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## Threads of Reason

*A Collection of Essays on Tekhelet*

by Rabbi Mois Navon

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About the Book

This collection of essays is the result of research spanning more than a decade, motivated by nothing more than the desire to reach a clear understanding of the issues surrounding the rediscovery of *tebbelet* through the *Murex trunculus*. Is it possible to renew a biblical commandment without a *mesorah* (tradition)? Must religious objects, like *tzitzit*, be made from kosher substances? Does one violate the *melakbab* (Shabbat labor) of trapping when obtaining a snail on Shabbat? Bringing together biology and halakhah, chemistry and *aggadah*, archeology and theology – and applying careful consideration and logical reason – these essays seek to address the numerous questions that arise in the endeavor to revive this unique commandment. And as *tebbelet* is a commandment that has been forgotten for over 1300 years, each essay is colored with the marvel of a lost biblical commandment returned anew to the Jewish people. This collection of essays, then, can be seen as a group of threads – threads of reason – spun into a cord strong enough to bind a new generation in the fulfillment of an ancient commandment.

Threads of Reason

And God spoke to Moses saying: Speak to the children of Israel and bid them that they make for themselves *tzitzit* on the corners of their garments throughout their generations, and that they put on the *tzitzit* of the corner a thread of *tekhelet*.

Numbers 15:37-38

With this statement, the Torah unequivocally commands the wearing of *tzitzit* with a thread of *tekhelet*;¹ and from the verse, “make for yourselves tassels (*gedilim*)” (Deut. 22:12), the Gemara (Men. 39b) learns that the tassel is to be composed of four strings. Of these four strings, some are to be white² and some *tekhelet*.³ In the event that either the white or the *tekhelet* is absent, the Mishnah (Men. 4:1) explains that such lack does not abrogate the fulfillment of the mitzvah.⁴ Nevertheless, it cannot be stressed enough that the permit to use white alone is less than ideal, permissible only if *tekhelet* is unavailable to fulfill the mitzvah in its fullness.⁵ *Tekhelet*, then, is not a *bidur* (enhancement) but an essential component of fulfilling the biblical command. Indeed, the essence – *ikar* – of the mitzvah of *tzitzit* is in the *tekhelet* strand itself.⁶

Given the great importance of fulfilling the mitzvah of *tzitzit* with *tekhelet*, the question is, where is one to obtain this all-important dye? The Gemara (Men. 42b, Men. 44a) reveals that the blue dye comes from the “blood”⁷ of a creature called the *hillazon*. And though one might assume that the *hillazon* is but one of many valid sources, the Tosefta (Men. 9:6) states unambiguously that the *hillazon* is the sole source of the dye: “*Tekhelet* is valid only from the *hillazon*, and if not from the *hillazon* it is invalid.”⁸

As such, since its disappearance some 1300 years ago,⁹ the yearning for the *hillazon* has been as deep as the blue sea to which it is compared.¹⁰ One of the most poignant expressions of this longing for *tekhelet* is found in R. Nachman of Breslav's prayer on *tzitzit*: "May it be Your will that this mitzvah of *tzitzit* using white wool be considered before You as if we fulfilled it using *tekhelet*; for it is revealed and known to You that our will is to do Your will and we desire and yearn to fulfill the mitzvah of *tekhelet* in *tzitzit*. And if we were to merit finding *tekhelet* for *tzitzit*, we would spend a great fortune to fulfill the mitzvah in its fullness."¹¹

This great yearning finally bore fruit in 1857 when the dye-producing snail, *Murex trunculus*, was first rediscovered by French zoologist Henri de Lacaze-Duthiers. However, it wasn't until the early 1980s, when Professor Otto Elsner ascertained how to produce blue dye from the snail,¹² that the quest for *tekhelet* gained momentum. For, while having identified a strong candidate for the long lost *hillazon*, much effort was still required to determine if indeed the physical evidence matched the references made in the Judaic sources (i.e., Torah, Mishnah, Gemara, Midrash, halakhah and commentaries).

Over the past decades much literature has been generated, and continues to be generated, demonstrating that indeed the *hillazon* and *tekhelet* have been found.¹³ Based on these and numerous other sources, I would like to review the fundamental Judaic references to the *hillazon* and *tekhelet* and compare them to the *Murex trunculus* and its dye. I will then conclude with a look at the issue of rabbinic support for the *Murex trunculus* as the *hillazon* of *tekhelet*.

Judaic References

The trappers of the *hillazon* are [located] from the Ladders of Tyre to Haifa.
Shabbat 26a

Archeological digs all along the northern coast of Israel and reaching up to the southern coast of Lebanon have revealed remnants of the *Murex*-based dyeing industry dating to Joshua's conquest of Canaan (c. 1200 BCE).¹⁴ As such, archeological evidence corroborates the location of the *tekhelet* production given by the Talmud. That is, precisely where the Talmud says the *tekhelet* industry was located is where we find a plethora of evidence affirming *Murex trunculus*-based dyeing.

One who traps a *billazon* ...

Shabbat 75a

Trapping, in the biblical sense, is generally said not to have occurred if one can simply pick up a creature like a snail.¹⁵ However, the Mishnah (Beitzah 3:1) teaches that anyone who says, “bring a trap that we may trap it,” is considered to have performed trapping in its biblical sense.¹⁶ In the case of the *Murex trunculus*, which lives burrowed in the rocks and sand at the bottom of the sea, one cannot simply pick it up. Rather, one must lay traps – baited nets being the method of choice in ancient times.¹⁷ So indeed, biblical trapping is necessary to obtain the *Murex trunculus*.

One who breaks open (*potzea*) a *billazon* ...

Shabbat 75a

R. Herzog explains the Talmudic use of the verb *potzea* to indicate breaking open something hard like a nut.¹⁸ Given this definition, we expect the *billazon* to have a hard shell, and indeed, the *Murex trunculus* is a hard-shelled mollusk which must be broken open with a rock or a hammer to obtain its dye stuff.¹⁹

Go and learn [about the clothes of the Jews in the desert] from the *billazon* – all the time that it grows, its shell (*nartiko*) grows with it.

Shir Ha-Shirim Rabbah 4:11

In consonance with this Midrash, the *Murex trunculus* is a mollusk born with a hard protective shell that grows to accommodate its growing body.²⁰

The *billazon* is this: its body is like the sea, its creation is like a fish, and it comes up once in seventy years and with its blood one dyes *tebbelet* – therefore, it is expensive.

Menahot 44a

While one might have thought this *baraita* provides the key to identifying the *billazon*, a closer examination reveals descriptions that are vague and ambiguous, making them ineffective for identifying a specific creature. Its purpose, however, can be discerned by noting its structure. That is, the *baraita* is divided into two by the word “therefore,” as in “therefore, it is expensive”; hence, it is readily

understood that what came before this divider is the justification for the conclusion – i.e., expense.²¹ The *baraita*, then, comes not to define halakhically the characteristics of the *hillazon*, but only to explain why it is expensive. Indeed, R. Herzog writes that the declaration, “it is expensive,” is out of place in a formal halakhic definition. He explains that it would, however, make sense as part of a justification to consumers far away in Babylonia curious as to the reason for the dye’s high price.²² This observation accords well with the *Murex trunculus*, which is an inherently expensive source of dye. Its cost is due both to the difficulty of obtaining the snails as well as the minute quantity of dye each snail renders.²³

One is more pleased that it should be alive, so that the dye should be successful.

Shabbat 75a

Rashi (ad loc.) explains the Talmud to be teaching that the “blood” from a live *hillazon* is better than from a dead one. To appreciate how this relates to the *Murex trunculus*, it is necessary to understand the physiology of the snail. Inside the hypobranchial (“under the lung”) gland of the *Murex trunculus*, the precursors of the dye, along with an essential enzyme (purpurase), exist together as clear liquid.²⁴ The chemistry of the dye formation in the *Murex trunculus* is such that when this clear liquid is exposed to oxygen, affected by squeezing the gland,²⁵ the enzyme reacts with the precursors to produce the colored dyestuff. The purpurase, however, deteriorates soon after the snail’s demise,²⁶ thus requiring that the dye extraction be done while the snail is alive, precisely as the Talmud explains.²⁷

God said: I distinguished in Egypt between a firstborn and a non-firstborn; ... I will exact retribution from him who attaches *kela ilan* to his garment and claims it is *tekbelet*.

Baba Metzia 61b

The rabbis who articulated this statement, though known for their acute ability to distinguish between various colors, were nevertheless compelled to state that only God can distinguish between the counterfeit vegetable-based dye, *kela ilan*, and the genuine *hillazon*-based dye, *tekbelet*. This fact, explains R. Shabtai Rappoport, stands as powerful testimony to the great degree that the two dyes are visually equivalent.²⁸ Now, *kela ilan* has consistently been identified as indigo,²⁹ the blue dye coming from, most ubiquitously, the *Indigofera tinctoria* plant.³⁰ Amazingly, the

blue dye obtained from the plant source is not only visually indistinguishable but molecularly equivalent to the dye obtained from the *Murex trunculus* snail.³¹ So indeed, only God can distinguish between the two dyes!³²

How is *tebbelet* made? One places the blood of the *billazon* and chemicals (*sammanim*) in a pot to boil.

Menahot 42b

Rashi, Tosafot and Rambam all grapple with the use of chemicals, given that *tebbelet* is, by definition, from the *billazon*. That is, we would expect *tebbelet* dye to consist solely of the extract from the *billazon*, yet the Talmud notes that chemicals were added. To account for the use of additives, the commentators explain that chemicals were necessary to fix the dye into the wool but not to give any color.³³ This is indeed true of the process used to produce the dye from *Murex trunculus* which consists of the following steps. First, the hypobranchial gland containing the dye stuff is removed, squeezed and boiled together with a strong base which is used to dissolve the snail meat and to create the chemical environment necessary for reduction. Second, the solution is chemically reduced to make the dye water-soluble, enabling it to take to the wool (as in typical vat dyeing).³⁴ Finally, an acid is added to neutralize the basic solution in order to prevent the dye solution from damaging the wool. From this description it should be clear that the chemicals are used only to enable the dyestuff to absorb into the wool and are not part of the color itself – just as the commentators stipulate.

How is *tebbelet* made? ... [W]e take out a little [dye] in an egg shell and test it on a piece of wool.

Menahot 42b

Ancient dyes are classified into three categories: vat dyes, mordant dyes, and direct dyes.³⁵ In vat dyeing, as opposed to mordant and direct dyeing, the final dye color is not discernible while in the vat but only upon removal from the vat. Regarding the *Murex trunculus* dye, it is a vat dye which produces colors ranging from blue to purple, depending on how much ultraviolet light it receives when in the reduction vat.³⁶ At this stage the *Murex* dye solution appears yellowish in color, and it is only upon removal from the vat that it takes on its final color in the wool. Since the resultant color can range from blue to purple, the dye must be tested to determine if it has been sufficiently exposed to ultraviolet light, which is, again, what turns the dye from purple to blue.³⁷ This being the case, the Gemara's requirement to

sample the dye fits well with the vat dyeing procedure used for the *Murex trunculus*.³⁸ Furthermore, the Gemara's intimation that vat dyeing was used for *tekebelet* production agrees with the historical record, which shows that the only blue dye known to the ancient world was the indigo vat dye (be it plant-based or snail-based).³⁹

If its color is permanent then it is valid.

Menahot 43a

The Rambam explains that *tekebelet* “is well known for its steadfast beauty and does not change” (Hil. Tz. 2:1). Due to the chemical process whereby the dyestuff is first reduced and then oxidized in the wool, the *Murex trunculus* dye binds very tightly to wool. Indeed, indigo dyes have the illustrious reputation of being the fastest dyes known to the Old World.⁴⁰ Anecdotaly, R. Chaim Twerski noted that soaking the dyed strands for three days in strong bleach had no effect on the dyed wool.⁴¹

“Hidden treasures of the sand” (Deut. 33:19) refers to the *hillazon*.

Megillah 6a

In consonance with this statement, the *Murex trunculus* indeed burrows into the sands and sediment on the sea floor.⁴² And though it is true that the Gemara explains each term of the verse “hidden treasures of the sand” (*sefunei temunei hol*) as applying to a different item (i.e., *sefunei: hillazon*, *temunei: tuna fish*, *hol: glass*), it can be understood as a whole to refer to all three. The Radzyner Rebbe, in his book by the same name, *Sefunei Temunei Hol*, states that “the verse includes all three things together for it is their way to be found in the sand” (2:8). And though some express reservation as to how three items could be intended, the Seforno is convinced that the statement does apply at least to the *hillazon*, explaining, “covered and buried in the sand is the blood of the *hillazon*...” (on Deut. 33:19). What can be learned from this Gemara is that the *hillazon* lives on the sea floor. Indeed, this is a point corroborated by the *baraita* (Men. 44a) which states that the *hillazon* “comes up,” meaning “from the earth” (according to Rashi), and upon which the Yavetz writes, “that means to say: from the seabed.”

Rabbinic Support

A final point which needs to be addressed is that of rabbinic support. For, while every Jew is enjoined to learn Torah and discover its truths, such enterprises are

often complex, requiring overarching perspective and complete devotion, such that even after a review of the issues, as has been provided here, one may still rightly wonder if something hasn't been overlooked. Therefore, the task of deciding difficult halakhic issues is submitted to the rabbis who have dedicated their lives to such endeavors.

The rabbis of great stature have, to date, absented themselves from this discussion. That is, they have not come out unequivocally on the issue. In 1998, R. Yosef Shalom Elyashiv issued a statement on the subject in which he raised a number of concerns regarding the acceptance of any candidate for the *hillazon*.⁴³ I later met with R. Shlomoh Fischer, who asked me what R. Elyashiv's opinion was on the matter. When I handed him R. Elyashiv's printed statement, he read it and without hesitation concluded, "He is avoiding the issue." However, in 2011, R. Elyashiv did give his blessing to his disciple, R. M. M. Karp, to issue his own letter stating that, though his personal lack of knowledge prevented him from giving a decision on the matter, "those who have verified the issue must fulfill it ... and anyone who desires to fulfill it ... will have great reward."⁴⁴

Now, while it is true that the rabbis considered the generation's "*gedolim*" have refrained, in one way or another, from the discussion, there are in fact many rabbis of prominence in the modern Orthodox world and in the *dati leumi* world, as well as a growing number in the *bareidi* world, who have come out in support of the identification of the *Murex trunculus* as the *hillazon* of *tekebelet*, and that does not include all of the rabbis who, for various reasons, choose to keep their decision private by wearing their *tekebelet* strings inside their clothing.

Now, though it might have been gratifying to publish a long list of well-known halakhic authorities who wear *Murex trunculus tekebelet*, this is really not necessary for one to decide in favor of wearing *tekebelet*. First of all, while there is a principle that we are to follow the majority, this does not apply when the two sides have not debated face to face, but only expressed their opinions in writing.⁴⁵ Second, there is an accepted principle that on decisions of biblical (*d'oraita*) law, we follow the stricter opinion regardless of the stature of the rabbis involved.⁴⁶ In the case of *tzitzit*, strictness would argue for fulfilling the words of the Torah in their fullness.⁴⁷ Third, R. Avraham Shapira explained that *klal Yisrael* has the power to decide (*psak*) more than even a thousand rabbis, and the rabbis today are simply waiting for *klal Yisrael* to decide to wear *tekebelet* so that they will not have to quarrel over the issue.⁴⁸

R. Meir famously teaches that *tekbelet* is magnificent because it is like the sea and the heavens (Men. 43b, Sot. 17a). Is it not more than coincidence that the Torah employs precisely these similes to spur us to action?

For this commandment which I command thee this day, it is not hidden from thee, neither is it far off. It is not in *heaven*, that thou shouldest say, Who shall go up for us to *heaven*, and bring it unto us, that we may hear it, and do it? Neither is it beyond the *sea*, that thou shouldest say, Who shall go over the *sea* for us, and bring it unto us, that we may hear it, and do it? *But the word is very nigh unto thee, in thy mouth, and in thy heart, that thou mayest do it.*

Deut. 30:11-14 (*emphasis mine*)

~ Notes ~

- ¹ R. Menachem Burstein (*Ha-Tekhelet* [Jerusalem: Sifriyati, 1988], pp. 93-4), explains that practically every halakhic decisor concerned with counting the mitzvot (“*rubam k’kulam shel monei hamitzvot*” – see esp. n. 51), enumerates the mitzvah of *tzitzit* with *tekhelet* as one singular mitzvah with two components.
- ² See my essay, “False *Tekhelet*” (herein, p. 96) for a discussion on the color of the non-*tekhelet* strings.
- ³ There are three opinions as to how many strings (per corner) are to be *tekhelet*:
- Rambam (Hil. Tz. 1:6) – Half of one string is *tekhelet*; when folded into the corner hole, one of the eight strings is *tekhelet*.
 - Raavad (Hasagot on Hil. Tz. 1:6) – One full string is *tekhelet*; when folded into the corner hole, two of the eight strings are *tekhelet* (as Sifri Shelah 115).
 - Tosafot (Men. 38, s.v. *ba-tekhelet*) – Two full strings are *tekhelet*; when folded into the corner hole, four of the eight strings are *tekhelet* (as Sifri Ki Tetzai 234).
- ⁴ Tosafot (Men. 38, s.v. *hatekhelet*) explain that one can fulfill the mitzvah with white alone or *tekhelet* alone. The Rambam (Hil. Tz. 1:4) understands the Mishnah in a unique way, such that “*tekhelet* does not invalidate fulfillment with white,” means that if one has only white, he fulfills the mitzvah, however, “white does not invalidate fulfillment with *tekhelet*,” means that if the white was torn short, the *tzitzit* are still valid (see R. Hershel Schachter, “Using Tekhelet in Tzitzit,” in *Tekhelet: Renaissance of a Mitzvah* [N.Y.: YU Press, 1996], pp. 54-57).
- ⁵ R. Shmuel Ariel (“Tekhelet in Tzitzit: A Choice Mitzvah or an Absolute Obligation,” *Techumin* 21 (5761), <http://tekhelet.com/pdf/muvchar.pdf>) argues that the white-only allowance is applicable only under duress (i.e., when *tekhelet* is not available), otherwise it is forbidden to wear a four cornered garment with white only. This opinion is countered by R. Yehuda Rock (“The Definition of Nullifying a Mitzvah,” *Techumin* 24 (5764), <http://tekhelet.com/pdf/bitulasei.pdf>) who explains that the white-only allowance applies in any case when one can’t wear *tekhelet* (not only under duress). However such fulfillment of the mitzvah is considered *bidi’avad* – less than ideal. See also R. Burstein, pp. 97-98.
- ⁶ See Rashi (Men. 40a, s.v. *b”sh potrin*); Ramban (Num. 15:38). See list in R. Burstein, p. 101, n. 81.
- ⁷ It is understood that the term “blood” is non-specific, simply implying “a secretion” (Tosafot, Shabbat 75a, s.v. *ki beikhi*).

- ⁸ See also Masekhet Tzitzit (1:10). Though there are some few who hold that *tekelet* may come from sources other than the *hillaẓon*, the overwhelming majority opinion is that it must come from the *hillaẓon*. See R. Bezalel Naor, “Substituting Synthetic Dye for the Hilazon,” *Journal of Halacha and Contemporary Society* 24 (1992), pp. 97-107; R. Yehuda Rock, “Renewal of Tekhelet and Issues on Tzitzit and Tekhelet,” *Techumin*, 16 (online expanded version), pp. 12-13; R. Burstein, pp. 25-27.
- ⁹ This figure is based on R. Herzog’s estimation that *tekelet* was lost to the Jewish people at the time of the Arab conquest in 639. For further discussion, see my essay, “On History, *Mesorah* and *Nignaz*” (herein, p. 18).
- ¹⁰ “... its body is like the sea” (Men. 44a).
- ¹¹ Quoted in R. Burstein, p. 139.
- ¹² Otto Elsner and Ehud Spanier, “The Past, Present and Future of *Tekhelet*,” in *The Royal Purple and The Biblical Blue* (Jerusalem: Keter, 1987), p. 175.
- ¹³ R. Menachem Burstein, *Ha-Tekhelet*; Israel Ziderman, “Reinstitution of the Mitzvah of Tekhelet in Tzitzit,” *Techumin* 9 (1988), pp. 423-46; R. Eliyahu Tavger, “Ma’amar ha-Tekhelet,” in *Kelil Tekhelet* (Jerusalem, 1993), pp. 312-34; R. Yehuda Rock, “Renewal of Tekhelet and Issues on Tzitzit and Tekhelet”; R. Chaim Twerski, “Identifying the Chilazon,” *Journal of Halacha and Contemporary Society* XXXIV (Fall 1997), pp. 77-102. R. Shlomoh Taitelbaum, *Lulaot HaTekhelet* (Jerusalem: Ptil Tekhelet, 2000).
- ¹⁴ Nina Karmon and Ehud Spanier, “Archaeological Evidence of the Purple Dye Industry from Israel,” in *The Royal Purple and The Biblical Blue* (Jerusalem: Keter, 1987), pp. 149-57.
- ¹⁵ The definition of what constitutes trapping is rather involved, and is dealt with in detail in my essay, “*HaZad Hillaẓon* – Trapping the *Murex trunculus*,” (herein, p. 51).
- ¹⁶ And such is the halakhah (*ibid.*).
- ¹⁷ Shabbat 75a. Similarly the ancients of other cultures used the same methods; see: Aristotle, *History of Animals* (5:15), and Pliny, *Natural History* (9:37).
- ¹⁸ R. Herzog, “Hebrew Porphyrology,” in *The Royal Purple and The Biblical Blue* (Jerusalem: Keter, 1987), p. 57. For a discussion on *potzēa*, especially regarding Rashi’s opinion, see my essay, “*HaPotzēo* – Extracting the Dye from the *Murex trunculus*” (herein, p. 32).
- ¹⁹ Ehud Spanier and Nina Karmon, “Muricid Snails and the Ancient Dye Industries,” in *The Royal Purple and The Biblical Blue* (Jerusalem: Keter, 1987), p. 180. Ziderman, *Techumin* 9, p. 430. Vitruvius explains, “After the shells are gathered they are broken into small pieces with iron bars; from the blows of which, the purple dye oozes out like tears, and is drained into mortars and ground” (Marcus Vitruvius Pollio, *De Architectura*, Book VII, Ch. 13, pt. 3).

- ²⁰ George Radwin and Anthony D’Attilio, *Murex Shells of the World: An Illustrated Guide to the Muricidae* (Stanford: Stanford University Press: 1976), p. 11.
- ²¹ R. Rock, n. 57.
- ²² R. Herzog, pp. 66-67. For further discussion of this *baraita* see my essay, “The *Hillazon Baraita*” (herein, p. 25).
- ²³ Empirical observation in the Ptil Tekhelet factory shows that it takes approximately thirty snails to produce enough dye for four strings. See M. V. Orna, et al., “Coordination Chemistry of Pigments and Dyes of Historical Interest,” *ACS Symposium Series* (1994), which records that it took 12,000 mollusks to render 1.5 grams of dye. “[T]he light violet purple ... a pound of it was sold for a hundred deniers; ... the Tarentine red purple ... of the same price. But after it, came the fine double dyed purple of Tyros, called Dibapha [Murex-based dye]: and a man could not buy a pound of it for a thousand deniers” (Pliny, *Natural History*, Book 9, ch. 39).
- ²⁴ Ehud Spanier and Nina Karmon, pp. 180, 183, 188; Israel Ziderman, “Halakhic Aspects of Reviving the Ritual *Tekhelet* Dye in the Light of Modern Scientific Discoveries,” in *The Royal Purple and The Biblical Blue* (Jerusalem: Keter, 1987), p. 214.
- ²⁵ Today the gland is cut out and squeezed; in ancient times the entire snail was simply smashed, thus squeezing the gland in the process. See my essay, “*HaPotzfo* – Extracting the Dye from the *Murex trunculus*” (herein, p. 32), especially notes 20 and 21 there.
- ²⁶ Baruch Serman, “The Science of Tekhelet,” in *Tekhelet: Renaissance of a Mitzvah* (New York: YU Press, 1996), p. 68.
- ²⁷ Note that this characteristic is also described by Aristotle: “Fishermen are anxious always to break the animal in pieces while it is yet alive, for, if it die before the process is completed, it vomits out the bloom [i.e., purges its dye]” (*History of Animals*, Book 5, part 15; http://classics.mit.edu/Aristotle/history_anim.5.v.html).
- ²⁸ R. Shabtai Rappoport, “*Simanim, Mesoret*, and Identifying Tekhelet,” <http://www.tekhelet.com/doc/ra01.doc>, p. 2.
- ²⁹ Arukh, s.v. *kela ilan*; Radvaz Responsa 2:685.
- ³⁰ See R. Burstein, p. 75. Also R. Ari Zivotofsky, “*Kela ilan*”: <http://www.tekhelet.com/DafYomi/EnglishDaf.pdf>. Indigo also comes from woad (*Isatis tinctoria*) as well as “some 30 to 40 species of unrelated plants” (John Edmonds, *The History of Woad and the Medieval Woad Vat*, John Edmonds Publisher, 1998, p.3).
- ³¹ See fn. 12. Note: While traces of bromine in the snail-based dye can be detected using modern techniques, the indigo molecule is identical from both sources.

- ³² It bears mentioning that the Gemara (Men. 42b) proposes chemical tests in order to distinguish between the two dyestuffs by causing the plant dye to fade. The question is then posed as to how such tests would be effective if the dyes are molecularly equivalent. Professor Roy Hoffman explains that the plant-based procedure called for merely soaking the wool in crushed leaves, thus not allowing the dyestuff to bond as well as the snail-based dye, which used a proper vat dye procedure. For further discussion, see my essay, “Chemical Testability” (herein, p. 47).
- ³³ For a detailed discussion on this issue, see my essay, “*Sammanim* – the Chemicals to Make *Tekhelet*” (herein, p. 40).
- ³⁴ Today a reducing agent is used. In ancient times, however, reduction was effected by long term cooking of the snail meat. See Dr. Zvi Koren, “The First Optimal All-Murex All-Natural Purple Dyeing in the Eastern Mediterranean in a Millennium and a Half,” p. 142, http://www.tekhelet.com/pdf/KOREN_DHA20_2005.pdf and Dr. Roy Hoffman, “Identifying Tekhelet: New Findings” (*The BaDaD Journal* 27 (2012), <http://tekhelet.com/pdf/naturaldyepaper3.pdf>).
- ³⁵ *The Real World of Chemistry*, 6th ed. by Lois Fruen Kendall/Hunt Publishing, see: <http://realscience.breckschool.org/upper/fruen/files/enrichmentarticles/files/ancientdyes/ancientdyes.html>.
- ³⁶ See fn. 31.
- ³⁷ See fn. 12.
- ³⁸ R. Gershon Bess, in a personal conversation.
- ³⁹ Personal correspondence with Prof. Zvi Koren, Edelstein Center for the Analysis of Ancient Artifacts at Shenkar College in Ramat Gan. See also fn. 35.
- ⁴⁰ John Edmonds, p. 21.
- ⁴¹ R. Twerski, p. 91.
- ⁴² Ehud Spanier and Nina Karmon, p. 181, p. 190; Israel Ziderman, *Techumin* 9, p. 429; R. Twerski, p. 85.
- ⁴³ *Yedion: Hillebot Sadeh*, The Institute for Agricultural Research according to the Torah, Vol. 109 (Shevat, 5758).
- ⁴⁴ <http://www.tekhelet.com/approbations/KarpApprobation.pdf>.
- ⁴⁵ Yabia Omer (Even HaEzer, Helek 8, Siman 12): “The *poskim* have already written that in a case when *poskim* did not debate face to face but only wrote their opinions individually, then the rule of ‘follow the majority’ does not apply.” See also *Minhat Hinukh* (78:1).

- ⁴⁶ Kesef Mishnah (Hil. Mamrim 1:5): “Even if one is greater than his peer in wisdom and age, in a case of Torah law one goes according to the stringent opinion.” So too, Tosafot (*Avoda Zara 7a*). Nevertheless, Rashba (*Avoda Zara 7a*) and Meiri (*ibid.*) argue that the superior authority is followed, and only in case of a disagreement over a Torah law between authorities of equal stature does one follow the more stringent authority.
- ⁴⁷ When weighing what it means to be strict versus what it means to be lenient in a positive commandment, being strict would mean going out of one’s way to fulfill the mitzvah, like the Vilna Gaon who paid every Kohen for his own *pidion bechorot* until he found a Kohen *meyubas*. So too with *tekhelet*, one should make every effort to fulfill it. See my essay, “False *Tekhelet*” (herein, p. 96, esp. fn. 21).
- ⁴⁸ R. Tzafania Drori, “Regarding the Placement of Tekhelet in Tzitzit,” *Me’Orot Amana* 4 (5760), http://www.yk8.org/artsfl/mamar_147.pdf, footnote 19.