712-332 BC (XXVth – XXXIst dynasty)	Unknown	2. resin-impregnated linen 50.27mg – 31.35mg (62%)	Animal fat, pistacia resin, beeswax

Shrew (package of) 1920-89 (Plymouth Museum)	664-332 BC (XXVIth – XXXIst dynasty)	Unknown	1. blackened linen wrapping 4.55mg – 1.84mg (40%)	Castor oil, animal fat, conifer resin, pistacia resin

Hawk 1983.727 (Plymouth Museum)	664-332 BC (XXVIth – XXXIst dynasty)	Unknown	5. 'resin'-impregnated loose linen wrappings 16.35mg – 7.16mg (44%)	Animal fat, conifer resin, pistacia resin, beeswax
Fish c2396/1 (Turin Museum)	712-332 BC (XXVth – XXXIst dynasty)	Unknown	1. 'resin'-impregnated linen 11.02mg – 1.43mg (13%)	Animal fat, conifer resin, 'balsam'
Egg A128-1968 (Bolton Museum)	664-332 BC (XXVIth – XXXIst dynasty)?	Unknown	1. 'resin'-impregnated linen 6.78mg – 0.29mg (4%)	Animal fat, conifer resin, 'balsam', a sugar/plant gum, beeswax

[1] The term 'resin' denotes physical appearance and does not presuppose any chemical composition or biological origin.
[2] Compositions do not necessarily reflect the original formulations due to possible chemical changes over time.

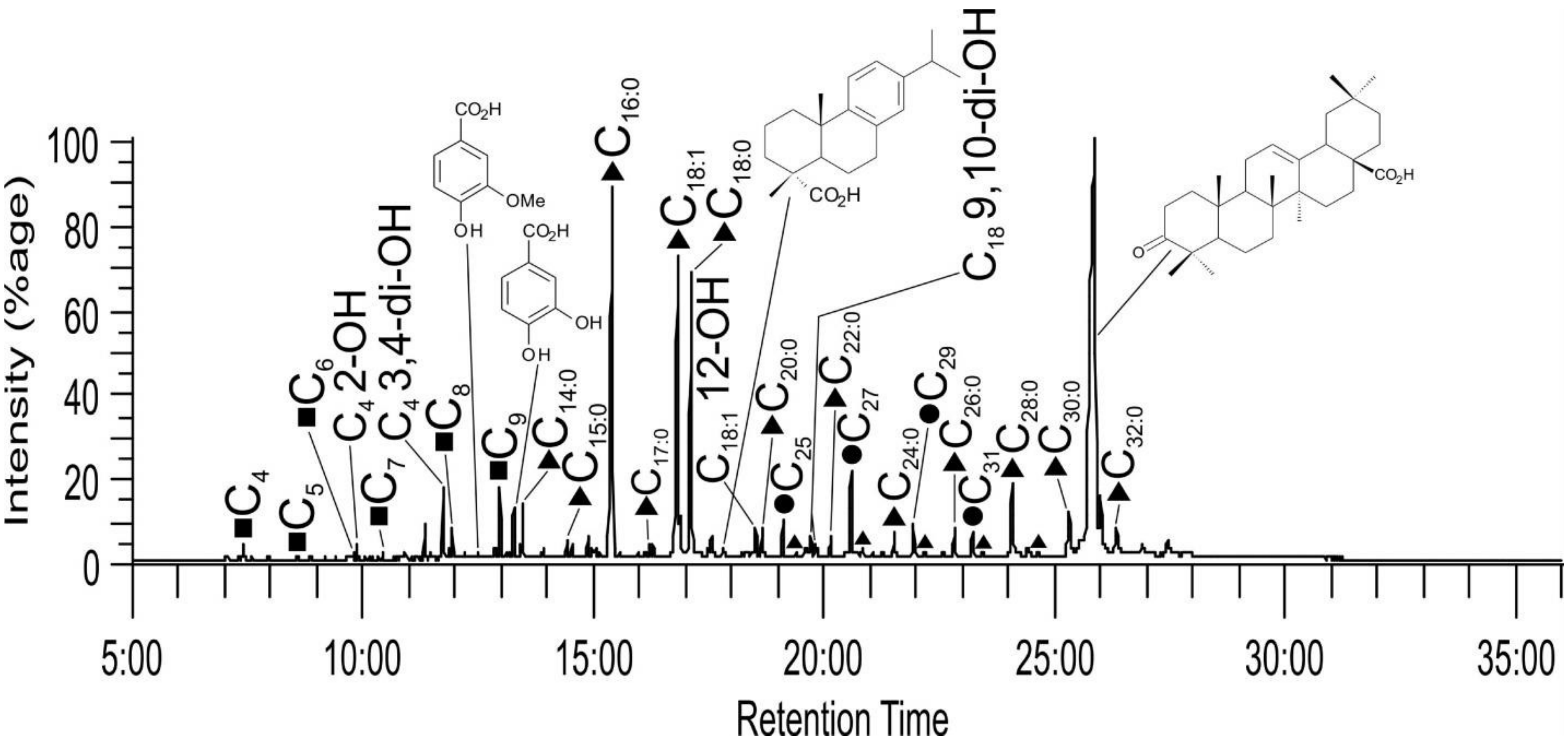

Figure 1 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Cat c2372/3, 712-332 BC (XXVth – XXXIst dynasty) 1. 'resin'-impregnated linen (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates α,ω-dicarboxylic acids; filled circles, C_x indicates *n*-alkanes. Also shown are the structures of two additional aromatic acids identified: vanillic acid and protocatechuic acid; a diterpenoid acid identified: dehydroabietic acid; a triterpenoid acid identified: oleanonic acid. $C_{18:1}$ 12-OH indicates ricinoleic acid and $C_{18:0}$ 9,10-di-OH indicates 9,10-dihydroxyoctadecanoic acid (*threo* isomer).

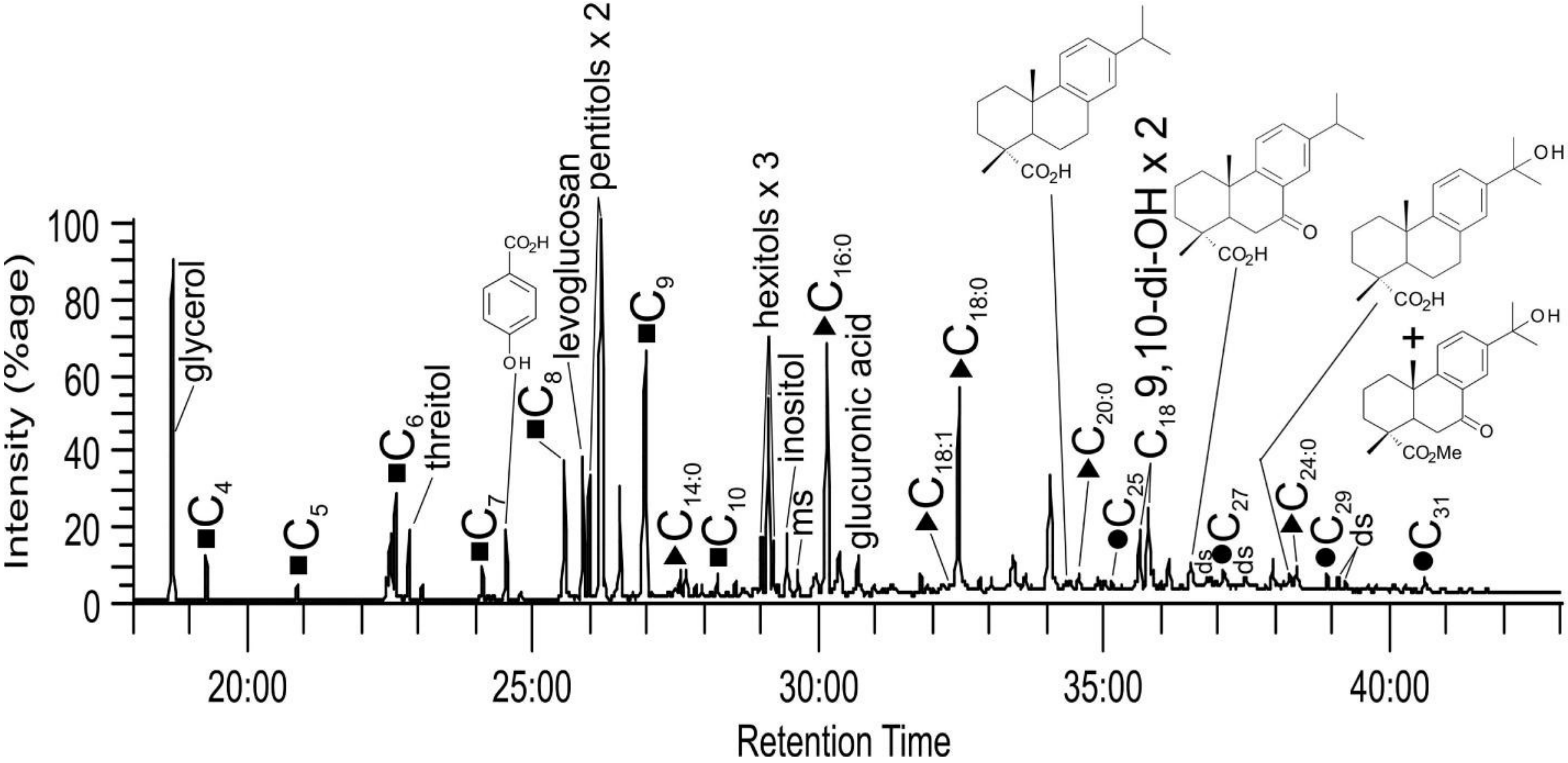

Figure 2 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Dog c2347/2, 712-332 BC (XXVth – XXXIst dynasty) 1. 'resin'-impregnated linen (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates α,ω-dicarboxylic acids; filled circles, C_x indicates *n*-alkanes. Also shown are the structures of an aromatic acid identified: 4-hydroxybenzoic acid; four diterpenoids identified: dehydroabietic acid, 7-oxodehydroabietic acid, 15-hydroxy-7-oxodehydroabietic acid and methyl 15-hydroxy-7-oxodehydroabietate. $C_{18:0}$ 9,10-di-OH indicates 9,10-dihydroxyoctadecanoic acid (*threo* and *erythro* isomers); ms indicates monosaccharides; ds indicates disaccharides. Additionally, glycerol, and the sugar/gum markers threitol, levoglucosan, pentitols (2), hexitols (6), an inositol and glucuronic acid are also labelled.

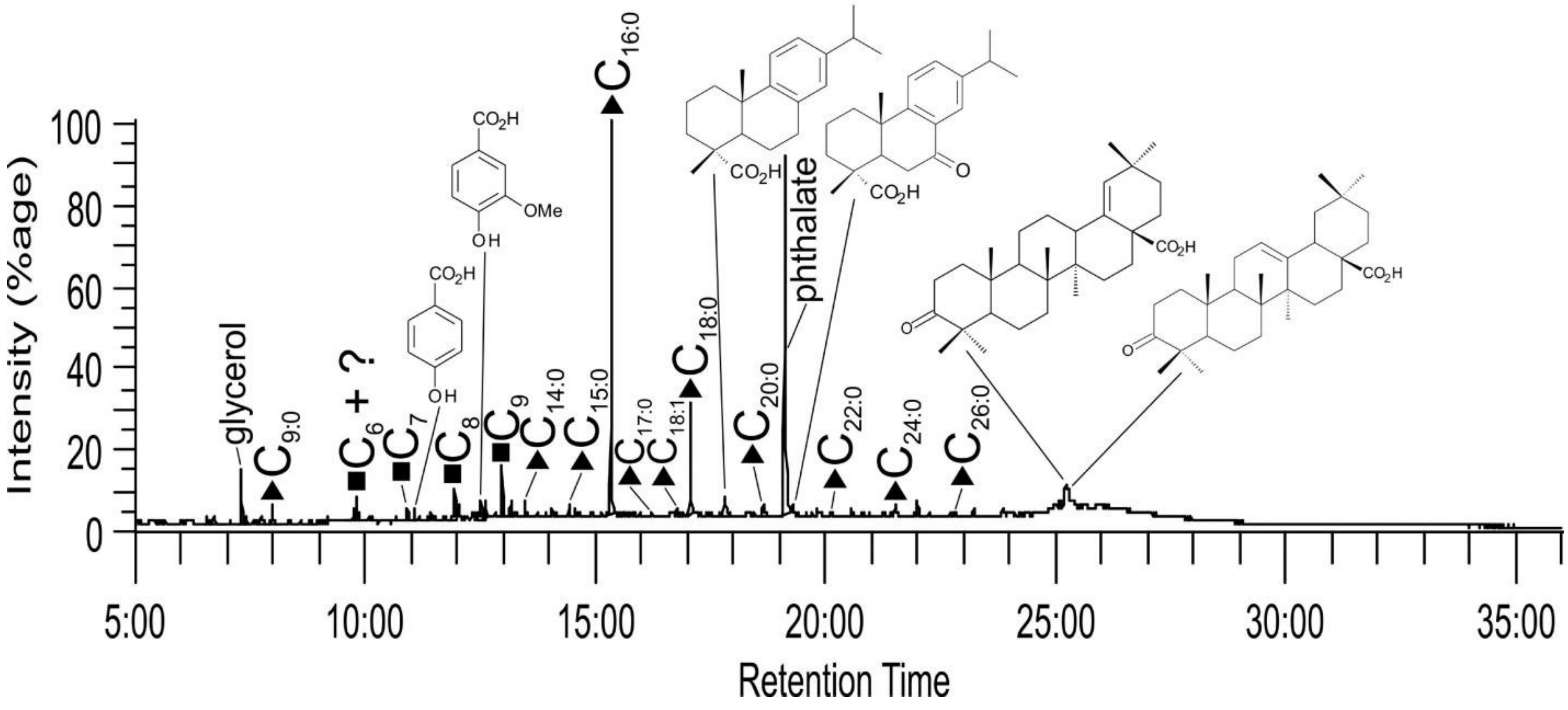

Figure 3 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Ichneumon (mongoose) S8191, 712-332 BC (XXVth – XXXIst dynasty) 1. 'resin'-impregnated linen (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates α,ω-dicarboxylic acids. Also shown are the structures of two additional aromatic acids identified: 4-hydroxybenzoic acid and vanillic acid; two diterpenoids identified: dehydroabietic acid and 7-oxodehydroabietic acid; two triterpenoid acids identified: moronic acid and oleanonic acid. Additionally, glycerol, and a phthalate (modern plasticiser) are also labelled.

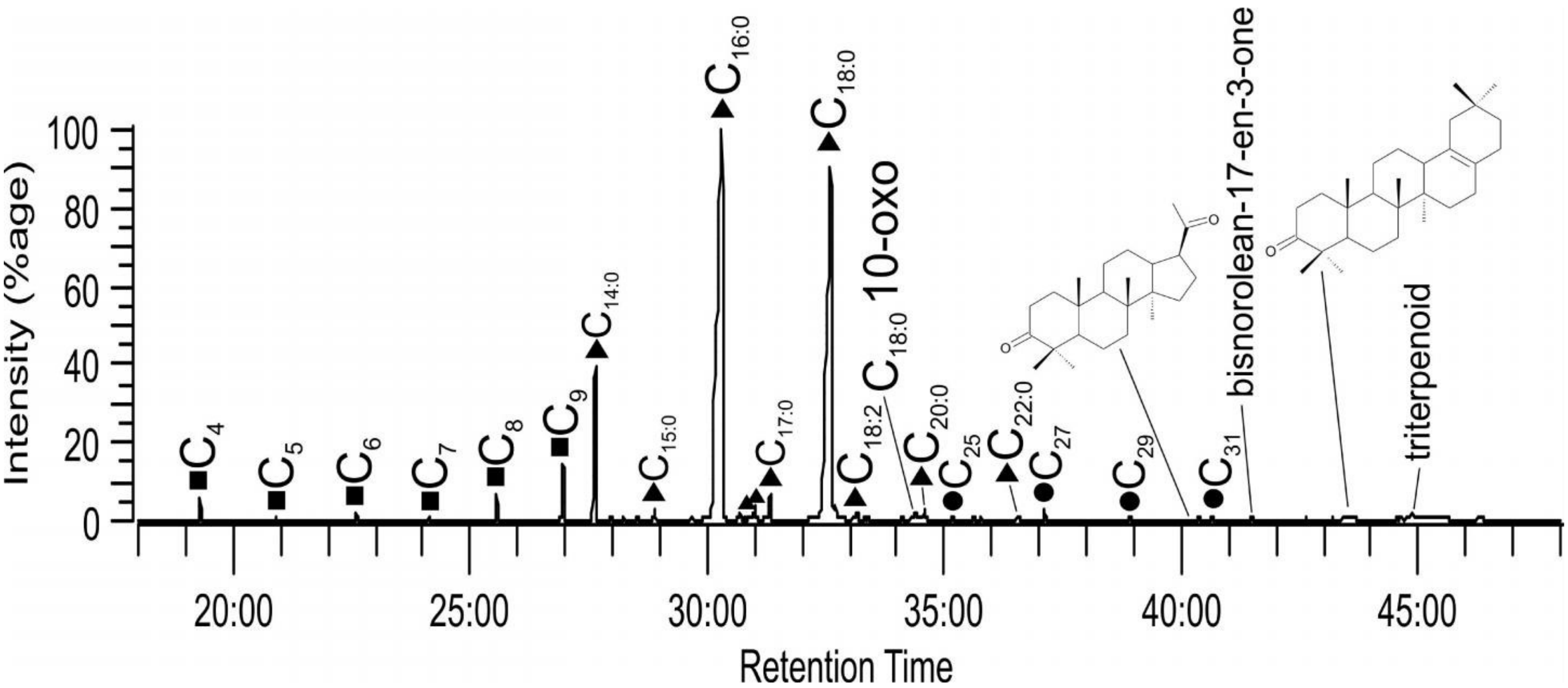

Figure 4 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Baboon 2345/1, 712-332 BC (XXVth – XXXIst dynasty) 2. resin-impregnated linen (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates α,ω-dicarboxylic acids; filled circles, C_x indicates *n*-alkanes. Also shown are the structures of two additional triterpenoids identified: 22,23,24,25,26,27-hexakisnordammaran-3,20-dione and 28-norolean-17-en-3-one. Additionally, bisnorolean-17-en-3-one and an unidentified triterpenoid are also labelled. $C_{18:0}$ 10-oxo indicates 10-oxo-octadecanoic acid.

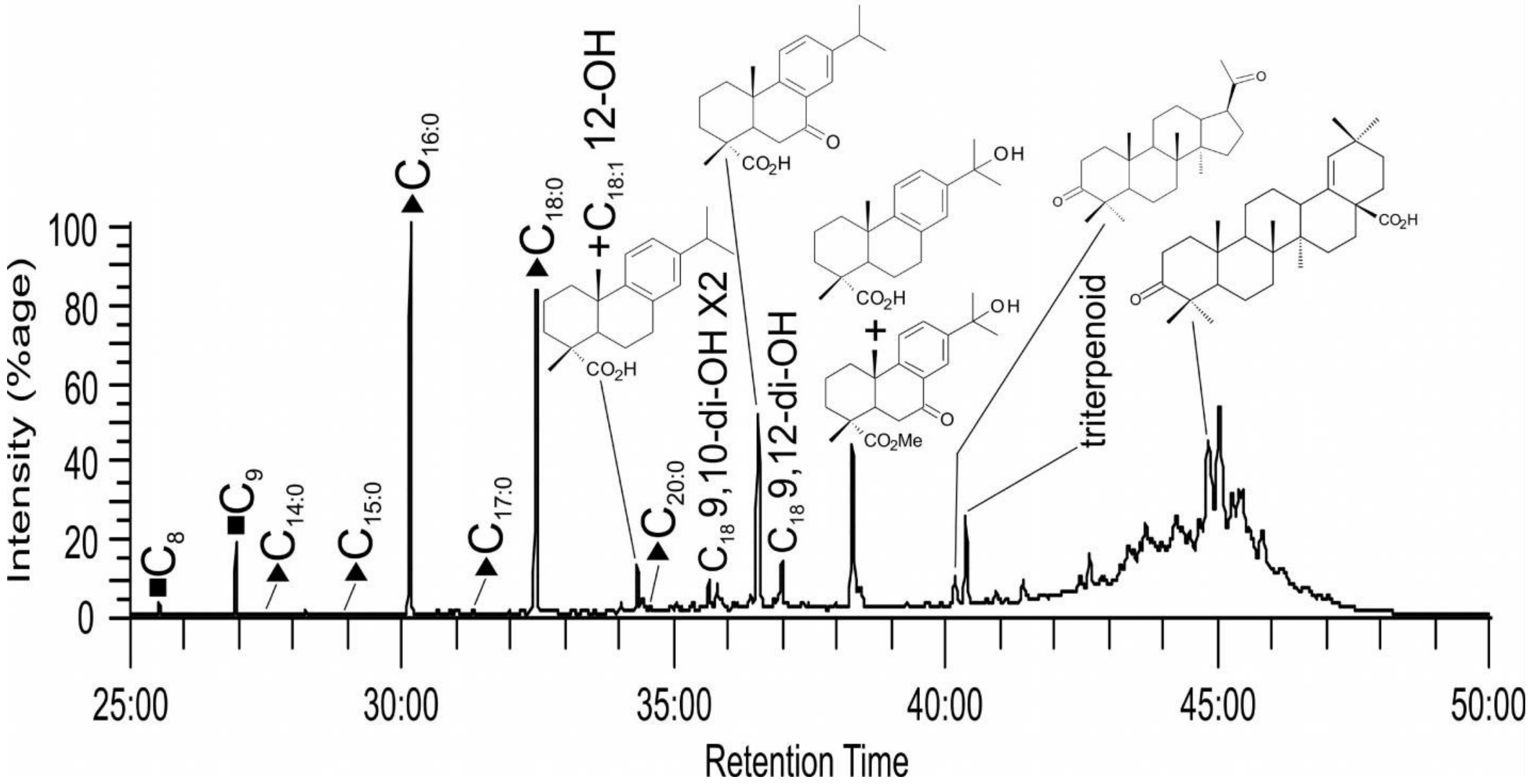

Figure 5 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Shrew (package of) 1920-89, 664-332 BC (XXVIth – XXXIst dynasty) 1.blackened linen wrapping (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates α,ω-dicarboxylic acids. Also shown are the structures of four diterpenoids identified: dehydroabietic acid, 7-oxodehydroabietic acid, 15-hydroxy-7-oxodehydroabietic acid and methyl 15-hydroxy-7-oxodehydroabietate; two triterpenoids identified: 22,23,24,25,26,27-hexakisnordammaran-3,20-dione and moronic acid. Additionally, an unidentified triterpenoid is also labelled. $C_{18:1}$ 12-OH indicates ricinoleic acid.

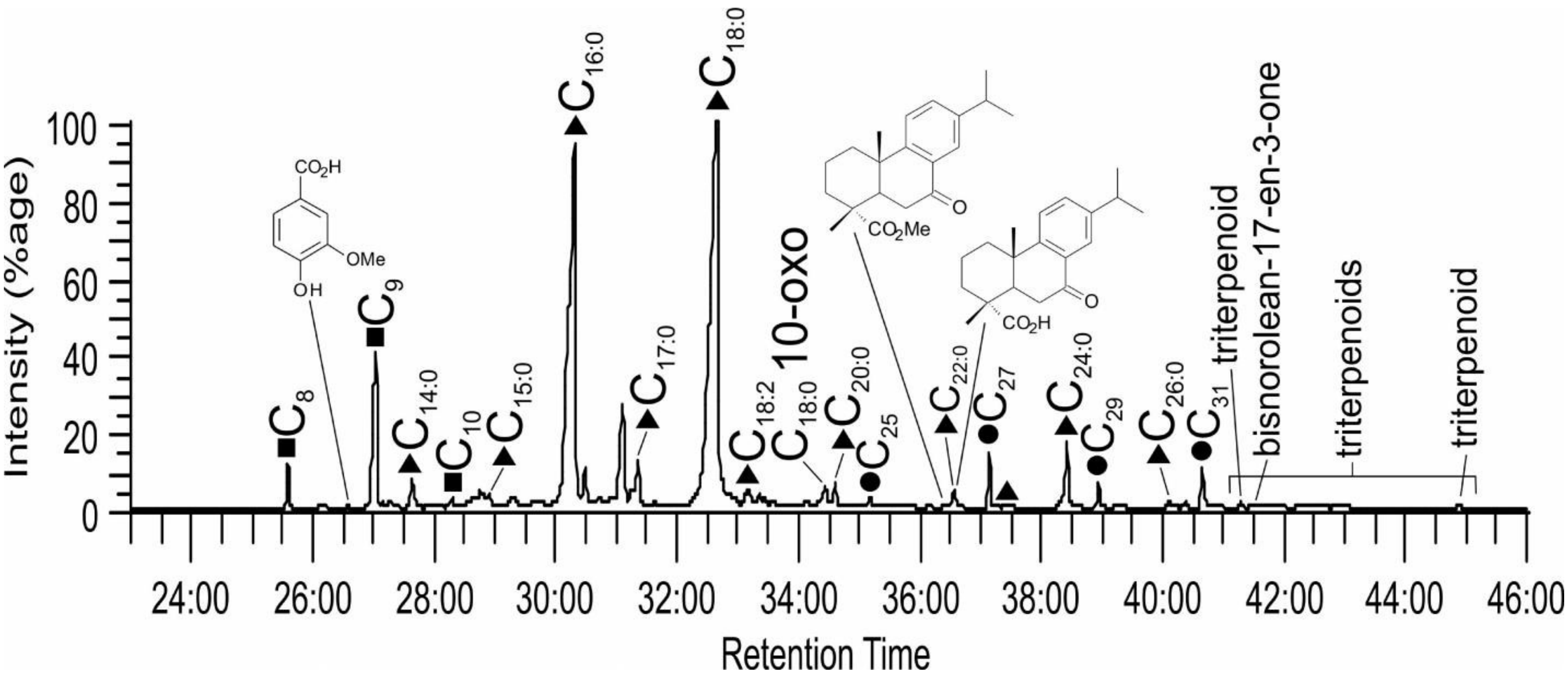

Figure 6 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Hawk 1983-727, 664-332 BC (XXVIth – XXXIst dynasty) 5. 'resin'-impregnated loose linen wrappings (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates α,ω-dicarboxylic acids; filled circles, C_x indicates *n*-alkanes. Also shown are the structures of an additional aromatic acid identified: vanillic acid; two diterpenoids identified: methyl 7-oxodehydroabietate and 7-oxodehydroabietic acid. Additionally, bisnorolean-17-en-3-one and three unidentified triterpenoids are also labelled. $C_{18:0}$ 10-oxo indicates 10-oxo-octadecanoic acid.

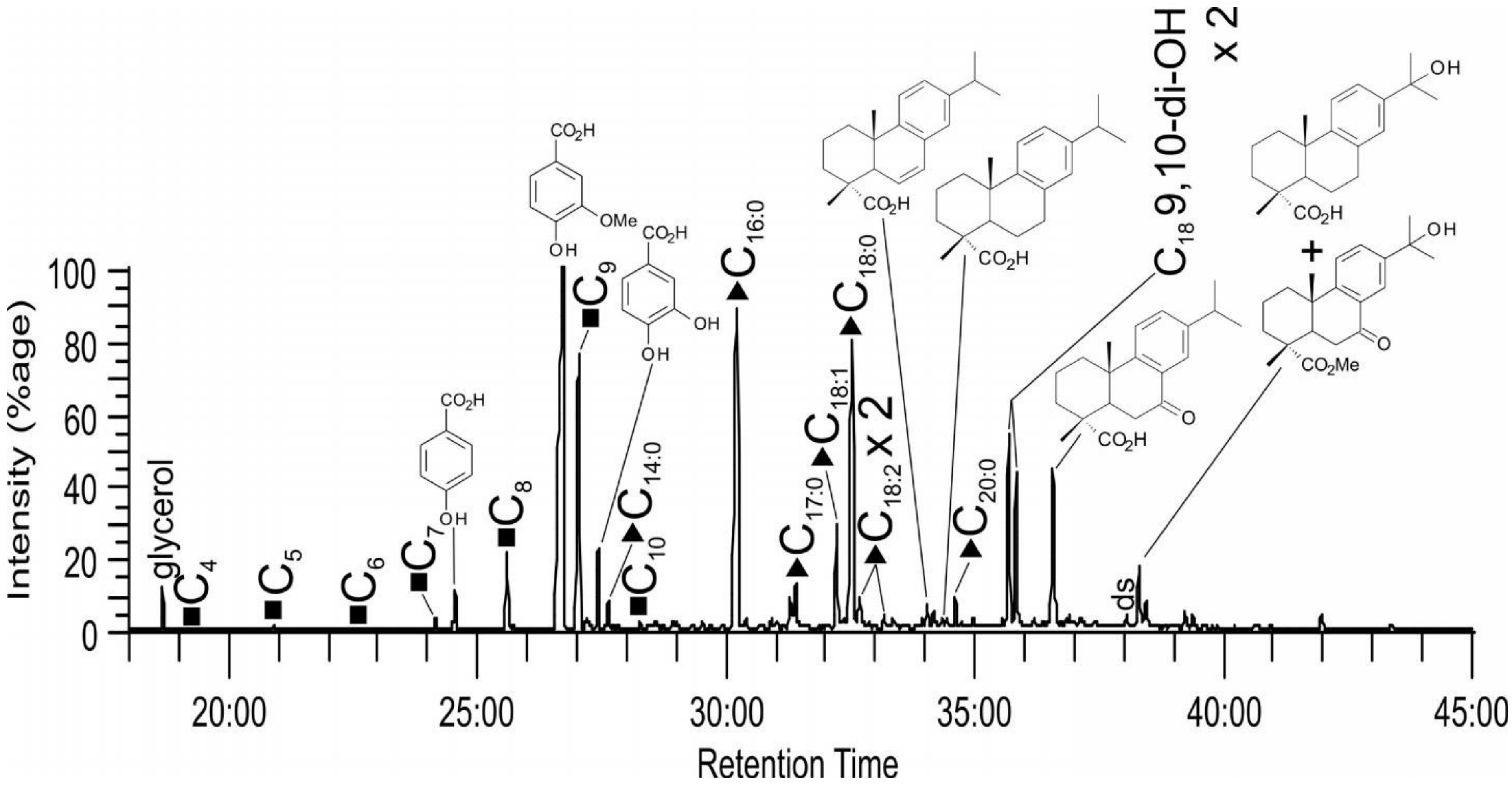

Figure 7 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Fish c2396/1, 712-332 BC (XXV[th] – XXXI[st] dynasty) 1. 'resin'-impregnated linen (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates α,ω-dicarboxylic acids. Also shown are the structures of three aromatic acids identified: 4-hydroxybenzoic acid, vanillic acid and protocatechuic acid; five diterpenoids identified: 6-dehydrodehydroabietic acid, dehydroabietic acid, 7-oxodehydroabietic acid, 15-hydroxy-7-oxodehydroabietic acid and methyl 15-hydroxy-7-oxodehydroabietate. $C_{18:0}$ 9,10-di-OH indicates 9,10-dihydroxyoctadecanoic acid (*threo* and *erythro* isomers); ds indicates disaccharides. Additionally, glycerol is also labelled.

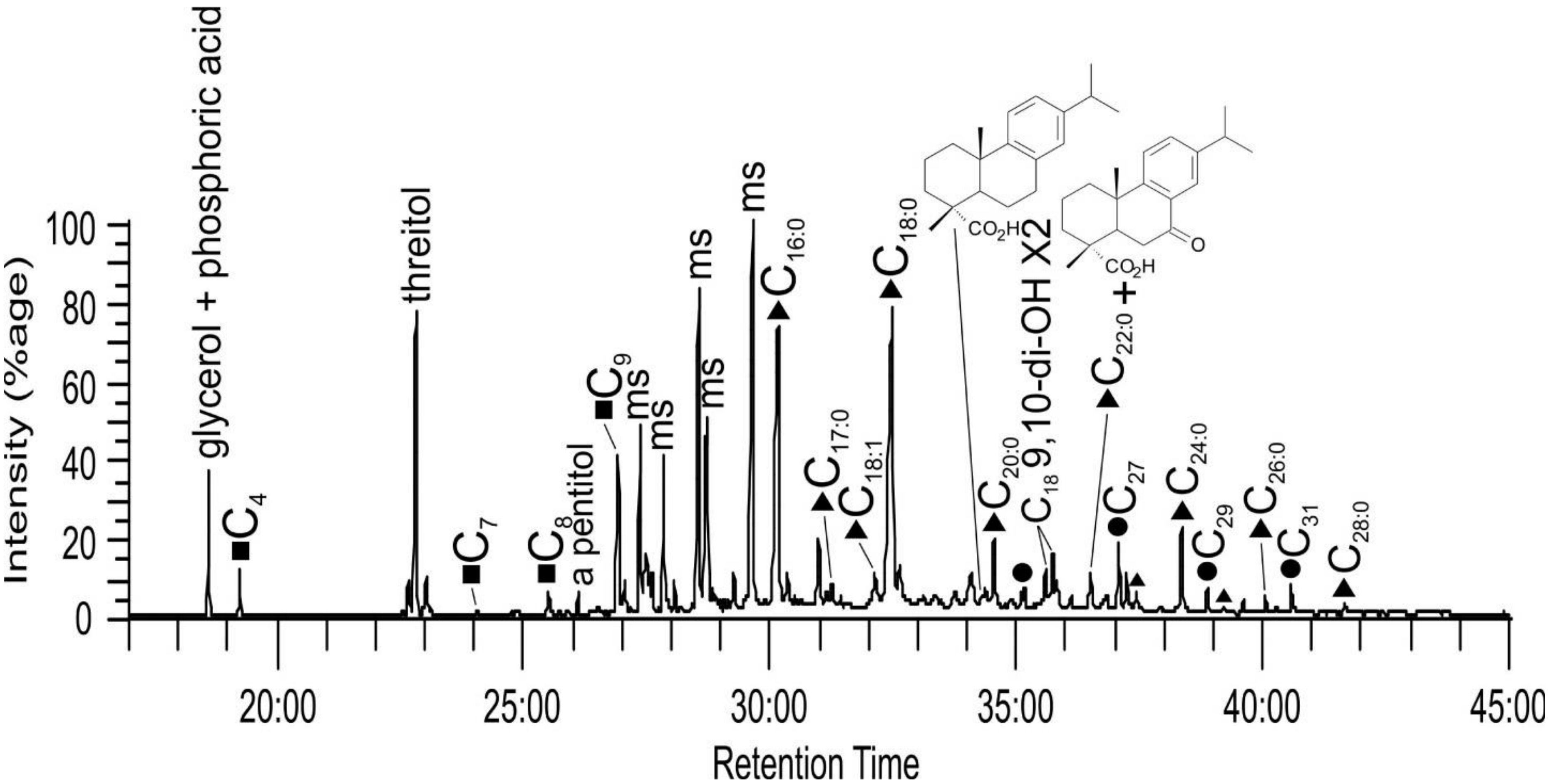

Figure 8 Reconstructed GC-MS TIC of the trimethylsilylated total lipid extracts of Egg A128-1968, 664-332 BC (XXVIth – XXXIst dynasty) 1. 'resin'-impregnated linen (see Table 1). Peak identities ('x' indicates carbon chain length; where shown, y indicates degree of unsaturation): filled triangles, $C_{x:y}$ indicates fatty acids; filled squares, C_x indicates α,ω-dicarboxylic acids; filled circles, C_x indicates *n*-alkanes. Also shown are the structures of two diterpenoids identified: dehydroabietic acid and 7-oxodehydroabietic acid. $C_{18:0}$ 9,10-di-OH indicates 9,10-dihydroxyoctadecanoic acid (*threo* and *erythro* isomers); ms indicates monosaccharides. Additionally, glycerol, phosphoric acid and the

sugar/gum markers threitol and a pentitol are also labelled.

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