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Archaeomalacology

*Molluscs in former environments
of human behaviour*

Edited by
Daniella E. Bar-Yosef Mayer

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11. Reconstructing *Murex* Royal Purple and Biblical Blue in the Aegean

Deborah Ruscillo

*The production of 'Royal Purple' dye had a significant impact on the social and economic worlds of the Aegean Bronze Age. Reams of cloth and garments were traded and offered as tribute to courts and shrines. Even the term 'Royal Purple' signifies the importance and wealth of the cloth as a status object. The crushing of thousands of marine gastropods of the species *Murex trunculus* was required to dye fabric a deep shade of purple. The work was intensive and unpleasant, beginning with the gathering of the creatures for the dye extraction from each individual, to the concoction of the dye itself.*

*Since the Roman times, other sources of purple have been used to dye cloth, and the techniques and recipes of *Murex* dye have been lost. Ancient authors, such as Pliny, superficially discuss the dye-making procedure but do not offer details. In the summer of 2001, with generous funding from the Institute of Aegean Prehistory, the author endeavoured to reconstruct *Murex* dye manufacturing techniques. The work was performed in Crete at the site of Kommos, where excavations of the Middle Minoan II/III period have produced industrial remains of a *Murex* dyeing installation. Crushed *Murex* has been found in contemporary levels at Palaikastro and Knossos, also on the island.*

This paper will illustrate the preliminary results of the baiting, extracting, concocting, and textile dyeing experiments. Swatches of cotton, wool, and silk will be presented to show colour ranges in reference to techniques used.

Introduction

The best Asiatic purple is at Tyre, the best African [dye is made] at Meninx and on the Gaetulian coast of the ocean, the best European purple is in the district of Sparta. The official rods and axes of Rome clear [the purple] a path, and it also marks the honorable estate of boyhood; it distinguishes the Senate from the Knighthood, it is called in to secure the favour of the Gods. It adds radiance to every garment, while in a triumphal robe it is best blended with gold.

Pliny (IX, 12;127)

Pliny the Elder (first century AD) wrote this account of *Murex* purple textile during early Roman times in his *Historia Naturalis*. These were not the reactions to Royal Purple by a select few; his statement reflects the

ostentatious nature of *Murex* purple in the Empire. We know that 'Royal Purple' and 'Biblical Blue' garments have a long history spanning more than three millennia. One of the earliest written accounts of purple textile originates from Linear B texts of prehistoric Greece from the site Knossos around 1250 BC. The Knossos tablets refer to *po-pu-ro2* which has been interpreted as 'purple', and to *po-pu-re-ja* possibly meaning 'female purple dyers' (Palmer 1963, 292, 297, 447). The modern Greek term *porphyra* for *Murex* species has a similar phonetic value to the Linear B *po-pu-ro2*, suggesting a relation specifically to *Murex* purple in the ancient texts. The Greek term is still used, albeit rarely, to describe deep purple, as in *porphyro potami* (the purple river) or deep crimson, as in *porphyro haema* (deep red blood). The term *wa-na-ka-te-ro-po-pu-re* in the Knossos tablets likely indicates textiles of '[*Murex*] purple befitting the

wanax or king', establishing an early beginning for what we still call today "Royal Purple" (Burke 1999, note 16).

Many ancient cultures, especially in the Aegean region and the Near East, refer to purple or crimson-dyed textiles and garments in their literary sources. From the Amarna letters in Egypt, we read that King Tushrath of the Mitanni people on the occasion of his daughter's wedding bestowed a fine violet purple garment and shoes to the groom, Pharaoh Amenhotep III's son around 1400 BC (Mercer 1939). In Homer's Iliad, Andromache, Hector's wife, weaves a purple cloth of double-fold in her home, on which she embroiders colourful flowers (*Il.* 22.440–442). From various cuneiform tablets in the Near East, we find that in the ninth century BC Ashurnasirpal II received booty in purple from the captured Hittite cities of Shuru and Hindani, and from the North Syrian King, Sangara of Carchemish (Reinhold 1970). Tribute was paid to Assyrian kings from the ninth to the seventh centuries BC in "purple garments of their lands", including the island of Arvad, and the cities of Beth Ammon, Ashkelon and Gaza. In the early sixth century BC, the prophet Ezekiel described "Assyrian warriors clothed in purple, governors and commanders" (Reinhold 1970).

By that time, the Phoenician city of Tyre had become the well-known producer of the most lavish purple crimson textiles. The Phoenicians established a reputation for manufacturing and trading the most sought-after, expensive, high-quality dyed fabrics. The term 'Phoenician' derives from the ancient Greek word *pho-e-ni-keo*, possibly referring to crimson colour. This word probably has its root in earlier Linear B with the syllabic term *po-ni-ki-jo* likely referring to crimson-dyed textiles used in trade (Astour 1965). Purple and crimson-dyed wool, and possibly cotton, linen, and silk, were traded for precious metals in the Bronze Age and early Greek, Persian and Roman markets. Xenophon wrote that, "everyone knows that the use of Median robes was restricted to those persons to whom the Persian King had given them" (*Cyr.* 8.2.8). By the end of the Persian Empire, Royal Persian Purple became the royal insignia for the Achaemenid monarchs, Alexander the Great, the Seleucid Kings, and other Hellenistic Rulers. Royal purple was donned by Roman emperors until the early Byzantine times, when cheaper and easier forms of purple dye, including madder and lichens replaced the famous *Murex* Purple. However, the price edict of Diocletian in 301 AD designates the price of *Murex* purple as equivalent to that of gold (Burke 1999, note 15).

These references of purple or crimson textile in ancient literary sources are by no means exhaustive; these are only a sample from various periods to illustrate the history and context of the importance of 'purple' or 'crimson' trade. From the Bronze Age Aegean *wanax* and Near Eastern kings and generals, to Roman emperors, purple was adorned and coveted by the most influential individuals in early history.

From these sources, we realize that Royal Purple was not the colour purple we recognize today, which is usually like the violet produced by a prism. Literary sources refer to purple, deep purple, black, red, crimson, and even blue. It is common knowledge that a mix of blue and red will produce purple of various tones. In antiquity, a variety of colors, not just one, was made from *Murex*, the most lavish of which were dark and vibrant. Pliny wrote that the most glorified purple was like that of congealed blood, blackish at first glance until held up to the light. Perhaps this is what Homer means when he referred to 'blood of purple hue' (Burke 1999, 77).

Some ranges of purple were produced in what were regarded as 'cheaper' forms. Purple produced from plant roots such as dyer's madder and the Egyptian *alkanet* were alternative forms of purple, but apparently cheaper to produce and perhaps less vibrant in color. Ethnographic studies in Egypt reveal textile manufacturers weaving red and blue threads together, forming an overall purple tone when examining the material at a distance (Burke 2001, pers. comm.). In central Medieval Europe, purple was produced by grinding lichens grown on rocks, and in the New World, a purple colour was produced from an insect called cochineal *Dactylopius coccus*.

In the Aegean, however, the most prized purple came from sea snails, especially *Murex*. This report examines the prehistoric dyeing techniques specifically of the species *Murex trunculus*, as reconstructed from the evidence produced by excavations in Minoan Crete.

Background

There are two main species of *Murex* that produce dye, *Murex trunculus* and *Murex brandaris*. A similar-looking species, *Thais haemastoma*, also produces dye. *Thais* species and perhaps *Murex brandaris* produces more of a crimson or wine color in textiles, while *Murex trunculus* is known to produce shades of purple.

In the Aegean, by far, *Murex* species have been recovered in the greatest quantity from archaeological contexts suggestive of dye manufacturing industry. From the Early Bronze Age to the later Roman period, *Murex* remains have been excavated in middens around the Aegean and eastern Mediterranean. The archaeological record consists of crushed or broken *Murex* shells either with holes in the shell body or crushed into pieces and in some cases pottery sherds with purple dye residues (Karmon and Spanier 1988). Sites include: Aghia Eirene, Aghios Kosmas, Asine, Corinth, Eleusis, Iklaina, Isthmia, Kastri, Knossos, Kommos, Kouphonisi, Kynthos, Mytilene, Palaikastro, and Petras in Greece; Troy in Turkey; Hala Sultan Tekke in Cyprus; Sarepta, Sidon, and Tyre in Lebanon; and D'jerba (ancient Meninx) in Tunisia (for a more extensive list of sites, see Reese 1980, 81–83; also Minniti, Karali, and Baruch *et al.* in this volume).

One of the earliest findings of *Murex* remains comes from the site of Kommos in Crete, located 65 kilometers south of Heraklion and five kilometers north of the resort of Matala. In Minoan times, Kommos was the probable harbour town to the Minoan palace of Phaistos, just six kilometers to the north. The site is situated on the shore of the Libyan Sea, on one of the finest beaches of the island. Adjacent to the site lies a natural reef known locally as the *papadoplaka* (the priest's rock), which may have offered some protection from the waves in Minoan times, allowing ships to be moored close to the town. Excavated since 1976 by Joseph and Maria Shaw of the University of Toronto, Kommos offers a unique insight into Minoan daily life, from the Middle Minoan (MM) and Late Minoan (LM) houses of the Hilltop and Hillside, to the palatial and civic buildings found in the southern area of the site.

In 1995, Maria Shaw cleared the central courtyard of palatial Building T and discovered an area paved with slabs with drainage channels (Shaw and Shaw 2003). The floor, channels and adjacent area were covered in crushed *Murex* shells, both *M. trunculus* and *M. brandaris* were represented in the sample. The *Murex* remains consisted of complete specimens, individuals with human-made holes in the body whorls, and crushed pieces of shell. According to the associated pottery dates determined by Aleydis Van de Moortel, the deposit dates from the MM IB or MM IIA or B period (Van de Moortel 2004). Dating as early as 1900 BC, these *Murex* remains are some of the earliest in Crete, and represent one of the earliest *Murex* dye installations in the ancient world. Stieglitz (1994) contends that the earliest known *Murex* industrial remains come from Crete, and therefore represent the place of origin of *Murex* textile dyeing techniques. Cretan sites like Petras, Knossos, Kouphonisi and Kommos have produced Middle Minoan *Murex* remains as early as MM IB, supporting his argument. On the basis of iconographic representations of *Murex* on pottery from Knossos, Bruin (1970) suggested that *Murex* dye production on Crete may have begun even earlier in the third millennium BC. *Murex* purple textiles could have been a major commodity traded from Crete, perhaps for precious metals or other resources, as early as 2500 BC, but certainly by the Middle Minoan period.

Studies of *Murex* remains have been limited in their scope. Often authors, excavators and even faunal specialists have reported archaeological *Murex* remains simply as 'crushed *Murex* possibly used for dye manufacture'. Exaggerated estimates of how many *Murex* specimens were required to make a garment were not only published once, but frequently cited because practical studies in dye manufacture were scarce. Experiments by Friedländer in 1910, for example, extracted only 1.5 grams of dye from 12,000 *Murex brandaris* individuals near Toulon (Reese 1980, 83). A report on display at the archaeological museum on the Greek island of Delos suggested that "thousands of *Murex* were needed to

produce one gram of dye". Other experiments, like those of Jensen and Jensen (1965) revealed that 100 *M. brandaris* shells could produce 6.8–12 mg of dye.

These earlier experiments focused on *M. brandaris* species and were performed out of archaeological context. Having spent a number of years examining the marine remains from the Minoan site of Kommos, I decided that the site itself would be an excellent place to attempt to reconstruct the Minoan methods of dye production based on the installations and *Murex* remains found there. In the summer of 2001, funded by a post-doctoral fellowship from the Institute of Aegean Prehistory, I embarked on a dye-producing expedition in southern Crete with an assistant, Elizabeth Watson, a student from the University of Manitoba. We would use only the local *M. trunculus* species during our experiment and later compare our debris with that produced some 3,900 years earlier found on the site. I had planned also to dye a range of materials and colours to get some idea what the Minoans of Kommos could have been producing and trading.

The experiments

Experimental archaeology was, in this case, a very important aspect of the study of the *Murex* remains from Kommos. After all, Royal Purple, as demonstrated above, was a major trade commodity and status symbol in the ancient Mediterranean world. Remains of such production should be considered highly significant archaeological discoveries on any site because *Murex* remains in substantial quantities reflect an important aspect of the social and economic life of site occupants. On a wider scale, evidence of dye production reflects the life of anyone along the trade routes, from the rulers and warriors who wore the Royal Purple, to the conquered who relinquished it, the merchant who traded it, the producers who manufactured it, right down to the slaves who collected the *Murex*.

By producing Royal Purple ourselves, we could establish a methodology for studying and interpreting archaeological *Murex* remains. We could calculate how much dye was produced from a sample and attempt to distinguish between *Murex* used for food and bait from those used for dye extraction. We might suggest how *Murex* were caught in any given area, and we could contribute to the general knowledge of this important resource in the ancient world through cross-site comparisons, and trade interconnections. This preliminary report, however, will address only the practical aspects of *Murex* production as produced by the experiments performed by the author in summer 2001.

Baiting and collecting

According to Pliny, *Murex* could be caught by baited baskets or baited pots. *Murex* are carnivorous creatures



Fig. 1. Baited pot and basket submerged in the Matala marina with *Murex*.

that thrive on meat and rotting flesh. For the baiting experiment, baskets and pots were acquired, and fish with which to bait them. The experiments began at Kommos near the rocks 500 meters south of the site where I had observed live *Murex* in previous summers. I baited a basket and two pots, found ideal areas around sunken boulders three meters deep and dove to set up the traps. The basket was more difficult to set up because of its buoyancy. The basket needed to be anchored with ropes and weighed down with rocks.

Five weeks passed with occasional renewals of bait, but not one *Murex* was caught in our traps at Kommos. The situation was hindered by days of rough weather that shifted our unshielded traps in the large bay. Perhaps the bay conditions would have been different in the Bronze Age if harbour installations were constructed by the town; no remnants of a breakwater exists there today adjacent from the site, but we know from geological studies that the *papadoplaka* offshore was more extensive in the Bronze Age than it is today (Gifford 1995). Due to millennia of surf wear and army maneuvers during the second World War, the reef has been reduced in mass considerably, and so has the protection it once offered from the rough sea.

Concurrently, we had also set up similar snares in nearby Matala, a smaller and more docile bay approximately 5 kms from the site at Kommos. Matala is today a tourist resort during the summer months and features a relatively short stretch of beach with a small marina along the south edge of the bay. Literally hundreds of *Murex* can be found in the marina during any fishing season. Fishermen discard unwanted fish into the harbour which attract the scavenging *Murex* into the marina. Yet, after four days of rough weather and resultant inability to fish there, not one *Murex* could be found in the vicinity since no food was provided for the scavengers.

With a baited basket and a baited pot, over 70 *Murex* were caught overnight in the enclosed bay of Matala with at least a hundred more specimens huddled around the container openings (Fig. 1). Although the concentration of *Murex* within portable containers was an expedient way of collecting snails, there were problems associated with these methods of acquisition. Firstly, setting up the snares, particularly the basket, took care and time. Minoans would have had to dive several times without a mask to place each basket trap. Secondly, many traps would have to be set to catch hundreds of *Murex*. Thirdly, pots filled with water and captured *Murex* were very heavy to lift to the surface with the attached rope, and finally, *Murex* were not the only creatures that the bait attracted. Eels and ground feeders like scorpion fish found their way into the traps, potential hazards for any diver raising baskets or pots. Hand collection of *Murex* from the floor of the marina was also a successful method of acquisition. With a number of divers and adequate *Murex* specimens attracted by marina refuse, hundreds could be collected by hand in an hour. Certainly the combination of baited traps *and* hand collection seemed like the best combination of methods to collect a significant number of specimens in the shortest amount of time. The individuals could then be collected in a holding tank or an artificial pond of sea water until adequate numbers had been achieved to begin dyeing on an industrial scale, as suggested in Spanier and Karmon (1987). Archaeological remains for holding tanks have not yet been identified at Kommos, however.

Pliny states that 'purples' can live up to seven weeks without food on their own slime and reach full size at one year (Book IX, 128). Therefore, it is possible that *Murex* could have been raised in tanks, as suggested by Columella (Book VIII, 16,7), though he suggested this specifically for locations that did not have direct access

to the sea, unlike Kommos which was established right on the coast. Again, there is no archaeological evidence at Kommos for such tanks.

Upon reexamination of the archaeological *Murex* remains at Kommos, it appears as if *Murex* was collected in antiquity using baited traps and hand collection. The presence of some dead specimens in the archaeological assemblage suggested that these were mistakenly hand collected with other live specimens. Shells collected dead were identified by water erosion and the growth of other marine life on the surface of the shell. The shells of marine mollusca deteriorate when the animal inside dies, and organisms like *Vermetus* begin to grow on the outside. I too collected two dead specimens of *Murex* shell mistakenly from the sea floor, recognizing only during extraction that the shell was actually empty rather than occupied by a gastropod. Clearly, dead specimens cannot crawl into traps unless occupied by a hermit crab, therefore these had to have been collected by hand.

The presence of tiny *Murex* in the archaeological sample confirmed the use of traps. These immature specimens (<2 cms in length) do not yield enough dye worthy of collection or the effort of extraction. We threw these small specimens back in the water from our snares, but the Minoans discarded them on land; they are often found intact in archaeological collections. These small specimens were attracted into traps and were not likely collected by hand. From this evidence, our experiments showed that the most expedient methods for collecting the greatest amount of *Murex* in the shortest time involved baiting and hand collection, something the Minoans seemed to recognize as well.

Dye extraction

The captured specimens were collected in a bucket of sea water and transported to the work site well away from the modern village. It is important to keep the specimens alive until the dye is ready to be extracted because after death, little or no mucus can be extracted from the dry *Murex*. The hypobranchial gland is the 'dye producing' gland in *Murex*; its function is to produce mucus to the mantle cavity of the creature. This gland could then be isolated and extracted to maximize the amount of dye produced from one individual.

Opening the shell composed of thick calcium carbonate was difficult, particularly for the thicker adult specimens. Creating tools from resources that were available to the Minoans, rocks were used to break the outer shell of each individual by pounding. However, in most cases, the shell could not be broken just by crushing them with rocks. The archaeological specimens often exhibited a hole in the main body whorl, presumably made mechanically because of the consistency of the opening size. Holes of approximately five millimeters in diameter can be seen on some of the archaeological specimens. Perhaps these holes were the clue to the secret of how to open *Murex*

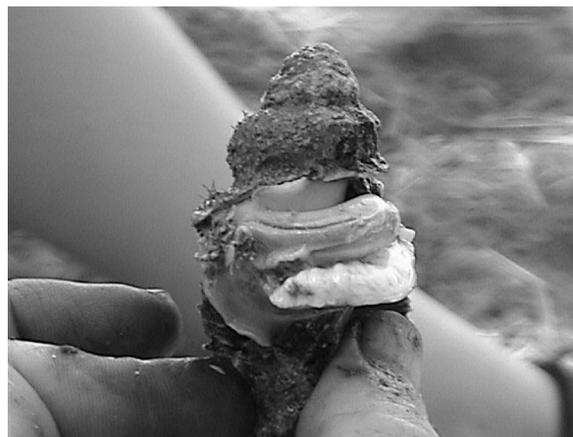


Fig. 2. Broken *Murex trunculus* revealing the hypobranchial gland.

trunculus shells. Using a sharp brass awl (in place of a bronze awl that may have been used in antiquity), we implemented indirect percussion by hammering the awl (using a stone) into the main body whorl of the specimen. This produced a rough hole of about five millimeters in diameter, and undermined the structure of the shell. Then, by direct percussion on the specimen with a stone, a larger piece of the main body whorl was opened more easily, in the exact location where the dye is produced in the creature.

No part of the visceral anatomy of *Murex trunculus* is purple in colour. Therefore, finding the hypobranchial gland is not straightforward. By dissecting the first specimen and separating the organs, it became apparent which gland was responsible for mucus production in the *Murex* gastropod. By separating the organs, the mucus oxidized and the gland producing the dye turned bright purple. The hypobranchial gland in *Murex trunculus* can be identified by the dark brown, grey or black line running through it. Figure 2 demonstrates the location of the gland, which has been separated from the mantle by a sharp instrument. In our case, we used the thorny tip of a century plant (*Agave* sp.), though these were not available on Crete in the Bronze Age. Any sharp metal or obsidian tool would have worked just as well.

The hypobranchial gland was cut out of each creature, and placed in a covered metal pot containing a cup or more of sea water. As the glands were added to the pot, the purple colour produced became more vibrant. The mixture also became thicker as more glands and mucus were added. The rest of the creature was discarded. Our refuse pile looked very much like the archaeological material we had excavated at Kommos in terms of breakage and preservation. Meanwhile, large flies and wasps hovered around us, the former to lay larvae, the latter to feast on the butchered remains. One hundred to 160 specimens were collected for each batch of dye produced; all in all, six batches were made using 825

Murex specimens. Each batch was prepared a different way, and with different additives and mordants.

Concocting the dye

Small amounts of dye were made for each batch (c. 20 fl oz or 590 ml), just enough to dye four 6 x 8 inch (15x20 cm) swatches of cloth. Swatches of pure wool, pure cotton, raw silk and processed silk were dyed in each batch. Linen was also woven and worn in the Bronze Age, as Linear B tablets testify, but pure unaltered linen was difficult to acquire in the modern market for use in these experiments.

According to Pliny, the water and dye mixture had to be steeped for three days, heated, then steeped for another nine. The first batch produced in these experiments followed the directions summarized by Pliny. During the concocting experiments, the mixture was accidentally boiled during heating, an event that actually spoiled the purple colour. The mucus was in effect cooked producing a fine purple powder at the bottom of the pot, but leaving the dye liquid a deep pungent grey. Boiling, however, served to kill the maggots that had been laid and deposited in the dye pots. Maggots could also be exterminated by heating just below the boiling point, while also preserving the integrity of the purple solution. The first batch of dyed swatches under Pliny's instructions produced an unimpressive and superficial grey/purple colour in all fabrics. One wonders if Pliny was not confusing *Murex* purple dye production with that of madder or alkanet dyes, also used in antiquity, whose roots require boiling and steeping for intensifying colour.

The first batch of dye was made with sea water alone, the second with only sweet water. The third batch was made with sea water and urine, and the fourth was made with sea water and an alum mordant. Batch five included sea water and vinegar, and batch six used sea water alone but was not steeped and heated like the other batches swatches were immersed in the concoction immediately after dye extraction. In each case, save for batch 6, the mixture was heated to 80 degrees Celsius after three days of steeping, and sieved to remove the soft tissue from the liquid. The swatches were introduced into the dye bath and left in the dye to cool slowly for several hours to avoid shrinkage. Then the swatches were hung on a line to dry outdoors, without rinsing. The colours produced using these methods were quite variable, and were contingent on fabric type, duration of time in dye bath, number of *Murex* used, and additives introduced into the dye recipes.

Results of dyeing experiments

In general, the experiments revealed that only processed silk or wool were the best receivers of *Murex* dye. The cotton and raw silk did not absorb well; the dried colours were dull and unpleasant. Poor absorption and drab colour

result of the dyed pure cotton suggests that linen, another vegetable fiber, would most likely not produce a better result due to its similarities of texture and composition. By today's standards, the processed silk colours were the most vibrant and attractive, ranging from a light dusty pink to a deep violet. In ancient times, however, the most coveted purple according to Pliny was that like "congealed blood", blackish at first glance but deep and rich in colour (IX, 125–142). Deep and rich blackish-violet colours were produced mainly by dyeing pure wool. The wool absorbed the dye immediately like a sponge, and maintained the deep colour even after rinsing.

This result showed that wool was likely the main fabric dyed with *Murex* to achieve the deep colours so valued in ancient times. During the experiments, both raw wool from freshly shorn sheep (washed in a vinegar wash to remove the oils), and woven wool were dyed using the *Murex* concoction. Both absorbed the dye well and dried into deep tones. The raw wool, however, dried into wool balls containing purple powder and left a purple residue during handling. The raw wool had to be rewashed after dyeing so that the fine purple dust would not overcome the person carding the wool into fleece, or spinning the yarn from the carded product. In terms of practicality, the wool would have been more easily woven into textile first, and then dyed. This system would require only one washing of the final garment rather than multiple washings during the dyeing process. Dyeing a garment or a bolt of cloth already woven might also insure consistency of colour. A bolt of woven wool as a commodity might have required manufacture from several different batches of raw wool. If the dyeing process occurred on raw unwoven wool, varying purple tones may have resulted from dyeing batches of raw wool separately. Colours produced using wool ranged from a light grey-violet to a deep, blackish purple. Therefore, woven wool might have been better dyed than raw wool. It is this dyed woven wool that may have been the tradable commodity in antiquity. For example, Assyrian documents from the first millennium BC mention "purple wool" in tax lists and in lists of booty (Budge and King 1902, 284, I, 88; 287, I, 97). This purple wool could indeed refer to bolts of dyed woven wool rather than dyed raw wool. Certainly, the value of woven dyed material would be still greater than that of raw dyed wool, and perhaps a more valued trade item.

The colours produced by Batch 6 were a complete surprise. These were the swatches immersed immediately after gland extraction in the unsteeped mixture of *Murex* glands and mucus with sea water, and left in the unheated concoction for only 10 minutes, and then hung to dry. I watched as the white, slimy swatches dried to beautiful blue hues. This experiment had recreated the 'Biblical Blue' or *tekhelet*, as it is known, sacred in antiquity as well as the present, particularly in the Jewish religion. It is known that this sacred blue was produced from marine snails. The *talit*, or ritual prayer cloth worn by men during

morning prayer or the wedding ceremony, was traditionally to have a blue fringe dyed from *Murex*. The Old Testament recounts the importance of this through instruction by God to Moses:

Speak to the Israelite people and instruct them to make for themselves fringes on the corners of their garments throughout the ages; let them attach a cord of blue to the fringe at each corner. That shall be your fringe; look at it and recall all the commandments of the Lord and observe them, so that you do not follow your heart and eyes in your lustful urge. (Numbers 15, 38–39)

There has been a resurgence of *tekhelet* manufacture in Israel using marine snails, outlined by Rabbi Herzog in the 1800's (Spanier 1987), and produced today by the *Tekhelet* Foundation in Jerusalem. *Tekhelet* means light blue in Hebrew; this experiment produced a light baby blue to a deep navy blue, all quite attractive.

A persistent problem throughout these extracting, concocting and dyeing experiments was the deep pungent smell of *Murex*. This penetrating smell remained even after washing in detergent. During heating and dyeing, I was forced to wear a mask around my mouth and nose just to bear the incredible stench. All colours were permanent, even without the use of mordants or additives, even through washing – but so was the terrible odour. Dyed textiles would have likely been aired for weeks, then doused with perfume just to be tolerable for the wearer. These experiments therefore make a case for the flourishing perfume industry in antiquity as well!

Conclusions

A hands-on approach to reconstructing *Murex* dye production in Crete can reveal more aspects of the ancient industry than mere speculation. Encountering problems in baiting, gathering, extracting, concocting and dyeing aid in realistically assessing the time and the effort of ancient dyers, and ultimately, the worth of the resultant dyed textile.

Several important facts became apparent during these experiments:

- 1) *Murex* individuals were probably baited and hand collected during antiquity;
- 2) *Murex* dye is colour-fast even without the use of additives and mordants;
- 3) Minimal water included with the dye glands produces deeper colours;
- 4) A urine additive makes the purple dye more vibrant;
- 5) Pliny never made dye himself;
- 6) Bringing the mixture to a boil ruins Royal Purple dye;
- 7) Steeping for three days produces a deep vibrant purple;
- 8) Steeping for more than three days is unnecessary;
- 9) Many shades of blue and violet can be produced from *Murex trunculus*;
- 10) Dyed hands remained coloured for six weeks until the nails grew out;
- 11) *Murex* mucus can be used for temporary tattooing, like henna;
- 12) Wool absorbed the most dye and attained the deepest shades;
- 13) Pure cotton, and probably linen, do not achieve a pleasing colour through these methods;
- 14) Processed silk produces the nicest colours, by today's standards;
- 15) Biblical Blue can be made from *Murex* species as well as Royal Purple;
- 16) The odour encountered throughout the dyeing process is terrible;
- 17) Dyed swatches maintained their colour and their stench even after washing;
- 18) Perfume would likely have been required on new garments.

One of the most important results from these experiments was the conclusion that one does not need thousands of *Murex trunculus* to produce adequate dye for the trim of a garment. Wool dyeing certainly required more *Murex* individuals, while lighter fabrics required less. But in general, hundreds often would suffice to produce a fine colour on lighter garments. A woolen cloak would likely have required thousands of individuals to produce a deep blackish purple, like that sought after in antiquity. Dye extracted from *Murex brandaris*, however, is said to be less than *Murex trunculus* by up to 50% per individual (Fouquet and Bielig 1971), so exaggerated estimates on *Murex* requirements for desired colour may have been based on the former during past speculation. Future experiments using *Murex brandaris* will establish how the dye quantities and colours vary between Muricidae species.

These experiments also revealed why *Murex* dyed textiles were so costly to produce and trade in antiquity. The number of human hours used to produce one garment is substantial, not considering the arduous tasks *Murex* dye production involve. From the sometimes dangerous diving and baiting to acquire enough specimens, to the battle with biting flies, maggots and wasps and the incredible stench throughout the dyeing process, one can realize only through experimentation how Royal Purple compared to other cheaper forms of purple. The colour-fastness also assured the long-life of a garment. Archaeological specimens of purple garments still survive, like that from the tomb of Philip of Macedon in Vergina buried some 2,400 years ago. Although there has been a recent resurgence of Biblical Blue made from *Murex trunculus*, it is doubtful that people will once again adorn the Royal Purple. In an age of vibrant synthetic colours, people are no longer willing to submit to the difficulties of *Murex* dye production, nor endure the over-powering

smell of these garments. Royal Purple, like many ancient wonders, will remain a part of the glorious past.

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