The History of the Sacred Purple:
The Use of Muricidae as a Dye Source

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Introduction

When mentioning the color of purple cloth to someone in a historical context, all sorts of misconceptions come into play. Some refer to the color as royal purple, or Tyrian purple. Some people say it refers to a certain shade, rather than the whole color pallet. Others will tell you that it is the color of kings and that no one else can wear the color. All of these statements are both true, and untrue at the same time. The intent of this research paper is to help correct those misconceptions, as well as to give background and insight into what is arguably the world’s most famous and least understood dye.

Historically, the word purple referred not to a particular shade of dye, but rather a family of dye colors that came from one particular type of animal, the marine snail *Murex*, commonly known as the rock snail (Cardon, 2007). The epicenter of their use, and where they are most famous, is the Mediterranean. But there are also other species that were historically used in China, Japan, Mexico, and parts of Central and South America (see Figure 1. Baker, 1974). Many species of molluscs in the family Muricidae are used for dye, there are now different genus names besides *Murex* used for the snails that were historically used for dye (Cardon, 2007).

![Image of a world map with historical sites marked in red](image)

*Figure 1. Historical sites of murex dyeing marked in red (Baker, 1974)*
For the scope of this research project, I will focus primarily on the Muricidae in the Mediterranean, and briefly discuss other parts of the world. When I refer to Murex colloquially, I shall be referring to all the species of that family, regardless of what genus they are currently assigned to. The main species I will be discussing was known as *Murex trunculus* (modernly *Hexaplex trunculus*). *Murex brandaris* (modernly *Bolinus brandaris*) and *Purpura haemastoma* (modernly *Stramonita haemastoma*) were also used for dye, but to a lesser degree. For this paper I will be using the historical names for clarity.

Biologically, it should be noted that these species are both different in size and in the ecological areas they inhabit. *M. trunculus* grows best in rocky areas that are up to 100 meters deep, whereas *M. brandaris* prefers sandy and muddy substrate up to 135 meters deep (Monaghan, 2001). Monaghan also states that those found in sheltered bays tend to grow much larger than those found on beaches and on rocky coasts. They were usually caught with small net snares thrown in at depth with bait (Pliny & Holland, 1847, Chapter XXXVII). Pliny goes on to mention in the next chapter that the best time to harvest is after the Dog-Star [Sirius] has risen, or before the spring. In the spring, the shellfish lay their eggs, and in doing so also exude the chemical that is responsible for the dye color. The fluid, which comes from the hypobranchial gland of the animal, is thought to be created for defensive purposes and be a poison to help immobilize its prey. In passing on that fluid to its offspring, it helps prevent predation of the next generation (Grierson, 1986). Both large and small individuals were harvested with the larger ones having the sack-like hypobranchial gland (which is found in the mantle cavity, that is to say the upper part of the shell away from the opening, see Appendix 4 for a diagram of where this gland is located in a similar species) removed intact and the smaller ones crushed (Schneider, 2012). The liquid can itself be immediately used to dye cloth; but once exposed to sunlight for a period of time, the chemicals present undergo reactions and the dye chemicals become insoluble and unable to stick to the fibers unless processed in a fermentation vat (Schneider, 2012). This will be discussed later.

M. Guckelsberger, in his doctoral dissertation (2013) for the University of Iceland postulates that the smaller snails referred to by Pliny as ‘bucinum’ is likely *P. haemastoma* and

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1 For a listing of all the species involved, please refer to *Tyrian Purple: An Ancient Dye, A Modern Problem* by J.T. Baker (1974). The genus names are out of date, but they can be easily referenced to their current counterparts by a quick internet search.
the larger ‘plegaium’ is *M. trunculus*, due to both their known size differences and the colors he says they produce. *M. brandaris* is likely that identified as ‘dialutense’. While Pliny does go on to mention more varieties that cannot readily be identified (Pliny and Holland, 1847), this does at least clear up some confusion that may prevent the reader from understanding this source.

The colors that could be achieved from *Murex* and *Purpura* ranged from pinks and fuchsias to blues and violets as we would describe them today. Different cities were known for particular shades, with Tyre being the most famous. This is where the nickname of Tyrian purple comes from. Both the biblical colors of “argaman” and “tekhelet”, a sky blue color, long known from the Talmud to come from a marine creature called a Hillazon (sometimes spelled Chilazon) come from *Murex* species. “Argaman” comes from *M. brandaris* whereas tekhelet was only recently discovered to come from *M. trunculus*. The difference in shades relates to the differences in environmental conditions of different dye sites around the Mediterranean. While *M. brandaris* and *P. haemoastoma*, create purple, this is nearly always used in conjunction with dye from *M. trunculus* to make the color stronger. Only *M. trunculus* can produce the full range of colors that can be achieved from *Murex* (Cardon, 2007).
The Origin of Purple (For Location Maps, Please See Appendix 2)

The first evidence of dyeing with *Murex* is credited to the Minoans on Crete, although dye centers from about that time have also been found on the island of Lesbos, also in the eastern Aegean Sea, in Turkey and around the Arabian Gulf (Guckelsburger, 2013). Production on an industrial scale as well as export is thought to have in full swing by 1700-1600 BCE. The Levant\(^2\) had knowledge of the dye processes a hundred years later and then the Phoenicians (Guckelsburger, 2013).

The Phoenicians, whose empire stretched roughly between 1500 BCE to 300 BCE, are the ones whom most historians credit with the first mass use of *Murex* purple. William F. Leggett in *Ancient and Medieval Dyes* (1944) postulates that it started in Minoan Crete for home use, and when the Phoenicians visited Crete by sea, they spread its use to the Mediterranean. J.T. Baker (1974) states that some archaeologists believe that the first purple dye was produced before 1600 BCE on Leuke, a small island to the south-east of Crete. This is substantiated by the fact that *M. trunculus* shells were found with pre-Phoenician artifacts during an expedition in 1903. There is also evidence of dyeing happening elsewhere on the Syrian coast, a clay tablet was found that describes the dyeing of wool with purple in the city of Ugarit in about 1500 BCE. Perhaps, as is suggested in *The Art of Dyeing* (Brunello, 1973), the discovery was made in several places at several times, and it is impossible today to say which was first.

There is also a persistent myth throughout the ages of how the dye was discovered. It was said that the god Melquart [or Merkarth] was strolling along a seashore covered in shells with his lover, the nymph Tyros. His dog bit into one of the shells, which stained its teeth purple. The god had a robe dyed in that purple and presented it to his lover as a gift. Another version states that the dog was brought before the king of Tyre, Phoenix, who decreed that this purple dye should be manufactured and sold and it should be used as the royal badge of office (Cardon, 2007). Whether any version of the story is true or not, the image of the *Murex* shell and the purple-toothed dog was later put on Tyrian coins (Miles, 2011) as a form of “business advertising”.

\(^2\) This could refer to a range of countries depending on when the term was used. In 1497, when the term first originates, it refers to Mediterranean lands east of Italy. In a more restricted modern sense, it refers to Cyprus, Egypt, Iraq, Israel, Jordan, Lebanon, Palestine, Syria and Turkey.
Once the dye was known, the search was on throughout the entire Phoenician empire. They discovered that different species of *Murex* produced different shades; with *M. trunculus* giving a blue-purple and *M. brandaris* a dark red. Different cities became known for producing their own particular shades. Lancel (1995) mentions that dyes were produced at Kerkouane, a Punic town in modern day Tunisia dating to the early third century BCE. Its main industries were salt-making, purple dye manufacturing and garum production. (Miles, 2011). By the seventh century BCE, Carthage was a major manufacturer known for cloth of deep purple and heavily embroidered garments, of a quality recognized throughout ancient literature from the Bible to Homer’s Odyssey (Miles, 2011, Wilson 2006). As in other cities, the area of work was outside the city walls (Miles, 2011). Motya, a city off the cost of Sicily, also had dye workshops and a dock for shipping exports (Miles, 2011). In fact, it could be postulated that nearly every coastal and island town was producing it. But by far, the most famous cities were Tyre and Sidon, so redolent with dye vats that they were considered “unpleasant for residence” (Wilson, 2006).

By the 8th century BCE, the Phoenician empire was in decline and the Greek empire on the rise, the transition made complete by Alexander the Great’s sack of Tyre in 332 BCE. Carthage, being far west of Tyre, continued to flourish until much later when Carthage fell to Rome in the Punic Wars in 146 BCE. The Greeks killed many rulers of the cities they conquered but kept trade going as it would profit them. The use of purple was widespread throughout Greece by the 4th century as a status symbol and the poets referred to it as the color of heroes and gods. Paint was also produced from *Murex* and used in artwork depicting the gods to show honor (Wilson, 2006).

The dye centers of Hermione in Argolis, and Meliboea in Thessaly became known for their quality of purple dye (Brunello, 1973). The town of Bulis on the Gulf of Corinth even had half its workers producing this dye (Wilson, 2006). Today archaeologists are able to identify which towns were producers because there are hills left on the landscape made entirely of *Murex* shells. Labor may have been cheap, but the dye itself needed vast quantities of shells, with 12,000 *M. brandaris* yielding just 1.5 grams (0.05 ounces) of dye. This caused the dye to be terribly expensive, up to $28,000 modern dollars per kilo (1 kilo = 2.2 lbs), and demand also meant that dyers were constantly looking for new supplies (Wilson, 2006). It seems though that the major sources were never completely depleted, merely reseeded with waste shells and left to
regenerate (Jensen, 1963). As the *Murex* became less common, a substance known as orchil, which is a purple dye achieved from lichens, was used as a base dye to reduce the amount of *Murex* needed (Cardon, 2007). The primary genus of lichen used for orchil was *Roccella*, of which several species were used. There were likely also fraudulent sales of people passing off orchil dyed cloth as being totally *Murex* dyed. Lichens are known to grow very slowly, and the use of orchil was likely not a sustainable industry over time. The traditional way to extract orchil dye was to first clean and dry the lichen and then crush the lichen to small pieces and mix with water. A certain quantity of ammonia is added and this mixture is frequently stirred and allowed to ferment. Various alkalis can be added to change the hue of the color (Grierson, 1986).

As the Greek Empire declined, the Roman Empire rose and expanded. With the Roman Empire’s reach extending all the way to the British Isles, they now had access to *Ochrolechia tartarea* and *Umbilicaria pustulata* for orchil (Dean, 2014). Originally, the Romans preferred simple cloth of natural colors but as they were influenced by their neighbors, they too began preferring bright colors, to the point where separate names were given to the dyers of each color. The *flammarii* were dyers of orange and the *crocearii* used saffron for yellow. There were brown dyers and red dyers, but of course the highest ranking were the *purpurarii* and their product was sold in separate shops called *tabernae purpurae*.* Even among purple, there was a hierarchy. The dark violet from *M. brandaris* and scarlet from *P. haemastoma* was mixed to produce a purple-violet and considered a base color. There were shades of violet and of blue-violet, but the most sought after was a red-purple known as *oxyblatta*, or *tyria* and it was the color of congealed blood. It was created by passing cloth through several dye baths of different shades, and so it was much more expensive than the others (Brunello, 1973).

In the beginning of the Roman Empire (753 BCE to 476 CE), the wearing of entirely purple garments was reserved for kings and priests. Later, as Rome became a republic, its use was extended to include higher officials who wore ribbons of that color on their togas to signify rank and power. Julius Caesar specifically dictated which types of citizens could wear which qualities and hues of purple, with the most luxurious and expensive being reserved for him. Caligula, Nero and Domitian also continued such decrees but all it did was create a fashion mania known as *purpurae insania* (Cardon, 2007). Romans had a passion for purple that could not be stopped; as the influence of the Empire spread, the amount of individual disposable wealth
increased as well as that of the empire as a whole. It eventually became simply a sign of wealth and power in general rather than a symbol of royalty. After all, why restrict people from wearing it when it could be another tax source? Under Alexander Severus (222-245 CE), the production of purple became a regulated monopoly of the state and all the fisherman of *Murex* became regulated into a corporation with set delivery quotas to fulfill to the dyers (Brunello, 1973).

After the fall of Rome in 476 CE, vast areas were taken over by Arabs, who didn’t use purple, but also didn’t destroy the factories either (Brunello, 1973). In the fifth century, methods of preservation were discovered that allowed dead *Murex* to keep for up to six months without a decline in dye quality and allow for transportation to areas not tainted with the discarded waste of dye factories, where the snails had a better chance of surviving. There is evidence of purple dye factories existing in Upper Egypt in the seventh century CE, but it is likely that this was one of the areas where good water existed and dead snails were exported from, as there was a lack of *Murex* shells from harvesting at that site (Brunello, 1973). We do know that the industry was still going in the time of Charlemagne (768 to 814 CE) as he had Venetian merchants importing purple cloth from Lebanon (Jensen, 1963). In the twelfth century, there were still dye works in Byzantium and in Palermo that created a small resurgence. It was also at this time that purple dye was used to color special parchment for the most precious books, or for writing important titles in books (Brunello, 1972). Eventually lack of demand, a decline in availability of resources and inability to distribute caused the industry to slowly collapse. The fall of Constantinople in 1453 to the Ottoman Empire was the final death knell for the industry (Dean, 2014).

In the Renaissance, the purple dye in question is then not *Murex* at all, but the previously mentioned orchil lichen dye. The 1574 Statutes of Apparel in Britain proclaimed that that none shall wear

> “any silk of the color of purple, cloth of gold tissued, nor fur of sables, but only the King, Queen, King’s mother, children, brethren, and sisters, uncles and aunts; and except dukes, marquises, and earls, who may wear the same in doublets, jerkins, linings of cloaks, gowns, and hose; and those of the Garter, purple in mantles only.” (Flavin, 2011)

While this still severely limits the amount of people who could purple, the number allowed are still a great many more than just the king, and many are not actually royalty. Like other items prohibited by Sumptuary Laws however, it is highly likely that people who were prohibited from wearing purple did so anyway and simply paid their fines. Flavin (2011) states that the Anglo-
Irish were particularly partial to the color. She lists that Ireland imported over 5,411 lbs. of orchil from Bristol in 1503, down to 595 lbs. in 1545 and an average of 2,683 lbs. by the end of the century. The fluctuations can possibly be explained by the introduction of New World dye plants and their subsequent ban, and the fluctuation of prices of woad and madder, which can be used together to produce a purple color. Since it is known that one can achieve different shades from lichens, it could also be hypothesized that, like the ancient Romans, there were different shades of purple available for different prices. Also, the Sumptuary Laws of England may not have applied as strictly to Ireland, and those living further away from London and the royal court could get away with flouting the laws easier.
Attempts to Recreate the Process

Pliny the Elder

Our best description of the original process of *Murex* dye used in antiquity comes from Pliny the Elder – 1st century CE Roman author, naturalist and natural philosopher – in his *Natural History* (Doumet, 1980), who states thus:

“Three days is the proper time for it to be steeped (as the fresher the salt the stronger it is), and it should be heated in a leaden pot, and with 50 lbs. of dye to every six gallons of water kept at a uniform and moderate temperature by a pipe brought from a furnace some way off. This will cause it gradually to deposit the portions of flesh which are bound to have adhered to the veins, and after about nine days the cauldron is strained and a fleece that has been washed clean is dipped for a trial, and the liquid is heated up until fair confidence is achieved. A ruddy colour is inferior to a blackish one. The fleece is allowed to soak for five hours and after it has been carded is dipped again, until it soaks up all the juice. The whelk by itself is not approved of, as it does not make a fast dye; it is blended in a moderate degree with sea-purple which is in demand; when their forces are thus mingled, the one is enlivened, or deadened as the case may be, by the other. The total amount of dye-stuffs required for 1,000 lbs. of fleece is 200 lbs. of whelk and 111 lbs. of sea-purple; so is produced that remarkable amethyst colour. For Tyrian purple the wool is first soaked with sea-purple for a preliminary pale dressing, and then completely transformed with whelk dye. Its highest glory consists of the colour of dried blood, blackish at first glance but gleaming when held up to the light; this is the origin of Homor’s phrase, ‘blood of purple hue’.”

Despite this description, either Pliny is writing about a completely different procedure than has been rediscovered since, or he was misinformed. Since dyeing is known to be a highly secretive art, with recipes not written down and false information routinely given out, it would stand to reason that Pliny’s information from the dyers of the day was incomplete (Edmonds, 2000). We know today that the component needed for *Murex* purple comes from the hypobranchial gland of the *Murex*. This is stated by Vitruvius – 1st century BCE Roman author, architect, civil and mechanical engineer – who was most famous for his multi-volume work on architecture (*De Architectura IV: 13*). He doesn’t say much on purple dye, other than the
secretions were obtained by breaking open the shells, collected in mortars and pounded with honey (Cardon, 2007). Pliny states that this works for larger shells, but that smaller shells were crushed outright. The real question is whether it was a direct dye or a vat dye, such as woad. Pliny’s description is similar to that of a vat dye, no direct dye bath would sit for that long, but there are not enough chemicals listed to make the process make sense. If one was to use the secretions for direct dyeing (as is known to be done in present day Mexico, see Appendix 2), the secretions would have to immediately be applied to the fibers as the reduction process is very quick. If left to sit, this process would form a precipitate that could be used as a pigment but useless as a dye (Cardon, 2007). This does not rule out that this method was used during antiquity, but it doesn’t make sense in the case of mass producing dyed fibers.

Dr. William Cole noted as early as 1685 that exposure to light was necessary to convert the extracted fluid into dye, and tests were conducted to determine the effect of light on the shade that resulted. It was also discovered that not all Murex species needed light exposure, and more questions were raised. In 1909, P. Friedländer discovered that the chemical compound involved specifically in Murex purple dye was 6-6’ dibromoindigotin, this chemical however does not exist in the hypobranchial glands of the Murex and the conversion process is still not fully understood on a chemical level (Baker, 1974). This compound is closely related in structure to that of indigo, lending credence to the idea that vat dyeing was the correct historical method. Indigo is a pigment, not a dye (dyes are water soluble and pigments are not) so either the fabric was painted (which seems unlikely both based on quantity and the fact that Pliny stated specifically it was a dye) or vat dying was used. So perhaps the methods for dyeing with indigo and woad (of which a medieval recipe was found and translated in 1995 by Dr. Cardon), may be more likely. It is also at this time that the pH log scale and then later meters to detect pH were invented. Knowing the pH of the dyebath as well as being able to alter it is now known to be an integral part of the dye process of woad, indigo and Murex purple and may explain previous failures (Edmonds, 2000).

Leyden and Stockholm Papyri

The Leyden and Stockholm Papyri, (so named for their current residences) which are really two parts of a whole, come from burial sites near Thebes in central Egypt and were almost certainly found by grave robbers. Around 1828, they came into the possession of Johann
d’Anastasy, who was at that time the Swedish-Norwegian Vice Council at Alexandria. They are not in the form of traditional rolled papyri but are rather in separate numbered sheets, and their text is in Greek rather than Egyptian hieroglyphics. They have been dated to the late 3rd to early 4th century CE and contain various dye recipes of all sorts. Twenty-four pages reside at the University of Leiden’s Museum of Antiquities in the Netherlands. The rest were given to the Swedish Royal Academy of Antiquities.

These papyri have many recipes that refer to archil, another term for orchil, the lichen often used as a substitute. In the whole of Caley’s translation (2008), Tyrian purple is referenced twice, in sections 148 and 151. The first section states:

“Preparation of Tyrian Purple: Phrygian stone is pulverized and boiled. The wool is put in and left there until it becomes cold. Then lift it out and put a mina of archil in a vessel, boil it, put the wool in again and let it become cold there. Lift it out and rinse it with salt water.”

Phyrgian stone is a type of pumice used in ancient times as an astringent. Note that the recipe refers to a lichen base, so it is possible this recipe is for mimicking a Tyrian purple color with lichens. Section 151 states:

“Dyeing of Tyrian or Guaranteed Superior Purple: Seven drachmas of alkanet; 5 drachmas of orpiment; 1 ounce of urine; 5 drachmas of quicklime; 1 kotyle of water.”

Alkanet is a plant that yields purples and pinks, and orpiment is arsenic sulfide. So despite mention of Tyrian purple, this is only a tenuous claim as a period source for royal purple, due to lack of evidence of any Murex based recipes in either section of the document.

Joseph Doumet

Joseph Doumet (Doumet, 1980) and Otto Elsner had successful direct dyeing with both H. trunculus and S. haemastoma, but reported that the color was less colorfast and less bright than samples achieved from the vat method (Cardon, 2007). Doumet attempted a dye bath that sat for three days but noted that the color precipitated out and was impossible to filter due to being a colloid (which is a substance in which one substance is suspended throughout another substance, but not dissolved). He went on to note that by causing the bath to be acidic with vinegar and boiled, then the dye can be filtered out and dried for later use. It would seem counter intuitive to make the bath acidic but Doumet (1980) states that the presence of an alkali slows down the precipitation and acidity speeds up the process along with the application of heat. He
hypothesizes that since seawater is slightly alkaline, that may have been enough to slow down precipitation. If not then the fermentation of urine into ammonia or lime-water made from water and lye may have been used. Both sugars and lead may have served as reducing agents to help the process along, and that vinegar would have been available as an acid.

Doumet’s first method resulting in a pale shade is as follows:

1) Preboil 500 cubic centimeters of seawater and cool it in order to remove the oxygen.
2) Crush the shells at room temperature into a lead vessel with their openings towards the bottom and mix with sea water in order to take out the dye. Over two hours, stir vigorously every 15 minutes.
3) At this point, the solution will become violet. Decant and filter the liquid to remove as much flesh as possible.
4) Add 100 cubic centimeters of rinse water and 30 grams of wool and immerse for three days.
5) Remove the wool and immerse in vinegar at room temperature for one hour.

Doumet then states that while this method produced encouraging results, the mixture’s precipitation after three days was not ideal and that likely Pliny left out the reducing agent. He then goes on to test various things such as alkali metals, sugars, sulfides, arsenides or various fermentation processes including that of sodium hydroxide, and the use of lead alloy and tin containers. The most successful are 1) using the dyebath quickly before precipitation can occur, 2) using a tin or alloyed vessel with baths that are clearly basic in pH and 3) using a mixture of both $M. trunculus$ with either $M. brandaris$ or $P. haemastoma$, in Pliny’s method.

**Michel and McGovern**

R.H. Michel and P. E. McGovern (1987) then attempted to reconstitute Murex pigment in a vat similar to how woad and indigo are used (Edmonds, 2000). Due to previous work by other scientists several decades earlier, as mentioned in their 1987 paper, they knew that the chemical reactions shown in Figure 2 were what was occurring, with purpure being the precursor compounds found in the Murex and 6,6’-dibromoindigotin being the actual dye compound. They, like Doumet, attempted to use Pliny’s method with limited success and note that precipitation must be prevented for the dye to work and that there are several ways this could be achieved.
They noted that some mollusks contained two precursors, which complicated the process. Firstly, there should be excess reducing agent (step 3 in Figure 2) and that care should be taken not to expose that agent to air. Secondly, that sunlight would cause some *Murex* extracts to convert into unusable compounds (Step 2), so sunlight should be avoided. Thirdly, this conversion (Step 2a) could be blocked by antioxidants to help stabilize compound VI and prevent it from converting into compound VII. Lastly, the prevention of the hydrolysis of the sulfate ester precursors (plainly, the breaking of the chemical bond of the R part of the compound from the rest of the compound, resulting in a double bond between the two main carbons). This prevention would occur by deactivating the purpurase enzyme. They mention that, of course, such chemistry knowledge was lacking in ancient times, but that by trial, error and observation, ancient dyers would know what worked to create a fast, good looking dye, even if they didn’t know why it worked.

Like Doumet, they also state that although Pliny does not mention certain materials in his procedure - such as alkalis like urine or salt - they were certainly available during the time. There is also mention of 3rd century Egyptian texts known as the Papyri Leidensis and Gracecus Holmiensis that mention purple dye in conjunction with an iron filing/fermented urine mixture. However, Michel and McGovern tested this mixture and found that it was reducing indigotin but not 6,6'-dibromoindigotin and that perhaps this method describes a different dye such as kermes, rather than purple from *Murex*.
John Edmonds

John Edmonds experimented in England with imported dried *M. trunculus* glands, but he reduced the pigment with vinegar-preserved cockles, which are not native to the Mediterranean. He states that cockles are alright to use as they are in the same family, but unless he is referring to something other than the common cockle *Cerastoderma edule*, he is misinformed as that species is in the family Cardiidae. He can be seen using *Murex* purple dye in a British television show called Worst Jobs In History television show (Season 2, Episode 2- Royal Jobs from 0:40:00 time stamp to the end of the episode). He does mention that pH is important to the vat; that clearly a basic solution is needed, but cautions not to go over a final pH of 10. Too basic a solution is detrimental to the integrity of the wool being dyed (Edmonds, 2000). The vat should also be kept covered and only stirred when necessary to avoid dibromination of the dissolved dye. He cautions that while we are not likely to be able to reconstruct the ancient methods precisely, since we don’t know how it was done (again reiterating that Pliny’s methods were flawed), it is clearly an analogous process to that of woad fermentation and extraction. A temperature of 40 degrees C is ideal for the vat and the alkalinity should be pH 9, caused by the addition of wood ash or lime with the vat being allowed to reduce for 10 days. He does not state whether the temperature should be constantly at 40 degrees C or whether that is only necessary when the wood ash or lime is added (Edmonds, 2000). A later article by Zvi Koren (2005) states that the excision method of separating the gland form the snail would result in a subpar amount of dye since a large amount would stain the rest of the snail, normally a waste product.

Zvi Koren

Zvi Koren’s experiments (Koren 2005) attempt what he says is the first maximal, best possible, all natural dyeing that has been done since it was used in ancient times. His title is perhaps slightly exaggerated in saying that it is the first time in 1,500 years that such a procedure has been attempted, but upon study of the article and the frequent references to the Levant area (today considered to encompass Syria, Palestine and Egypt) as well as to the biblical colors *tekhelet* and *argaman*, it is likely that he means in that area rather than as in the Mediterranean as a whole. Koren experimented over the course of eight years using live *M. trunculus* collected from the seabed off the coast of Mikhmoret, Israel. They were kept in his laboratory in a seawater aquarium for about a month. He does not state the conditions (temperature, salinity,
dissolved oxygen, etc.) of the aquarium tank, but it would make sense to assume he mimicked the water conditions of the snails’ natural habitat as best he could. He then processed them under normal light conditions by smashing them with a hammer in a way that caused the hypobranchial gland to be punctured on purpose.

The broken shell and animal were placed in a glass jar which was then sealed loosely, covered from light and left for three days. He then added aqueous sodium carbonate to cause reduction of the pigment and covered the solution again to prevent oxidation. The mixture was kept at 50 degrees C and stirred twice each day gently for four days, with the pH checked daily and adjusted if necessary. He states that a good ratio is 1 gram of wool, 7 medium snails and 70 mL alkaline solution. He concludes with the fact that the snail contains the chemical reductant needed since the liquid from the snail turns purple before the alkaline solution is added, and that sodium carbonate is found naturally in the area. In my opinion, this research doesn’t really yield new information but it is nice to see dyeing experiments being done with fresh Mediterranean specimens in a country that isn’t part of Europe.

Ingle Boesken

This experiment uses potash instead of sodium carbonate, and since the experiment mentions potassium carbonate separately along with potash, we can assume that that is not the compound in question. Boesken never mentions precisely the chemical formula of the compound used but since the straining of wood ash with water through a filter is mentioned, it’s probably caustic potash, also known as lye or potassium hydroxide. Other than that, the method used is identical to previous methods tried (Boesken 2005).

The Recipe I Used

This recipe was given to me from my contact in Tunisia from whom I purchased the dye in powdered form. He himself harvested the *Murex* from both *M. trunculus* and *M. brandaris* and extracted the precursor chemicals and concentrated them into pigment form. He had both a concentrated form suitable only for dyeing as well as a less concentrated one that could be used as a paint or dye. It is mixed with calcium to give it texture for painting, but that settles out in the dye process. I bought the cheaper one because both were expensive and I thought being able to make paint from it would also be fun. The ancient fermentation method requires constant
monitoring for several days at a constant temperature, so he has not tried it either but hopes to soon. I know he is currently researching how to make his own lye from wood ash. The spectralite is a modern chemical that mimics stale urine with less harmful side effects, and is added to dissolve the pigment and reduce it back into a leuco-soluble form. Spectralite is also commonly used in woad and indigo vats. Alternatively, sodium dithionite can also be used, but you will need twice as much as the spectralite. Sodium hydroxide is lye.

Ingredients:
- 0.2 g of wool or small silk piece moist and previously washed
- 0.2 g of purple pigment
- 25 ml Water
- 0.1 g Sodium hydroxide (a bit more or less)
- 0.1 gram spectralite
- 0.1 g citric acid (I needed to add more)

Process:
1. Use glass jar about 50cl with lid
2. Add pigment to the water and heat to about 50°C in a double boiler
3. Slowly add the solid sodium hydroxide and stir gently until dissolved wait 30 min (PH should be 11)
4. Then add the spectralite and stir. Wait 10 more minutes
5. Add the citric acid slowly in order to reduce the PH to 9.
6. If the solution is yellowish, you can immerse the wet fabric for at least 1h then expose to air.

I attempted to dye seven fibers: 1) Debbie Bliss Pure Silk yarn, 2) 2/12 Silk thread from Eugene Textile Center, 3) Cascade Yarns Heritage Silk yarn, which is 85% wool, 15% silk blend, 4) Madelinetosh Prairie yarn, which is 100% superwash merino, 5) 100% handspun Falkland wool, 6) a strip of washed linen fabric and 7) 100% handspun angora rabbit fiber. The biggest problem I encountered is that the fan in my kitchen is currently broken, so I heated the water and the dye and then took the jar into the garage for steps 3 to 6 because of the caustic chemicals (lye and spectralite) involved. My small vat never went yellowish so I hypothesis that one or more of the following may have happened: 1) Not being able to keep the heat constantly at 50°C influenced the dye vat, 2) I may have introduced oxygen into the vat, 3) the amounts used were so small that I may been off and not had the correct pH when I needed to. Lastly, it may just be that brighter colors than the very light blue and purple tints I ended up with just aren’t possible without fresh Murex to add to the mixture.
My own samples done with Murex dye powder from Tunisia. All samples were put in the same vat at the same time.
Other Species of Snail Used for Dye Around the World

Purpura patula (now Plicopurpura patula) have been used on the west coast of Central America and fragments from pre-Columbian times have tested positive for purple dye (Brunello, 1972). It is now currently only found in the northwestern Atlantic coast of North America and in Europe, so it is probable the climate has shifted or overharvesting decimated populations. It was also used as an ink for writing in codices (Manos-De-Oaxaca Website). Observations have been made from as far back as 1625 of locals harvesting the secretions of the mollusks and applying the liquid directly to agave fibers that were then used to make traditional garments (Manos-De-Oaxaca Website). This species is able to be live extracted because the hypobranchial gland is closer to the mouth of the shell. It takes about 400 shells to dye one 12 oz. skein of cotton and the dyers must work in the few hours that are low tide since the Plicopurpura lives in the intertidal zone (Manos-De-Oaxaca Website). Local dyers know that the species can regenerate its dye fluids every 28 days so they harvest cyclically and only the mature shells. Plicopurpura pansa is used today in Oaxaca, Mexico in traditionally made garments, but the market is small because of a lack of resources and an inability to export the product out of the remote area. (Terada, 2008). Unfortunately, a Japanese corporation in the early 1980’s nearly stripped the Oaxaca coastline of its colonies with no attempt to reseed the area. After protests, the corporation was barred from harvesting and the species is now protected with harvest only permitted among a few individuals for cultural heritage purposes (Manos-De-Oaxaca Website).

Evidence of Purpura lapillus (now Nucella lapillus) has been found in Norway, England (Gunderson, 2014) and Ireland (Biggam, 2006; O’Sullivan et al., 2010; Murray & McCormick, 2011; Gunderson, 2013). There are several locations in Ireland containing middens with broken Murex shells, which shows that dye was produced at that site. In Doonloughan, Co. Galway, there are two sites that are dateable (most are not). The first is dated to 723-889 CE while the second is undated, as are most sites, but thought to be from the early medieval period due to certain finds (O’Sullivan et al., 2010). Some sites show evidence for habitation during the time the shells would have been harvested, others do not. Some show intermittent habitation dating back to prehistoric times, with shells dating predominately to the Bronze Age with some later examples (O’Sullivan et al., 2010). There are also extant examples of silk cloth dyed purple (Gunderson, 2013). Bronze Age inhabitants were also known to use the previously mentioned
*Ochrolechia tartarea* and *Umbilicaria pustulata* to create orchil purple. (Dean, 2014). The orchil was much more common and less costly than the *Murex* purple. There are also 8th to 9th century Anglo-Saxon texts that have tested positive for the chemical bromine that indicates the presence of *Murex* purple dye. Currently there is still research going on to determine whether the Anglo-Saxon purple dyes and paints were created in England or rather they were imported from Ireland or the Mediterranean (Biggam, 2006).

*Rapana venosa* was recently discovered to have been used to dye silk historically in Japan. The only place it has been discovered so far is at Yoshinogari site 4 (Kyushu Island), and only on a few fragments in three burial jars of unique dates. The site dates between the 3rd century BCE and the 3rd century CE. Archaeologists believe that the silk found was woven in Japan and that it belonged to people of high social status. The more northern city of Hitatchi has yielded shells that cause historians to believe extraction methods were similar to the sustainable ones used in Oaxaca, rather than the destructive ones of the Mediterranean industry (Terada, 2008). Unlike the Oaxaca and Mediterranean species, *Rapana venosa* has spread around the world due to marine farming and long distance transport of ballast water and it is now listed as invasive in many parts of the world. The DAISIE European Invasive Alien Species Gateway lists it as one of the 100 worst alien species in Europe. This is partly due to the fact that it is carnivorous and also that it reaches up to 7 inches (18 cm) in length, much larger than other Muricidae species. As with many invasive species that flourish elsewhere in the world though, it is under threat in its native habitat (Terada, 2008).
Other Sources of Purple

It should be noted that various lichens give similar shades of purple, referred to as orchil, though these were thought to be inferior dyes due to their fading from washing and sunlight. Recent testing showed that if the dye was applied such that lichens were used as a base in conjunction with an alum mordant, and then overdyed with *Murex*, the result was actually superior to the *Murex* alone (Casselman and Terada, 2012). These tests did however use the genera *Umbilicaria* and *Parmotrema*, both of which are found in Japan (the former is also found in North America and Europe), and not the traditional genus *Roccella*.

The New World plant logwood (*Haematoxylum campechianum*) also yields various shades of purple but was banned for many years in England (Public act 23, c. 9 during 1580, in the reign of Queen Elizabeth) for being a “deceitful” dye. This phrasing is presumed to refer to the fact that it was not known to be dye fast at the time, due to a lack of understanding of its use. It is of course, likely that the Queen wanted to restrict the wearing of purple to herself and her court. Further refinement of this ban was written down in Public Act 39, c. 11 in 1597 (www.parliament.uk).

On a final note, it is now known that there are a whole host of related chemicals that result in the shades of color from *Murex*, and that some are more dominant than others (Meijer, 2006). This is likely part of what is responsible for the large range of shades of purple. I have many sources to delve into that discuss the organic chemistry side of *Murex*, but that would be a whole separate research paper in itself. It is also a very technical subject that could be difficult for those who have not had formal learning in the subject, I myself have taken two quarters in that subject and still barely understand the subject. So for these reasons, I have omitted such information as well as scholarly sources involving using chemical analysis on extant samples.
Bibliography

32. www.parliament.co.uk. Parliamentary Archives.
Appendix 1. Other Sources Relating to Murex Purple.

Chemistry of the dye


Lichens and Orchil


Other Species


The rediscovery of Biblical tekhelet

Appendix 2. Location Maps for Murex Dyeing

The Island of Leuce, site of the first *Murex* purple dyeing in history. (Image source: Google Maps)

Greek and Phoenician Empires. (Image source: http://www.ccis.edu/courses/HIST101mtmcinneshin/week03/images/map-02-06.jpg)
Ancient dye centers of the Phoenician Empire. Djerba is site of Meninx. (Image source: Google Maps)


Left, Yoshinogari Historical Park, Japan (Image source: Google Maps)
Right, Hitatchi City, Japan. (Image source: Google Maps)
Appendix 3. Complete Text of Pliny’s Natural History, Book 9: Referring to Murex

CHAPTER XXXVI.

The Nature of the Purpura* and the Murex.

PURPURJE, for the most Part, live seven Years. They lie hid for thirty Days about the rising of the Dog Star, like the Murices. They collect together in the Spring, and with rubbing one against another they spit a clammy Substance, in the Manner of Wax. The Murices do the like. But that Bloom which is so much in request for dyeing Garments the Purpurse have in the midst of their Throat. Here is placed a white Vein, containing a very little Fluid; from whence is derived that precious and bright Colour of deep red (Nigrantis) Roses. The Rest of the Body yieldeth Nothing. Fishermen endeavor to take them alive, for when they die they cast up that Juice with their Life. Now the Tyrians, when they obtain any great Purpurse, remove the Shell from the Flesh; but the lesser, they break in a Mill, and so at last collect that Humour. This is the best in Asia; but in Africa, that in the (Island) Meninx, and the Coast of the Ocean by Getulia; and in Europe, that of Laconica. It is for this the Roman Fasces and Axes make Way; this is it that stands for the Majesty of the Childhood; this maketh the Distinction between the Senate and a Knight; this is summoned when they offer Sacrifice to pacify the Gods: this giveth a Lustre to every Garment; and in their triumphal Procession it is interlaced with the Gold. It is thus that the Madness after the Purpurse is to be excused. But how should the Conchylia be so highly prized? What strong Smell in the rank Colour, so harsh a Colour in the blue, and resembling rather the angry Sea? But to come to the particular Description. The Purpura hath a Tongue the length of a Finger, so sharp and hard at the End that it pierces into other Shell-fishes, and feeds on them. In fresh water they die, and so also if they are plunged into a River; otherwise, after they are taken, they will continue alive fifty Days in their own slimy Humour. All Shell-fish grow very rapidly, but Purpurse remarkably so; for in one Year they come to their full Size. Now if I should proceed no further, Luxury would think itself defrauded, and condemn me for Negligence. Therefore we will follow the Subject into the Shops, that as every Man for the Necessity of this Life knoweth the Price of Victuals, all who take Pleasure in these Things may be well versed in the Costs of this their Existence. These Shell-fishes that serve for purple Colours, and the Conchylia, all consist of one Material: the Difference is only in the mixing. They are of two principal Sorts. The Buccinum is a smaller Shell, resembling that Horn with which Sound is uttered; and from this it took its Name. The round Orifice is cut in at the Edges. The other is named Purpura, protrudes a long Snout like a Channel, and within the Side of this Channel it is tubulated, to allow a Passage for the Tongue. Besides this the Shell is studded as far as to the Wreathe with sharp Spines, in about seven Rows, placed in a Circle; which the Buccinum doth not possess. But so many Circles as each of them has, so many Years old they are. The Buccinum fastens to Nothing besides Rocks, and therefore is gathered about rough Places.

CHAPTER XXXVII.

How many Sorts there are

PURPURJE have another Name, and are called Pelagiae. There are many Sorts of them, which differ either in their Situation or Food. The first is the Lutense, nourished by rotten Mud: the Algense, the worst of all, feeding upon Seaweeds close to the Shore; and the Taeniens, which is better than either of the former, and is gathered about the Borders of the Sea called Tenci. And yet this Kind yieldeth only a light and diluted Colour. There are also some termed Calculosae, from the Sea-gravel, which
is wonderfully good for Conchylia. And by far the best, the Purpurae dialutense, that is, a Kind which is fed by various Kinds of Soil. Now these Purpurae are taken with very small Snares, like Nets, thrown into deep Water. Within these, for a Bait, are some Shells, that will shut, and are ready to snap, as we may see the Mituli. These, when half dead, are put back into the Sea, when reviving and gaping for Water, the Purpurae eagerly seek for them with their pointed Tongues, which they thrust out and so annoy them: but the others, feeling themselves pricked, presently shut their Shells together, and compress those that bite them. Thus the Purpurae, through their Greediness, are taken, hanging by their Tongues.

CHAPTER XXXVIII.

The Fishing-time for Purpuree.

THE best Time to take Purpurae is after the Dog-Star is risen, or before the Spring. For, when they have borne Young their Juice is waterish. But the Shops of the Dyers do not know this, although their highest Skill turns on this Point. When they are caught they extract the Vein before-mentioned; and they lay it in the necessary Salt, in the Proportion of a Pint and half (of Salt) to every Hundred-weight. It is right to soak it for about three Days, for the newer the Colour is, so much is it stronger. They heat it in Lead, and to every Amphora of Water they put one hundred and fifty Pounds of the Colour so prepared. They boil it with a gentle Fire, and therefore the Pipe must lead a good Way off from the Furnace. During this Time, the Flesh being now and then skimmed off (for some of this cannot be prevented from sticking to the Veins), for the most Part about the tenth Day the Kettle is sufficiently prepared; and to make Trial of it, they dip into it a Fleece of Wool that has been washed out of one Water into another: and until their Wish is satisfied, they persist in trying the Liquor. The red Colour is worse than that which is dark. The Wool absorbs the Colour in five Hours: then they card it, and put it in again, until it hath drunk up all the colouring Matter. The Buccinum maketh no good Colour of itself; for it loses the Dye again. And, therefore, usually they join to it the Pelagium; which, to its too great Blackness, giveth that Depth and Brightness which is sought for in Cloth dyed in Grain. Thus by mixing the Force of both they raise one another, or bind each other more closely. The amount of the Preparation to each Pound of Wool is two hundred of the Buccinum to a hundred and eleven Pelagian Purpurse. In this Manner is made that rich Amethyst Colour. But the Tyrians thoroughly dye the Wool in the Furnace of the Pelagian Purpurae only, while not yet thoroughly prepared, but still green; and afterwards they change it into another, where the Buccinum has been boiled. It is most highly commended when it is as deep a red as congealed Blood; blackish at the first Sight, but when viewed between you and the Light, it shows a shining Lustre. And hereupon it is that Homer calleth Blood Purple.

CHAPTER XXXIX.

When they began at Rome to wear Purple.

I SEE that Purple hath been always used in Rome; but Romulus wore it in his royal Robe (only). It is well known that Tullus Hostilius was the first of the Kings who, after he had subdued the Hetruscans, put on the Toga Pretexta and the Latus Clavus. JVepos Cornelius, who died under the Reign of Divus Augustus, says: When I was a young Man, the Violet Purple was in great Request, and a Pound of it was sold for a hundred Denarii i 1 and not long after the Tarentine red Purple. After this came the double-dyed Tyrian Purple, which could not be bought for a thousand Pounds of Denarii. 2 P. Lentulus Spinter, in his Curile a Edileship, is reproached for having first worn it in his Robe. But now (says Nepos), who does not form the Hangings of his Parlour with Purple? Spinier was a Edile in the seven hundredth Year after the Foundation of the City, when Cicero was Consul.
This Purple was then called Dibapha, which was twice dyed; as being of magnificent Expense; whereas now almost all the genteel Purple Cloths are thus dyed. In the Cloths dyed with the Conchylia the other Things are the same, except that there is no Buccinum. Moreover, the Broth is tempered with Water instead of the Excrement of a Man's Drink; and only a half of the Preparations is added. And thus is made that pale Tint so highly commended, as being deprived of the full Colour; and it is so much the more diluted, as the Wool has been suffered to drink it up.

CHAPTER XL.

The Prices of these Cloths.

THE Prices are lower, according to the Abundance of the dyeing Material found on the Coast. But it was never known in any Place that a Pound of the Pelagian (Colour) has exceeded five hundred Sesterces: nor a Pound of the Buccinum (Purple) cost above one hundred: which they who sell these Things raise to an extravagant Price. But this is far from being the End; and Men have a Delight to trifle with the Expense: to deceive by mixing over again, and so double the Produce, adulterating even the Adulterations of Nature; as to stain the Tortoise, to mix Silver with the Gold, and so form Electrum: and by adding Brass to these, to make the Corinthian Metal.
Appendix 4. Images of the Common Murex Species


Right, Wool skeins dyed with *Murex* purple from Carthage, dyed and on display at Rotorua Museum. (New Zealand) (Image source: Unknown museum curator of Rotorua Museum)


Internal parts of *Nucella lapillus* male and female, including the important hypobranchial gland (h in both figures) (Photo source: Cardon, 2007)

Appendix 5. Other Murex Related Pictures.

100-120 CE. Mummy portrait of a wealthy Roman woman wearing a garment likely dyed with Murex. One of many of the era. (Photo source: http://www.britishmuseum.org/research/collection_online/search.aspx?searchText=fayum+portrait)

A fragment of the shroud in which the Emperor Charlemagne was buried in 814. It was made of gold and Tyrian purple from Constantinople. 9th century. Musée National du Moyen Âge, Paris. (Photo source: https://en.wikipedia.org/wiki/Tyrian_purple)

Detail of saffron from fresco mural “The mistress of animals (Potnia Theron) and crocus gatherer)”. Painted with Murex purple pigment. 1600 BCE. From the excavation site of Akrotiri, on the Greek island Thera. (Image source: http://pourpre.inge.free.fr/, photo taken by Inge Boesken Kanold)
Murex hill in present day Sidon (Photo by Mohammed Ghassen Nouira)

A dyeing basin in Kerkouane, Tunisia (Photo by Mohammed Ghassen Nouira)
Left, wool dyed with lichens *Umbilicaria* sp, *Evernia prunastri* and *Xanthoria* sp fresh out of the dye-pot. Right, the same dyed wool after drying. (Image source for both: http://mycopigments.com/lichen-dyes/)

Test samples done with lichens available in North America and Japan, as well as the Japanese species *Rapana venosa* (Casselman and Terada, 2012).