

The Science of Tekhelet

Baruch Stermán

“There is an obligation upon all who are capable, to search for [tekhelet], to merit Israel with this commandment, which has been forgotten for the last several centuries. And he who succeeds in this, will surely be blessed by God.”

(Rabbi G. E. Leiner, the Radzyner Rebbe)

The Bible in the book of Numbers relates God’s charge to Moses:

Speak to the children of Israel, and bid them make fringes in the corners of their garments throughout their generations, putting upon the fringe of each corner a thread of blue. And it shall be unto you for a fringe, that you may look upon it and remember all the commandments of the Lord, and do them,¹

This passage, part of the *kriyat shema* prayer complex, is recited twice daily by observant Jews who till this day can be seen with fringes - *tsitsit* - dangling from their prayer shawls. The eleventh century Biblical commentator, Rashi, explains how looking at the fringes reminds one of all God’s commandments. The word *tsitsit* - fringes - is numerically equivalent to 600. *Tsitsit* are traditionally tied with eight strings and five knots for a total of 613 - the number of commandments in the Torah.² Linguistically, however, the subject of the sentence - that which is to remind us of God’s commandments - is not the *tsitsit*, but rather the thread of blue, the *tekhelet*.

The secrets of the *tekhelet* color, its source and method of manufacture have been lost for over 1300 years. As a result, many of the laws pertaining to its use have been deemed “academic”³, and their study was, to a certain extent, neglected as compared with the more prosaic statutes. What is the significance of the blue thread and why has this commandment fallen into disuse?

Over the past few years, there has been an increasing awareness and renewed discussion regarding the Biblical dye *tekhelet*. In this article, I would like to survey the history of the search for *tekhelet* and describe the recent advances in our understanding of the topic in light of archeological, chemical, and biological findings.

Tekhelet in the ancient world

One of the earliest recorded mentions of *tekhelet* is in the Tell-el-Amarna Tablets (1500-1300 BCE). *subâtu sâ takîlti* - a garment of *tekhelet* - is listed as one of the precious articles sent to Egypt by Dusratta, King of the Mittani, as dowry to the Egyptian prince who was about to marry his daughter.⁴ The archeological evidence now available suggests that the origins of the

¹ Numbers, 15; 38-39

² Rashi on Numbers, 15; 39. Nachmanides proposes that when one gazes upon the blue string he is reminded of the sea and sky and ultimately of God and all His commandments.

³ So, for example, instead of ruling on a certain debate, R. Yosef Kara, declares: “It would appear that we should not pay regard to this argument since it makes no difference at this time [since the *tekhelet* is no longer available].” (Bet Yosef, Hilkhos Tsitsit, O.H. 11)

⁴ Mercer, Samuel A.B., *The Tell El-Amarna Tablets*, Macmillan, 1939, Presents from Tusratta to Amenophis III, p. 85 line 18, 29, 36.

purple and blue dye industry can be traced to Crete, where the Minoan islanders were already manufacturing sea-purple by 1750 BCE.⁵ Chemical analysis of stains on a vat found at Tel Shikmona (1200 BCE.) reveal that by that time, an advanced dye industry using *Murex trunculus* snails was well established on the Canaanite coast⁶, and mounds of crushed *Murex* shells from the same period have been found at Sarepta⁷, Dor,⁸ and various other locations along the shores of Northern Israel and Lebanon.

From the start, the colored garments were greatly revered, as can be attested to by a Minoan priestess figurine dated 1600 BCE which has what appear to be dark blue decorations on her attire.⁵ The dyes were rare and valuable, and wool colored with them was worth up to 20 times its weight in gold.⁹ These precious dyes were reserved for royalty; they colored the robes of the kings and princes of Media, Babylon, Egypt Greece, and Rome, and to wear them was to identify with nobility. The Greek writer Julius Pollux relates the tale of the discovery of the dyes. According to the legend, Hercules' dog bit into a *Murex* on the shores of Tyre, his purple stained mouth revealing the dye. Hercules presented his cherished find to the king (in some versions, nymph) of Tyre.¹⁰ Tyrian coins (200 CE) depicting this legend have been found, with the *Murex* shell clearly identifiable.

Moreover, the ancient scholars write about these dyes in great detail. Pliny¹¹ and Aristotle¹² describe the snails, how and where to find them, and the procedure for dyeing with them. Vitruvius mentions that there is a connection between the varied colors (purple through blue) obtainable from the snails and differing degrees of sunlight to which they are exposed. "For it does not yield the same color everywhere, but is modified naturally by the course of the sun... As we proceed between the north and west it becomes a leaden blue."¹³ Scholars have positively identified these shells (*purpurae* and *bucinae* in Pliny's terminology) with the mollusks *Murex trunculus*, *Murex brandaris*, and *Thais Haemastoma*.

By the time of the Exodus from Egypt, *tekhelet* and *argaman* (purple) were well known commodities throughout the ancient world. They are mentioned in the Bible along with gold and silver in the list of materials needed for the Tabernacle, and it is generally assumed that the Jews brought these with them from Egypt. In the Book of Esther, Mordechai leaves the Persian court wearing "royal apparel of *tekhelet*..."¹⁴ and Ezekiel speaks of the *tekhelet* and *argaman* found in Tyre and the Isles of Elisha.¹⁵ It seems clear that the blues and purples used by all of the other nations in ancient times (derived from *trunculus* and *brandaris*) are identical with the *tekhelet* and *argaman* of the Jews.

Tekhelet was worn by nobility and priests throughout the ancient world. It is found in those contexts within the Bible as well; it adorns the Tabernacle and comprises the special clothes of

⁵ Stieglitz, Robert R., "The Minoan Origin of Tyrian Purple", *Biblical Archaeologist*, 57:1 (1994) pp. 46-54.

⁶ McGovern, P.E. and Michel, R.H. *Anal. Chem.* 1985, 57, 1514A-1522A.

⁷ Pritchard, J.B. *Recovering Sarepta, A Phoenician City*, Princeton University, Princeton, 1978.

⁸ Karmon, Nira,

⁹ Born, W. *Ciba Rev.* 1937, 1, 106-111, 124-128.

¹⁰ Pollux, J., *Onomasticon* 1.45-48.

¹¹ Pliny the Elder, *Natural History*, Book IX, LX-LXV.

¹² Aristotle, *De Animalibus Historia*, p. 175.

¹³ Vitruvius. *De Architectura*, Libr. VII, ch. 13.

¹⁴ Esther 8; 15

¹⁵ Ezekiel 27; 7

the high priest. On this basis Professor Jacob Milgrom has suggested an explanation of the significance of the blue thread on the Jew's garments.

... *Tzitzit* is the epitome of the democratic thrust within Judaism which equalizes not by leveling but by elevating: all of Israel is enjoined to become a nation of priests. In antiquity, the *tzitzit* (and the hem) was the insignia of authority, high breeding and nobility. By adding the blue woolen cord to the *tzitzit*, the Torah combined nobility with priesthood: Israel is not to rule man but to serve God. Furthermore, *tzitzit* is not restricted to Israel's leaders, be they kings, rabbis or scholars. It is the uniform of all Israel...¹⁶

Talmudic descriptions of tekhelet and the hillazon

Aside from the secular references, Jewish sources have maintained a tradition as to the nature of *tekhelet*, and its marine source, the *hillazon*. Though there is some confusion as to the precise hue of the dye,¹⁷ one authority's charming, if not totally convincing proof deserves mention: "the simple tradition in all of Israel that has been preserved in all of the oral and written interpretations in teaching schoolchildren. And so we learned in elementary school: *tekhelet* - sky blue."¹⁸ This identification can be borne out in a more rigorous fashion. The Talmud in numerous places notes that *tekhelet* is similar to the sky (or sea)¹⁹. The Septuagint, the oldest translation of the Bible renders *tekhelet* as *Iakinthos* - blue. The Babylonian sage Saadia (born 882 CE) translates it as *asma'ngon* - "like the color of the clear sky"²⁰, and Maimonides (born 1135) states, "it is the color of the clear sky visible near the sun".²¹

The Talmud relates that due to the extreme scarcity of *tekhelet*, avaricious individuals introduced a counterfeit dye, *kala ilan*, obtained from a much cheaper vegetable source. This fraudulent counterpart provides the most direct demonstration of *tekhelet's* color. The Talmud states that it was absolutely impossible to outwardly distinguish between true *tekhelet and kala ilan*,²² - consistently identified as indigo²³ - which is the color of a clear sky.

Perhaps the most important characteristic of the *tekhelet* dye was that it was steadfast in color. Maimonides writes that "its dyeing is well known for its steadfast beauty and does not change."²⁴

Jewish sources have also described the source of the *tekhelet* - the marine organism called the *hillazon*. One must be careful not "[to huddle up] all references to the *hillazon* as applying

¹⁶ Milgrom, J., "The Tassel and the Tallit," The Fourth Annual Rabbi Louis Fineberg Memorial Lecture (University of Cincinnati, 1981).

¹⁷ Some of the confusion may come from differences in color designation between modern and classical terminology. For example, Rashi on Shemot 25:4 writes regarding *tekhelet*, "and its color is green", while on Bemidbar 15:41 he comments, "and so the color of *tekhelet* resembles the color of the darkened sky at dusk."

¹⁸ Herzog, I, Kol Kitvei, Orach Haim siman 8, page 59.

¹⁹ Menachot 43b, Hulin 89a, Sota 17a, Y. Berakhot ch 1 hal. 2, Sifre Bemidbar 15:38, Medrash R. Naso 14:3, Medrash R. Shelakh 17:5, Medrash Tehillim Mizmor 24:9 and 90:10, and Yalkut Shimoni Tehillim 90.

²⁰ Rav Kapakh's version, Shemot 25:4, p. 71 n. 2.

²¹ Hil. Tsitsit 2:1.

²² Bava Metzia 61b, "The Holy One Blessed be He said: I have distinguished between the drop of [semen that was to become] a firstborn and that of a non-firstborn, I will exact retribution on he who attaches *kala ilan* to his cloth and claims it is *tekhelet*."

²³ Aruch on the word *kala ilan*, Yad, Tsitist 2:1 and Rav Kapakh's comments, Herzog, *The Royal Purple*, p. 94-96.

²⁴ Yad, Hil. Tzitzit, 2:1.

exclusively to the *tekhelet-hillazon*.²⁵ Indeed, *hillazon* in modern Hebrew is used to describe all kinds of snails, both land and sea species. This having been noted, a portrait of the *hillazon* can, nonetheless, be surmised.

The *hillazon* was found along the Northern coast of Israel²⁶, it had a shell²⁷, and the dye had to be taken from it while it was still alive²⁸. Its color was similar to the sea²⁹, it “came up” periodically³⁰, and its form or procreation was similar to a fish³¹. One important source quotes the Jerusalem Talmud as translating *tekhelet* with the word “*porphiron*”³², which was the Greek and Latin name for snails of the *Murex* family.

The suppression and eventual demise of the Jewish tekhelet industry

Due to the lucrative nature of purple and blue dyeing, and the status associated with wearing garments colored with those dyes, control over the dye industry was always coveted and often a source of tension. It has been suggested that the war between the Caananite general Sisera, and the Israelites led by Deborah recorded in Judges 4-5 were over this issue.³³ During the Roman period the contention reached its climax as the dye industry slowly came under imperial control. Caesar and Augustus restricted the use of the dyes to governing classes.³⁴ Nero (d. 68 CE) issued a decree that gave the emperor exclusive right to wear purple or blue garments.³⁵ Under Constantius (337-362) the restrictions were slackly enforced.³⁶ In 383, an edict by Gratian, Valentinian, and Theodosius deemed the manufacture of higher quality purple and blue a state monopoly³⁷.

Hints of the political complications associated with *tekhelet* are echoed within the Talmud and Medrashim. It seems clear that Israel was the center for dyeing *tekhelet* and the Babylonian Jewish community received blue strings from there. Abaye (a Babylonian Amora) asks Rav Shemuel bar Rav Yehuda (who emigrated there from Israel approximately 337) “This *tekhelet*, how do you dye it?”³⁸ Towards the end of the second century, the impression is that only members of the *Sanhedrin* were wearing *tekhelet*,³⁹ though it has been argued that the *tekhelet* mentioned here is not the blue strings of the *tsitsit* but rather a unique blue hem on the gowns of the judges.³⁴ The Talmud relates the dangers of exporting *tekhelet* in a story of two students

²⁵ Herzog, *The Royal Purple*, p. 60.

²⁶ Shabbat 26a “Between the ladders of Tyre and Haifa.” See also Megilla 6a. R. Borstien discusses the problem regarding the exact demarcation of the portion of Israel belonging to Zevulun. see his book, *Hatekhelet* page 29, footnote 22.

²⁷ Devarim Rabba par. 67;11, Shabbat 85a.

²⁸ Shabbat 85a and Rashi *ad loc*.

²⁹ Menachot 44a.

³⁰ Once in 70 years (Menachot 44a) or once in 7 years (Masechet Tzitzit hal. 21). See Rav Borstien *Hatekhelet*, page 38 footnotes 76 and 77. Also, Rav Herzog in *Kol Kitvie* page 52.

³¹ Note R. Eliyahu from Vilna claims that the Rabbis term anything in the sea “fish”. (Eliyahu Rabba, Kelim 10;1)

³² “And we learn in the Jerusalem Talmud, between *tekhelet* and *karti* - between *prophira* and *prifinin*. It is a garment that is called *porphyra* in other languages.” (Ra’avyah commentary to Berakhot 9a siman 25).

³³ The northern coastal tribes were involved in that war, and Sisera’s mother expects of her son, “to Sisera a booty of divers colors, a plunder of many colored needlework, dyed double worked garments for the spoilers.” (Judges 5;30).

³⁴ Seutonius, *Vita Caes*, p. 43, Dio Cassius, bk XLIX, p.161.

³⁵ *Vita Neronis*, p. 32.

³⁶ Herzog, *The Royal Purple*, pp. 107-113.

³⁷ Baker, J.T., “*Tyrian Purple: an ancient dye, a modern problem*”, *Endeavour*, **33**, (1974) pp. 11-17.

³⁸ Menachot 42b see also Menachot 43a

³⁹ Medrash Raba Beraishit 85;9.

who were caught by the eagle (a metaphor for Rome) smuggling *tekhelet*, and miraculously escaped death.⁴⁰

In the beginning of the sixth century, *tekhelet* was still being brought from Israel to the Babylonian Jews.⁴¹ This is the last positive indication of the use of *tekhelet*. One can assume that *tekhelet* was available at the end of the redaction of the Talmud (570). In the work Sheiltot D'rav Achai (760) there is no mention of *tekhelet* and the Medrash Tanhuma⁴² (750) laments “and now we have no *tekhelet*, only white.” It would appear that sometime between 570 and 750, *tekhelet* was lost. Rabbi Isaac Herzog suggests that the final destruction of the Israeli dye industry can be attributed to the Arab conquest of Israel in the year 683.³⁴ A sporadic purple dyeing industry remained along the shores of Tyre and in Constantinople, until the fall of that city, May 29, 1453⁴³.

The search for the ancient dye by secular scholars

Guillaum Rondelet (d. 1566) was the first to identify Pliny's *purpura* with the species *Murex brandaris*,⁴⁴ and Fabius Columna in 1616 further suggests *Murex trunculus* as having been utilized in the ancient dyeing process.⁴⁵ In 1685, William Cole noted that a colorless fluid in the hypobranchial gland of marine mollusks (*Purpura lapillus*) found off the coast of Britain, was converted to a red color on exposure to light.⁴⁶ The apocryphal story of the rediscovery of the ancient dye snails (which has wrongly been attributed to William Cole) has the French zoologist Henri de Lacaze-Duthiers sailing from the Minorcan port of Mahon in 1858, where he noticed a fisherman painting yellow streaks on his shirt with the juice of a snail he had broken open. The stains soon turned red in the sunlight, and the scientist realized that the shellfish, *Thais haemastoma*, was the source of the ancient Tyrian purple.⁴⁷ Lacaze-Duthiers' subsequent work showed three mollusks in the Mediterranean which produced dye material, *Murex brandaris*, *Thais haemastoma*, and *Murex trunculus*.⁴⁸ In 1909, the German chemist Paul Friedländer identified the chemical structure of the purple dye to be dibromoindigo, and later work by him and others showed that this compound was a major component of the Mediterranean species as well as of mollusks in other parts of the world.⁴⁹ From 1955 through 1980, the chemical and biochemical stages in the production of the dyes were investigated and the precursors to the dye isolated.⁵⁰

The search for tekhelet by Jewish scholars

During the mid-19th century, the issue of *tekhelet* began to surface among Jewish writers. (It should be noted that the secular research on this topic was as yet unknown to the rabbinic community.) Along with the renewed Messianic interest and questions regarding the rebuilding of the Temple, the problem of how to fabricate the clothes of the priests without *tekhelet*

⁴⁰ Sanhedrin 12a

⁴¹ Chulin 59b

⁴² Tanhuma, *parashat Shelakh*.

⁴³ Herzog, *The Royal Purple*, p. 114.

⁴⁴ Lamarck, Jean Baptiste, *Système des Animaux sans Vertèbres*. Paris (1822) v. IX pp. 559-560.

⁴⁵ Columna, F. *Opusculum de Purpura*. Rome. 1616.

⁴⁶ Cole, W., *Philos. Trans. R. Soc. London*, **1685**, 15, 1278-1286.

⁴⁷ Ziderman, I., *Chem. in Brit.*, 22, 419, 1986.

⁴⁸ de Lacaze-Duthiers, H. *Ann. Sci. Nat., Zool. Biol. Anim.* 1859, 4th series 12, 5-84.

⁴⁹ Friedländer, P., *Ber. Dtsch. Chem. Ges.*, 1909, 42, 765-770.

⁵⁰ Bouchilloux, S. and Roche, *J. Bull. Inst. Océanogr. Monaco*, 1955, No. 1054, 1-23; Baker, J.T. and Sutherland M.D. *Tetrahedron Lett.*, 1968, 43-46; Fouquet, H. and Bielig, H., *Angew. Chem, Int. Ed. Engl.*, 1971, 10, 816-817; Fujise, Y., *et al.*, *Chem. Lett.*, 1980, 631-632.

became manifest. Rabbi Baruch Isaac Lipshuetz suggests that for the priestly garments, *tekhelet* from the authentic *hillazon* was not essential, but rather any dye which was of the correct color and had steadfast and permanent qualities could be considered *tekhelet*⁵¹. The great Hasidic Rebbe, Rav Gershon Henokh Leiner of Radzyn, did not accept this opinion, and, faced with the obstacle that the lack of *tekhelet* posed for the rebuilding of the Temple, resolved to take it upon himself to find the long lost *hillazon*. Rav Leiner wrote a short monograph, *Sefunei Temunei Chol*, presenting his plan of action and offering a general preliminary discussion on the issues regarding the *hillazon*. He had heard the suggestion that a type of squid, *Sepia officinalis*, fit the description of the animal, and set off to the great aquarium in Naples to study the matter first hand. He became convinced that *Sepia off.* could indeed be identified with the source of *tekhelet*, but was unable to procure a blue dye from the squid's black liquid excretion. Herzog suggests that the Radzyner Rebbe consulted with local chemists who showed him how to transform the black ink to blue. With this recipe in hand, Rav Leiner returned to Radzyn, opened up a dye factory, and within a year 10,000 of his followers were wearing the blue strings on their garments.

The new *tekhelet* was not widely accepted by the general rabbinic world. The Radzyner wrote two more books, *P'til Tekhelet* and *Eyn Hatekhelet*, to explain his ideas and to counter opposition from other rabbis. These books still stand as the definitive works on the subject, and form the legalistic foundation for any discussion on the topic.

In 1913, Rabbi Isaac Herzog, then Chief Rabbi of Dublin and later the first Chief Rabbi of the State of Israel, as part of research towards his doctoral thesis, sent samples of the Radzyn *tekhelet* to leading chemists and dye experts in Germany, France and England for analysis. The results that he received were surprising. The experts determined that the blue dye of Radzyn was not organic in nature, but rather was the inorganic dye known as Prussian Blue, or ferric ferrocyanide. Herzog refused to believe that the Radzyner Rebbe would have purposely misled his followers and wrote to the dye masters of Radzyn asking for their process. Upon investigation, the solution to the riddle became apparent. The Radzyn recipe called for heating the squid ink to very high temperatures and then for the addition of iron filings. What in fact happens under these conditions is that the organic molecules break down and the constituent atoms of carbon and nitrogen recombine with the iron, yielding Prussian Blue dye. The squid ink is not an essential component for this reaction; any organic substance could be substituted, since the structure of the molecule is irrelevant and only the elemental components are utilized. Herzog could not accept the notion that the Talmudic requirement for a specific marine source, the *hillazon*, could be based on such an indirect and vague relationship. He therefore concluded that the Radzyn *tekhelet* could not be considered authentic.⁵²

(As an interesting side note of history, during World War II with the destruction of East European Jewry, the *tekhelet* factories of Radzyn were ruined and the process lost. When the survivors of Radzyn made their way to Israel after the war, they asked Rabbi Herzog for the correspondence between himself and the Radzyn dye makers, and through those letters reestablished a *tekhelet* industry in Israel which still exists to this day. Thus Herzog is responsible both for discrediting Radzyn's *tekhelet* and at the same time for rescuing their process from destruction.)

⁵¹ *Kupat HaRochlim*, found in the Tefferet Yisrael's introduction to the order of *Moed*.

⁵² Herzog, *The Royal Purple*, 114-118; Herzog, *The Dyeing of Purple in Ancient Israel*, The Israel Malacological Society, p. 13.

Herzog himself was unable to come to a definite conclusion regarding the *hillazon*. Virtually all of his doctorate deals with the snails from the *Murex* family, showing how the consensus among the scientific community is that they (*trunculus* in particular) were the source of the *tekhelet* dye. “Of the species *known* to have been used by the Phoenicians in purple-dyeing, the one which furnishes a dye answering at least to some extent to the tradition of the *tekhelet* nuance is none other than the *Murex trunculus*.”⁵³ Herzog shows conclusively that these mollusks were used in ancient times for dyeing blue, and he notes the difficulty with the contention that Jewish *tekhelet* came from some marine animal different than that used by the entirety of the ancient world, an organism that was unknown to the ancient scholars, and has left no archeological evidence. Herzog admits that “it is very unlikely that the *tekhelet-hillazon* is not the snail called *Murex trunculus*, but though unlikely, it is still possible.”⁵⁴

Despite the overwhelming proof, Rabbi Herzog was unable to categorically identify the *hillazon* with the *trunculus*, for a number of reasons. First, he felt that *trunculus* did not fit the Talmud’s description of *domeh l’yam* - having the appearance of the sea. In fact, however, Herzog had seen only specimens cleaned and polished. In that state, the shells are colored with brown and white bands. *Trunculus* found in the ocean, on the other hand, are covered by small organisms whose texture and color varies from place to place, but the same sea-fouling will be found on all the rocks and shells in each region. Sometimes the coating has a blue or green coloring, and this would fit the description as similar to the sea. Moreover, since the word *yam* in Biblical and Talmudic Hebrew also means “sea bed”⁵⁵, perhaps the *hillazon* is being portrayed as similar to the surrounding landscape, which is a perfectly fitting representation of the *trunculus* in its natural habitat.⁵⁶

Second, *trunculus* has no periodic cycle corresponding to seven or seventy years. Herzog admits that “Science knows nothing of such a septuagenarian ‘appearance’ of any of the denizens of the sea.”⁵⁷ Maimonides does not mention the periodical appearance of the *hillazon*, which has led commentators to conclude that he did not consider this an essential characteristic of the animal.²⁷ Indeed both he⁵⁸ and the Radzyner Rebbe⁵⁹ deal with this particular criterion of the *hillazon*. They raise the possibility that the cycle refers to periods of greater or lesser availability or accessibility, but that the animal itself is always obtainable.

Third, Herzog was under the impression that the dye obtained from the *trunculus* was not a steadfast one. Modern dye experts disagree with this and contend that both indigo and dibromoindigo do indeed bind tightly to wool and are among the fastest natural dyes. Though indigo is not known to be a particularly enduring dye, this is true only of cotton dyed indigo. Both dibromoindigo (purple) and indigo, however, bind very tightly to wool and will neither rub out nor fade over time. Prof. Otto Elsner⁶⁰, a leading dye expert, has asserted that these dyes were among the fastest dyes available to the ancient world. Our own experience has shown that strings dyed with *trunculus* blue have maintained their color through daily wear and periodical washing for more than ten years.

⁵³ Herzog, *The Royal Purple*, p. 73.

⁵⁴ Herzog, *Hatechelet Byisrael*, 5;1, in Rav Borstien’s book "עֵצֵי", p. 421.

⁵⁵ See for example Isaiah 11; 9 “as the waters cover the *yam*.”

⁵⁶ Tevger, E., *Kelil Tekhelet*, Chemed Press, Jerusalem, 1993, p. 226.

⁵⁷ Herzog, *The Royal Purple*, p. 69

⁵⁸ Herzog, *Kol Kitvei, Orach Hayyim*, 7; 50-52.

⁵⁹ R. Leiner, *Sefunei Temunei Chol* p. 4.

⁶⁰ in a personal correspondence.

The fourth, and most substantial problem that Herzog had with *trunculus*, was that the dye obtained from that snail produced a blue-violet color, and not the sky-blue hue traditionally associated with *tekhelet*. This issue was really the core of the difficulty in identifying the *hillazon* with the *trunculus*. “However”, Herzog writes, “if we unequivocally determine that the appearance of *tekhelet* had no violet (purple) component, then this would be enough to dislodge [disprove] the assertion that [*Murex trunculus* is the *hillazon*].⁶¹”

Herzog proposed another candidate for the *hillazon* - the snail *Janthina*. Though he had never dyed with that snail, the fact that the shell had a violet color fit well with the description of being similar to the sea. Modern research, however, has shown that *Janthina* could not have been used in any dyeing industry. It lives in floating colonies and washes up on the shores of the Mediterranean after storms, either dead or dyeing, and it is scarce to the point of being unavailable. Moreover, it does not produce a “dye” that can be used to color cloth. It does secrete a blue liquid, but that fluid turns brown after a few minutes, and is water soluble. Chemists have so far found no way to use the secretion as a viable fabric colorant.⁶²

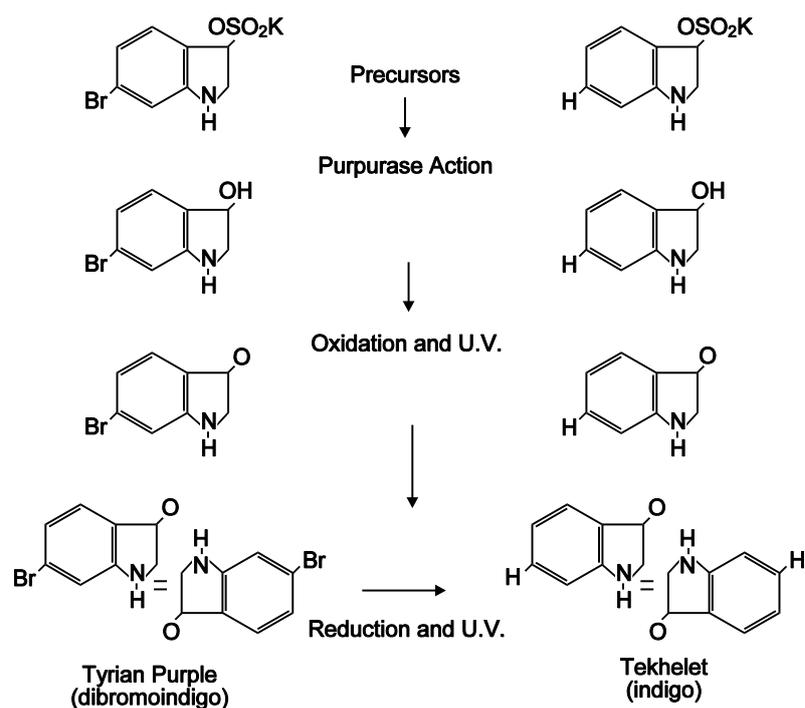
The science of tekhelet

In the early 1980’s while researching ancient dyeing techniques, Otto Elsner of the Shenkar College of Fibers in Israel serendipitously discovered the secret of producing a pure blue color from the *trunculus* snail, thus solving Herzog’s fourth and most compelling difficulty. Elsner noticed that wool dyed on cloudy days tended towards purple, while on sunny days the color was pure blue. Together with Ehud Spanier of Haifa University, he investigated the photo-chemical properties of the *trunculus* dye and found that when the dye is in a reduced state (a prerequisite for dyeing wool), exposure to ultra-violet light will transform the blue-purple colorant to unadulterated blue.

⁶¹ Herzog, *Hatekhelet BiYisrael*, ch. 11 “*Is the Murex Trunculus the Hillazon of Tekhelet?*”, found in R. Borstein’s book *Hatekhelet*, p. 224.

⁶² H.K. Mienis and E. Spanier, “A review of the Family *Janthinidae* (*Mollusca, Gastropoda*) in Connection with the *Tekhelet* Dye,” *The Royal Purple*, p. 197.). This assertion has also been confirmed in personal correspondence with the late Otto Elsner.

The chemistry and bio-chemistry of the dyes can be summarized as follows: Inside the hypobranchial gland of the snail, only the precursors to the dye exist as a clear liquid. (The indigo molecule contains a substance called indole, also found in the intestines of animals, which is a waste product of the proteins that constitute most of meat. Indole is a poison and does not pass out of the body directly. In order to remove it, animals unite it with sulfur, and this harmless combination is excreted through the kidney.



Murex snails incorporate bromine and potassium, in

addition to sulfur, to neutralize the indole and the resultant molecules become the dye precursors⁶³.) When the precursors are exposed to air and sunlight in the presence of the enzyme purpurase which also exists within the gland, they turn into the dye material. Purpurase quickly decomposes, so in order for this reaction to take place, the gland must be smashed soon after being taken from the live snail, (in accordance with the Talmudic passage that the *tekhelet* is taken from the *hillazon* while still alive). In the *trunculus*, these reactions result in a mixture of dibromindigo (purple) and indigo. The dye must be put into solution (usually accomplished by reducing the dye molecule) in order for them to bind tightly to wool. In this state, if dibromindigo is exposed to ultraviolet light, the bromine bonds will be broken and it will transform to indigo, turning the *trunculus* colorant from purplish-blue to pure blue. (It should be noted that the blue dye obtained from *Murex trunculus* is molecularly equivalent to indigo the Talmud's counterfeit *kala ilan*. If *trunculus* dye may not be used for *tekhelet*, then, as Herzog argues, the Talmud would have had to assert that not only is *kala ilan* unacceptable, but even *tekhelet* obtained from some marine animals - namely the *Murex* - is also unsuitable for the *mitzvah*, since the two dyes (*kala ilan* and *Murex* blue) are equivalent⁶⁴.)

Tekhelet today

Over the last few decades, much work has been done to reestablish the *tekhelet* dying process. Dr. Irving Ziderman, from the Israel Fiber Institute has published a number of articles

⁶³ Fox, H.M., *Blue Blood in Animals*, Routledge & Kegan Paul, London, (1928), pp. 51-61.

⁶⁴ Herzog, *The Royal Purple*, page 73. Rav Herzog finds this proof for the identification of the *hillazon* with *trunculus* irrefutable, but for one possible loophole. "Should the dye of the *Janthina* prove to be faster than that of the *Murex trunculus*,... then the tests [recorded in the Talmud] might well distinguish *tekhelet* dyed with *Janthina* from that dyed with *M. trunculus*." Subsequent research done on *Janthina* has shown that not only is that dye not fast, but it is in fact not even a dye. The pigment is water soluble, does not bind to the wool, does not color the wool homogeneously, and stains the fabric brown and not blue. (See the article by H.K. Mienis and E. Spanier, "A review of the Family *Janthinidae* (Mollusca, Gastropoda) in Connection with the *Tekhelet* Dye," *The Royal Purple*, p. 197.) With this loophole eliminated, Rav Herzog's original argument remains conclusive. In fact, the Radzyner anticipated this argument. See *Sefunei Temunie Chol*, p. 19.

describing the scientific aspects and religious implications of the *Trunculus* dye. Rabbi Herzog's doctorate has finally been published after nearly 80 years, while Rabbi Menakhem Borstein has published a book surveying the relevant Jewish legal aspects of *tekhelet*. Prof. Tzvi Koren from the Shenkar College of Fibers has done rigorous chemical analysis of the dye from present day snails as compared with samples from archeological artifacts dating back to 3500 BCE. But until a few years ago, the knowledge had remained mainly in the laboratory and the library.

In 1985, Rabbi Eliahu Tevger of Jerusalem began researching a book on the subject of *tsitsit*. He became convinced that the true *tekhelet* - from the *trunculus* - had been discovered. He was determined to actualize his newfound knowledge and, after much trial and error, Tevger succeeded in applying the process according to the details of *halakha* from beginning to end. A few years later, Joel Guberman, Ari Greenspan and myself joined with Rabbi Tevger in an effort to provide *tekhelet* to the general public. The main obstacle in our path was that the snails were difficult to obtain. Since there is not much demand for shellfish (which are not kosher), the snail fishing industry in Israel has never really developed. Furthermore, invertebrates in the coastal waters are protected by the Israeli government's nature authority. The solution to this problem was found by using snails from Greece, Spain and France where they are sold for food. The connections with these suppliers has assured an ample stock of snails, at a reasonable price. In 1993, we established the non-profit *P'til Tekhelet Foundation* to produce *tekhelet* strings, and promote research and educational projects. At present, more than 2,500 Jews from various communities the world over are wearing *tekhelet* obtained from the true *hillazon*, the *Murex trunculus*. After a 1,300 year interlude, Jews from Jerusalem to New Jersey are once again wearing the royal, priestly garb with the cord of *tekhelet*, as commanded in the Bible.