The Biblical Dye *Tekhelet* and its Use in Jewish Textiles

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Historical introduction

Two purple textile dyes are referred to in ancient records: one had a blue hue and the other a red.[1] The bluish purple was named *tekhelet* in biblical and Talmudic Hebrew and 'hyacinthine purple' by the Romans. The reddish variety was called *argaman* in the Hebrew and 'Tyrian purple' by the Romans. Archaeological findings in the Mediterranean area have indicated that the ancients utilised three species of marine shellfish for dyeing, namely: banded dye-murex (*Hexaplex trunculus* (Linnaeus, 1758) = *Phyllonotus trunculus*, *Murex trunculus*), spiny dye-murex (*Bolinus brandaris* (Linnaeus, 1758) = *Murex brandaris*) and dogwinkle or rock-shell (*Stramonita haemastoma* (Linnaeus, 1766) = *Thais haemastoma*, *Purpura haemastoma*) (Fig. 1). All three are extant today and the dyes are prepared from their hypobranchial gland.

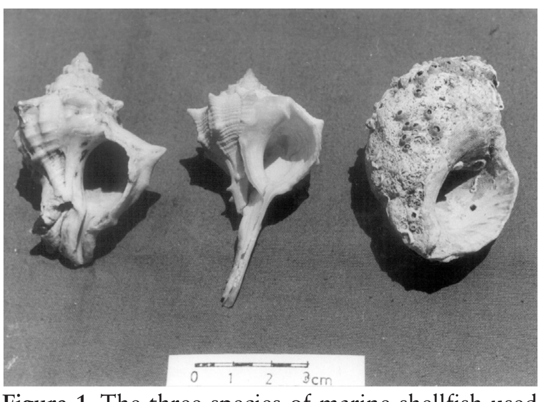

Figure 1 The three species of marine shellfish used in antiquity for manufacturing purple dyes. The shells are, left to right, banded dye-murex (*Hexaplex trunculus*), used for dyeing *tekhelet*/hyacinthine purple, and spiny dye-murex (*Bolinus brandaris*) and dogwinkle (*Stramonita haemastoma*), both used for dyeing *argaman*/Tyrian purple. The dogwinkle shell bears signs of marine wear and encrustation of biological fouling.

The broken shells found at the sites of ancient purple dye-houses are principally those of banded dye-murex.[2] This suggests that banded dye-murex was the main source of purple in antiquity. Now, there has been much confusion as to the colour and chemical composition of the dyestuff obtained from this shellfish.

Semantics of colour[3]

In order to facilitate a discussion of this issue, it is necessary first to clarify the semantics of the words that have been used to describe the various colours. Colour designations (e.g. blue, violet, red and purple) may be regarded as having one of three meanings:

- *aesthetic*: an abstract term for colour sensation or hue;
- *chemical*: name of dyestuff substance;

- *coloured material*: for example, dyed textiles (fibres, yarn, cord, fabrics or garments) as commercial commodities.

Ancient references – biblical, classical and Talmudic – should typically be understood in this third sense. Accordingly, identification of an ancient colour often means identifying a commercial textile, rather than a particular shade. The semantics of colour varies both within a language and between languages. Furthermore, there is a distinction between generic names and hue colour names. The cases of purple, violet and blue are discussed below.

Purple

In English, 'purple' is not only the name of a particular hue, but also a generic term describing a range of hues or a class of similar hues. It is generic in three senses:

- *Coloristic*: purple is the sensation of mixing spectral red and blue lights in various ratios; it is outside the spectrum.
- *Tinctorial*: in hyacinthine and Tyrian purples, a blue tint in the former gives a bluish purple, while red in the latter gives a reddish purple. Since a red tint characterises modern usage of 'purple' in English colour terminology, it would nowadays be sufficient to use 'violet' and 'purple' respectively for bluish purple and reddish purple.
- *Malacological*: dyeings with any species of shellfish, whatever the colour.

Violet

In English, 'violet' is a spectral division and very limited in its range of hue. However, in some other languages, such as German and French, 'violet' is a generic term that would translate to the English 'purple' as defined above, as does the Hebrew *segol*.

Blue

In Tyndale's 1529 rendition of the Bible into English, *tekhelet* is translated 'jacinth', a word signifying 'hyacinth'. The King James version of the Bible published in 1611 renders *tekhelet* as 'blue.' Tracey Rihll has discussed the changing meaning of 'blue' in English since the 17th century:[4]

> Blue was used in the 1800s ... to describe a pony, a pig, cows, milk, flint, a number of diseases in animals (e.g. 'blue-spald' in cattle), of numerous plants some of which we think of as blue but many others as green (e.g. ground ivy, marsh grass), of a lot of birds which we would call grey, brown or black (e.g. hedge sparrow, black tern, pigeon).
>
> It is also worth noticing, on the symbolic front, that it had and still has negative connotations in English: in Shakespeare's time it was the colour of servants' clothes and could be used as shorthand to refer to someone of low standing; a 'blue gown' in Scotland was a licensed beggar; a blue-belly was a Protestant dissenter; a blue day was one on which something bad had taken place (opposite to 'red letter' day); we still of talk of 'being blue' to mean melancholy. Given its socio-economic and symbolic focus, I cannot imagine that people had in mind either azure-type hues or expensive dyes.
>
> The change over to meaning blue-blue (i.e. not red-blue, green-blue, blue-black, blue-grey, blue-brown) seems to start in the 18th century (and takes longer to penetrate dialectical usage), after Newton anyway, and at the same time the range of the meaning of violet and indigo started shrinking – they have practically disappeared in modern English. So when Newton (or anyone before him speaking English) said 'blue', he did not mean what we now assume the word to mean.

Accordingly, in 1611, 'blue' was a generic term that designated a range of hues and would have included reddish blue, i.e. 'violet' in English. Indeed, 'violet' is now preferred for *tekhelet* in several dictionaries and modern translations of the Bible (*The Jerusalem Bible*, London 1966; *The New English Bible*, London 1970). The colours that are obtained from the various shellfish, as detailed in the following sections, confirm the validity of this translation as 'violet' in English.

The colours obtained from banded dye-murex

During the last 150 years, various investigators have made dyes from banded murex, but different colours were obtained. In 1832, Bizio obtained a bluish purple and found it to be a mixture of indigotin with a purple substance.[5] Accordingly, he concluded that banded dye-murex was the source of hyacinthine purple, and that Tyrian purple was the reddish purple that he had obtained from both spiny dye-murex and dogwinkle, and which he identified to be the same purple substance as he had found in the dye mixture from banded dye-murex. This purple compound is now identified as 6,6′-dibromoindigotin (DBI), the predominant ingredient of Tyrian purple dyeings. Bizio's identification of the two purple dyes was supported by his chemical research, which has since been corroborated in independent studies of these shellfish species by other investigators.[6]

But Lacaze-Duthiers reported in 1859 that, in his hands, banded dye-murex yielded not only violet, but occasionally either blue or purple.[7] He contended that it was only the purple colour which characterised the banded murex, just as it was for spiny murex and dogwinkle. The other colours from the banded murex would have been produced by modification of the primary purple, introducing varying amounts of blue. Accordingly, Lacaze-Duthiers rejected Bizio's assignment of banded dye-murex as the specific source for hyacinthine purple and of spiny dye-murex for Tyrian purple. As a result, he left no hypothesis regarding the source and nature of hyacinthine purple/*tekhelet*. The controversy between the two scholars on this issue remained unresolved.[8]

Gender segregation of precursors[9]

Elsner, too, observed that some individuals of banded dye-murex yield blue and others purple. He discovered that this difference was correlated to the snail's sex, males largely giving blue and females purple: in other words, there is a gender segregation of dyestuff precursors in the hypobranchial gland of the snails. The females contain the bromoindoxyl, while the males have predominantly the indoxyl (see Plate 8). Two molecules of indoxyl can couple together forming indigotin, the blue dye from males. Similarly, two molecules of bromoindoxyl can react to form DBI, the purple dye from females. Thus, natural segregation of precursors can account for the blue and purple colours that are obtained from banded murex individuals. Using a commingled population of males and females, the resulting mixture of purple DBI with blue indigotin will be a violet dye, as was described by Bizio for hyacinthine purple.

Furthermore, banded dye-murex males undergo sex reversal to functioning females (protandric sequential hermaphroditism) after one season. Since the penis is retained, this female may be erroneously identified as a male, even though it now produces only DBI.

The formation of 6-monobromoindigotin (MBI)

Another factor that contributes to the formation of a range of colours with banded dye-murex was revealed by the recent discovery that, together with DBI and indigotin, the dye contains a third ingredient, 6-monobromoindigotin (MBI).[10] The formation of MBI may be understood on considering the gender distribution of dyestuff precursors in the snails' hypobranchial gland.[11] An intimate admixing of glandular material from a catch of male and female snails would permit a mixture of the two precursors, indoxyl and bromoindoxyl, to react together chemically to form MBI (see Fig. 2). Thus, three chemical reactions would compete with each other, leading to variations in chemical composition

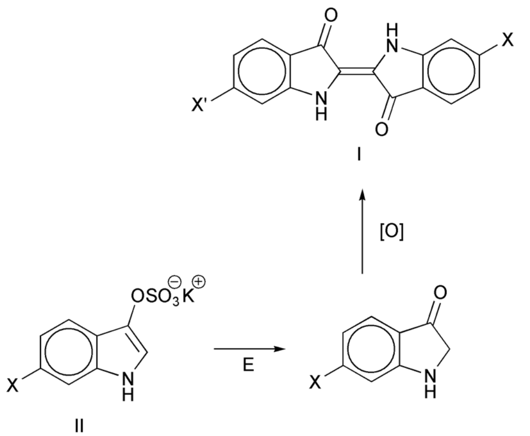

Figure 2 Major pathway for formation of indigotin dyes, I, from colourless indoxyl precursors, II, obtained from the murex hypobranchial gland. In indigotin, X = X′ = H. In MBI, X = Br and X′ = H. In DBI, X = X′ = Br. The precursor II is an indoxyl sulfate salt and its 6-bromo derivative, as found in banded dye-murex. There is no evidence that it is the potassium salt in the mollusc: the potassium comes from the alkali added to the separated indoxyl sulfuric acids that emerge from the chromatography column. E = enzymatic or acidic hydrolysis. [O] = aerobic oxidative coupling reaction. This transformation does not have a photolytic step dependent on sunlight, in contrast to the requirement with the precursors from all other species, since the latter contain a C-2 substituent that is absent in banded dye-murex. (Reproduced with permission from Ziderman 1981 (see note 14) © 1981 Society of Dyers and Colourists.)

of the dye formed. The colour of MBI was still unknown then, since it had not yet been isolated, but was presumed to be purple. Accordingly, it was proposed that depletion of the indigotin content, due to enhanced formation of MBI, would give redder colours that are purple rather than violet. Different colours would thereby be possible, depending upon the reaction conditions used.

There is considerable variation in the proportional ratio between the three compounds in the dye from banded dye-murex, as analysed by the different workers. These contrasting results are dependent on the gender composition of the snail catch and on the experimental conditions used by the investigator to prepare the dye.

The nature of *tekhelet*

Several textile remains have been found to be dyed with a mixture of DBI and indigotin that corresponds empirically to the product of banded dye-murex.[12] Furthermore, 'a *Ph. trunculus*-type' dye was found on a textile from a Sarmathian tomb of the first century BCE on the Black Sea coast, according to its analytical data – indigotin (70%), DBI (7%) and MBI 23%.[13] Accordingly, the bluish purple from the banded murex may be identified as biblical *tekhelet*, the hyacinthine purple of classical antiquity.[14] This corroborates Bizio's view in his disputation with Lacaze-Duthiers (see above). In Plate 8 the colour and source of hyacinthine purple are depicted, and compared with the other two precious dyes of antiquity, namely Tyrian purple and kermes (Hebrew *tola`at shani*, from the scale insect *Kermes vermilio* Planchon).

Ancient recipes for making imitation *tekhelet* substantiate that ancient *tekhelet* was a violet colour. Thus a 7th-century document recently discovered describes the imitation of hyacinthine purple by double dyeing with woad and madder.[15] This chemical composition has also been reported in a new analysis of the violet wool tassel from the Dead Sea Cave of the Letters,[16] previously considered to have been dyed with woad and kermes as an imitation of *tekhelet* for use on ritual tassels. Such a dye combination corresponds to the Talmudic description (Midrash *Sifrey*, on Numbers 14:41) of forging ritual *tekhelet*: 'Behold! I use red dye and indigo so that they resemble *tekhelet*: who could then expose me?'

The hyacinth connection

Tekhelet was translated 'hyacinth' in Greek by Hellenistic Jews and in Latin by the Romans. What does the term signify in this context?

In classical Greek, 'hyacinth' had meant a flower and not murex purple. In the Hellenistic period, however, several Jewish translations of the Bible into Greek appeared, in which *tekhelet* was consistently rendered 'hyacinth'.[17] This translation is surely authentic, having been made at a time when the use of *tekhelet* in the Second Temple was completely familiar to both the translators and their readers. The new usage of 'hyacinth' for a dyestuff would appear to have derived from its similar hue to *Hyacinthus orientalis* L., a violet-coloured flower native to the Phoenician hinterland.

Concurrent with this usage in Hellenistic Greek, 'hyacinth' was one of the two classes of purple dyeing described in Latin by the Elder Pliny (Book XXI.xxii.45–6; also called 'amethyst' and 'ianthine').[18] In an earlier passage (Book IX.lxi.130–lxiv.140), Pliny describes two hyacinthine dyeings: namely, hyacinthine purple, made from a mixture of *bucinum* and *pelagia* molluscs, and a paler one (also called *conchylia*), made from *pelagia* alone.[19] *Bucinum* appears to be today's dogwinkle, while *pelagia* is a category for the various dye-murexes.[20] Thus Pliny's description of 'hyacinth' is compatible with identification of banded dye-murex as the source for *tekhelet*.

In classical Greek, two terms describe the colour purple.[21] *Porphorous* is from *porphora*, murex shellfish. *Phoinikous* means red, scarlet or purple: it is of uncertain origin and was not used for murex. Did they perhaps correspond to the two purple products, hyacinthine and Tyrian?

Jewish textiles

Tekhelet was the most precious dye of the ancients, and was required for the most holy textiles of the religious rites in the biblical Tabernacle and in the Temple in Jerusalem. Detailed descriptions are given in the biblical book of Exodus (chapters 24–40) of the awnings, curtains and priestly garments. The Book of Numbers (chapter 4) describes coverings for the sacred vessels during the wanderings in the Wilderness.

The Talmudic tractate *Menahot* contains descriptions of how *tekhelet* was made from shellfish.[22] The details are remarkably similar to those of Pliny's description of shellfish dyeing, including treatment of wool with 'fresh' and 'clear' extract, and the test dyeing.[23] Furthermore, the Talmud there states that the colour of *tekhelet* resembles the sea and the sky, and details how to use it in tying ritual tassels. There is also the following test to distinguish *tekhelet* from indigo: liquid alum, juice of fenugreek and urine that had been kept for 40 days were mixed. The test sample was soaked in the mixture overnight. If the colour did not fade, it was genuine *tekhelet*. If it faded, it was baked inside a piece of hard leavened barley dough. If the colour then improved, it was genuine *tekhelet*, but if it deteriorated it was indigo.

Ritual tassels

In the Book of Numbers (ch. 15), there is a commandment that *tekhelet* cord be tied together with white cords to form a tassel (Hebrew *tsitsit*) attached to each corner of four-cornered garments. Incorporation of *tekhelet* in ritual corner-tassels was abandoned in the seventh century, when Moslem conquerors destroyed the purple dye-houses in the Holy

Figure 3 The author wearing a prayer shawl with *tekhelet* on the corner-tassels.

Land. However, it is now being revived there using hypobranchial glands from banded dye-murex.

In rabbinical and Karaite traditions of Jewish practice, different patterns are used for tying the tassels with *tekhelet*. A special four-cornered vestment (Hebrew *tallit*) was introduced to fulfil the biblical obligation. There are two such ritual garments: one is the Jewish prayer shawl (see Fig. 3); the other is a short cassock-like garment worn under or over the shirt.

Founded in the 8th-century, the Karaite Jewish sect still use blue cords in the tassels on their prayer shawls, since they do not require shellfish *tekhelet* and may use any blue dye. Each tassel is composed of eight white cords and eight blue cords that are doubled over and then tied together as a corner-tassel of 32 hanging cords (see Plate 9).

Among rabbinical Jews, the practice is to take only four threads, double them over and then tie them as a tassel of eight hanging cords. In the absence of *tekhelet*, white cords are used in their stead so as to preserve the required number of eight cords. In the Middle Ages, three different presumptions were made as to the way the ancients would have incorporated the long-lost *tekhelet* in ritual tassels. Accordingly, of the eight tassel cords, one, two or four would be *tekhelet*. One of the cords is much longer than the others and is wound around them repeatedly: when available, *tekhelet* is used for these windings, except for the first and last windings, nearest and farthest from the garment corner respectively, which must always be white (see Plate 10).

The prevalent pattern is to make 39 windings that are separated by double knots into sets of 7, 8, 11 and 13 windings. Furthermore, Talmudic law requires that, when genuine *tekhelet* is used, these windings must be arranged throughout in groups of three. Winding each group of three through an individual loop has been used to preserve the integrity of each set of three windings.

Colour instability of MBI

The revival of *tekhelet* dyeing in Israel has been undertaken in order to renew its use in ritual corner-tassels. The initiative began with a scientific study that determined the historical source of the required dye to be banded dye-murex, the colour to be violet and the chemical composition to be indigotin and DBI.[24] Experiments with shellfish glands confirmed that a violet colour may be made with banded dye-murex and a purple with spiny dye-murex and with dogwinkle.[25] But usually a purple colour was obtained, which was considered inappropriate as *tekhelet* since it was the same colour as the Tyrian purple from spiny dye-murex. The nature of this purple from banded dye-murex has been revealed through the discovery of the thermal instability of the colour.

Wool that had been dyed purple with banded dye-murex changed colour to blue on heating.[26] This intriguing finding may not be ascribed to a change occurring in any DBI present, since this compound is eminently stable. It was therefore hypothesised that this purple dyeing contains mainly MBI, and that MBI has this peculiar property of thermal colour instability.

When synthetic MBI became available later, it was found to have a violet colour.[27] On heating wool dyed with this MBI, it indeed changes colour to blue, thereby proving the validity of the hypothesis.[28] Pure MBI behaved similarly.[29]

But what is the mechanism of the colour transition in MBI? The hypothesis considered initially was that the colour change might be due to a possible thermal debromination of MBI forming indigotin. This view has since been shown to be untenable because chemical analyses of the blue product have established that no change in chemical structure or composition has occurred.[30]

Photolytic debromination

In order to produce a bluish colour that could be marketed as *tekhelet* for the ritual tassels, the purple from banded murex (largely MBI) has been photolytically debrominated to indigotin, which was vat-dyed *in situ* onto wool.[31]

Driessen discovered photolytic debromination of DBI in 1944.[32] An aqueous solution of the halogen-containing indigoid in the *leuco*-form is first prepared by reaction with the powerful reducing agent sodium dithionite. Then the solution is exposed to sunlight or an equivalent ultraviolet source, while held in a transparent glass vessel for effective irradiation. But dithionite is a modern synthetic reagent that was not known in antiquity, and neither were glass reaction vessels. Therefore it is questionable whether photolytic debromination was available in antiquity to make indigotin. Furthermore, it would have been unnecessary in that era to make indigotin from purple, considering the ready availability of inexpensive woad and/or indigo from plants, then used for producing indigotin dye. Besides, the highly precious value of the purple dye would have been squandered.

But it should now be possible to prove murex provenance of an indigotin dyeing by using analytical chemistry. A diagnostic test could be performed by high-pressure liquid chromatography (HPLC). This sensitive technique can detect the presence of residual traces of DBI and MBI that are too minute to affect the colour, but must be present in every dyestuff originating in shellfish. HPLC analysis of archaeological textiles dyed blue with indigotin has not hitherto detected a vestige of brominated indigotin.[33] Accordingly, they are vegetable dyes, either woad or indigo. Hence, analytical evidence has not yet been presented to suggest that shellfish were used for dyeing blue by debromination of purple to indigotin.

Conclusion

The new understanding of the status of MBI in the banded dye-murex dye, as described above, should lead to the development of a marketable *tekhelet* dye that is not merely indigotin. Firstly, the thermal transition of the purple to form blue would seem to be a more acceptable process, as an alternative to photolytic debromination to indigotin. Secondly, investigation of the chemical reactions of the natural dye precursors from banded dye-murex should reveal the empirical conditions required for direct synthesis of a stable dye mixture of indigotin and DBI that resembles the violet colour of the hyacinth flower.

Editor's note

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