Scientific thoughts on specific Talmudic passages

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Introduction

As part of a *daf yomi*, each day the group studies one complete page of a specific tractate of the Talmud. The Talmud contains much science, including medicine, biology, chemistry, physics, earth science, and cosmology. At times, it is difficult to comprehend the science of a Talmudic passage. This has lead to much debate and many suggestions in the Torah-science literature, trying to elucidate the passage. This article is an attempt to explain some of such Talmud-science passages. However, it should be clearly understood that these explanations are not an attempt to second-guess the explanations offered by *Chazal*, but rather an attempt to satisfy the questions in my mind.

Freckles

In the Talmud (Berachos 58b), there is a discussion on the blessings recited upon seeing unusual creatures, including humans that appear different from the norm. Rabbi Yehoshua ben Levi said that upon seeing "spotted" people one was obligated to recite the blessing, "Blessed are You …. Who diversifies the creatures." Rashi explained that "spotted" referred to "freckles." The Mishnah Berurah (225:24) described these spots as of a light red hue with glistening white skin between them. Rabbi Yehoshua ben Levi's opinion was challenged by a Baraisa which enumerated examples of people with various deformities for whom, upon seeing, one was required to recite the blessing of, "Blessed are you … the true Judge." Included in this enumeration, were leg and hand amputees, the blind, a person covered with boils, and "spotted" people. Thus, there was disagreement upon the appropriate blessing to recite upon seeing a person with freckles. The apparent contradiction was resolved, as Rabbi Yehoshua ben Levi referred to freckles present at birth, whereas the Baraisa referred to freckles acquired in later life. The Mishnah Berurah (225:26) noted that the commonality among the people enumerated in the Baraisa was that their deformities and infirmities were acquired later in life.

What bothered me was the difference in the nature of the two blessings. The blessing, "Blessed are You …. Who diversifies the creatures," has positive connotations, as it extols the power of *HaShem* to add phenotypic variations within His creations. However, the blessing, "Blessed are you … the true Judge," is recited during times of emotional distress (see note 44, Artscroll edition of Berachos 58b). For example, this blessing is recited by mourners when they rip the outer garments prior to the eulogy; it is recited upon hearing unusual bad news; and it is recited upon seeing a destroyed synagogue. Apparently, there is something different about the nature of freckles that trigger the recitation of "Blessed are You …. Who diversifies the creatures" from freckles that trigger the recitation of Blessed are You … the true Judge"

The Baraisa included "spotted" people with those individuals with infirmities and deformities, suggesting that these "spots" were symptomatic of a medical condition. While, the "spots" referred to by Rabbi Yehoshua ben Levi, apparently, referred to a normal, nonpathological condition. Normal freckles are clusters of skin melanocytes that overproduce the pigment, melanin, thereby causing a change in skin color. Freckles although rare in infants, occur more usually in prepubertal children. As freckles are not a skin disorder, the blessing, "Blessed are You …. Who diversifies the creatures," would be the appropriate blessing upon seeing a freckled individual.

The Baraisa, however, may be referring to a pathological case of freckling. A freckle-based pathology that would be a potential candidate for reciting the blessing, "Blessed are You … the true Judge," is xeroderma pigmentosum (XP; Figure 1), an autosomal recessive genetic disorder in which the XP individual lacks the ability to repair DNA damage caused by exposure to ultraviolet solar light. This genetic disease has a frequency of about 1 case per a population of 250,000. In XP people, development of freckles occurs at an early age, usually in infancy or early childhood. At birth, the skin appears healthy, but after 6 months of age, the skin is characterized by diffuse erythema, scaling, and a freckle-like area of increased pigmentation. By two years of age, in response to sunlight, XP children develop freckling of

the face and arms and are at a heightened risk for skin cancer and, perhaps, for brain cancer. About 30% of XP people develop progressive neurological disorders, *e.g.*, hearing loss, difficulty in walking, loss of intellectual function, and seizures, which tend to worsen with time [1, 2]. The recitation of the blessing, "Blessed are You … the true Judge," upon seeing "spotted" people is appropriate if the freckles are symptomatic of a pathology, such as XP, and even more so if the observer feels pain on seeing a fellow human in such distress.

Figure 1. Boy with xeroderma pigmentosum.

Liver

An animal with one of a specific list of fatal defects would prohibit it from being eaten, even if it was properly slaughtered. Such an animal or bird is a *tereifah* whether it was born with or acquired one of these life-threatening defects which led to death within a year. Conversely, if the animal would live for 12 months, it is not a *tereifah* and can be consumed. The sages of the Talmud (Chulin 57b) compiled a list of various defects which rendered an animal as a *tereifah*. The liver is an essential organ for viability and an animal completely lacking the liver is a *tereifah*. What about an animal with a partial liver? The Talmud (Chulin 45a,b, 46a, 54a) recorded a dispute to the status of an animal if the remaining liver was less than a *k'zayis* (*i,e*., the size of an olive). The accepted opinion is that for the animal to be considered viable (*i.e.,* not a *tereifah*) its liver must be at least the size of olive. As explained by Rashi, this amount of liver is sufficient for the remaining liver "to produce healing" and thereby to continue to perform its life sustaining functions. A defect in the liver was considered non-fatal, whereas defects in other organs were deemed life-threatening. Why?

Current thought is that the Talmud was referring to the regenerative nature of the liver [3], as the liver is the only internal mammalian organ capable of natural regeneration of lost tissue. In the research laboratory, liver regeneration was studied by surgically removing 2/3 of the liver mass of rodents (mice and rats), a technique known as 2/3 partial hepatectomy. The researchers followed the regrowth of the liver. The regenerative process in mice and rats was rapid, with complete restoration of the liver within 5 to 7 days post-surgery [4]. How did Chazal know of the regenerative nature of the liver? Katznelson, in his book on Talmudic medicine, *Hatalmud Vechochmas Harefuah* (1928), theorized that the rabbis of the Talmud carried out experimental hepatic resections on animals to prove liver regeneration from an olive-sized liver. Westreich [5] countered that "this seems highly unlikely, and the theory is based solely on semantic evidence." If so, how did *Chazal* know of the regenerative nature of the liver? Apparently, this information must have been transmitted as *mesorah* down through the generations.

Oculocardiac reflex

A section in tractate Avodah Zarah (28b) discusses the seriousness of eye ailments and the permissibility of applying ocular ointments on Shabbos. Examples of ocular ailments that can be treated on Shabbos include excessive discharge, a stabbing pain in the eye, blood in the eye, excess tearing of the eye, and an inflammation of the eye. Mar Shmuel explained that permission to apply ocular ointments on Shabbos was that "eye sight is connected to the muscles of the heart." *Tosafos* cited a version of Rashi that implied a physical connection of some sort between the eyes and the heart. Although this association may seem strange, Rashi was on target and the physical connection may refer to the nervous system, with a nervous reflex arc triggered from the eye may lead to slowing of the heartbeat and even death. This reflex, termed the oculocardiac reflex, as a possible explanation of this Talmudic passage, was brought to my attention by Mordechai Shedrowitzky, P.T. and Natan Tracer, M.D. The stimuli associated with this reflex include traction applied to the extraocular muscles and compression of the eyeball. Upon stimulation, afferent nervous impulses are transmitted via the trigeminal nerve to the brain stem in which they transmit the nervous impulse to the

parasympathetic nervous system via the vagus nerve, which innervates the sinoatrial node of the heart. The result is a decrease in the heart rate (sinus bradycardia), junctional rhythm and asystole, all of which may be life-threatening [6].

Sperm viability

Following cohabitation, sperm can survive in the vagina for up to several hours. The lifespan of sperm in a woman's body is largely dependent of the cervical fluid, which provides the nutrients for sperm survival in their journey to the ovum in the fallopian tube. Once sperm enter the female fertile genital tract, *i.e.*, the cervix and uterus, most sperm die within 1-2 days. Sperm cells exposed to room air on clothing or bed linens lose motility rapidly; once the semen dries, the sperm cells are dead [7].

Viability of sperm obtained from the female genital tract has been studied both microscopically and with a variety of metabolic assays. Wallace-Haagens *et al.* [8] studied sperm survival, in terms of numbers, motility, viability, and metabolic activity, in vaginal washings obtained daily from 22 healthy, fertile, married women during one complete menstrual cycle. The numbers of sperm were never large compared to the number of sperm in a single ejaculate. Forty-eight hours after intercourse, only 6% of the specimens showed any evidence of sperm. Motile sperm were observed in only six of 94 postcoital specimens examined within 12 hours after intercourse. Fluorochromatic studies of recovered sperm treated with acridine orange were used to indicate sperm viability and phase contrast studies of sperm treated with tetrazolium salts were used to study metabolic activity. Their data on sperm motility, numbers, and staining reactions supported the conclusion that the small number of sperm that remain in the vagina after intercourse quickly inactivated. The study cited above is one of the early studies to evaluate sperm viability in the fertile female genital tract. Sophisticated laboratory techniques, both microscopic and chemical, were used to evaluate sperm viability. The key finding in this study, and in all subsequent studies, is that sperm remain viable in the female fertile genital tract for 1-2 days, with most dead by day 3. Interestingly, the three-day viability of sperm in the female reproductive was the basis for the prohibition of a husband and wife having intimate relations during the three-day period prior to the giving of the Torah at Mt. Sinai (Shemos 19:15).

To understand the Torah aspect, a little background information is needed. After intimate relations, a woman may discharge some viable sperm cells. Regarding the laws of *tumah* and *taharah* (not, the laws of *nidda*), such a discharge of viable sperm cells would make the woman unclean (*tamei*) until the night after immersion in a *mikvah*. However, the discharge of non-viable sperm cells from the female reproductive tract, *e.g.*, such as that >3 days after intimacy, does not make the woman *tamei*. On the sentence, "He (*i.e.*, Moshe) said to the people, "Be prepared after a three-day period: do not draw near a woman"" (Shemos 19:15), Rashi commented, "For this entire 3-day period, so that the women should be able to immerse themselves by the 3rd day and thereby be *tahor* to receive the Torah. For if they were to have relations within the 3-day period prior to the giving of the Torah, perhaps a woman would discharge (*living*) sperm after her immersion and would become impure again. But once she waited 3 days after having relations, the semen has already become putrid (*i.e.*, *was not viable*) and is not fit to fertilize and is pure regarding contaminating the woman who discharges it." Thus, the 3-day separation between husband and wife was necessary to ensure that the woman would be *tahor* for the giving of the Torah (Shabbos 86a). What is unusual is that *Chazal,* without the use of a microscope to visualize sperm cell motility and without the knowledge of metabolic chemical assays to assess sperm viability, understood that sperm viability in the female reproductive tract lasted for a three-day period. Apparently, this information must have been transmitted as *mesorah* down through the generations.

Food cravings of a fetus

A Mishnah in tractate Yoma (82a) states, "If a pregnant woman smelled food or drink and craved it on Yom Kippur, we feed her until she feels relieved." Rashi noted that the fetus smells the food and craves it and if the mother does not eat it, both she and the fetus will be in danger. A fetus is fed through the gestation umbilical cord and flavor perception is experienced through the sensations of taste (tongue) and smell (nose), with smell the larger factor in the perception of flavor (*e.g.*, for a person with an upper respiratory infection who cannot smell, food has no flavor). Logically, it would seem that food

preferences and cravings should begin after birth, not *in utero*. Yet, Rashi implied that a fetus, albeit fed through the umbilical cord, experiences tastes and smells *in utero*, thereby developing cravings for pleasurable foods. Current research shows Rashi was correct, as (a) the ability to perceive flavor begins *in utero* with the development and the early functioning of the olfactory and gustatory systems and (b) amniotic fluid contains molecules derived from the mother's diet [9].

Taste sensations result from activation of the gustatory system and are directed to the sensations of salty, sour, bitter, sweet, and umani (savory). Regarding the perception of odor, thousands of different odors stimulate the olfactory system to create smell sensations. The perception of food flavor results from the integration of the odor and taste sensory systems.

Morphological and functional development of taste cells on the tongue and the olfactory receptors in the nasal passages begin in the first trimester of fetal development. Taste buds are mature and functional *in utero* by the beginning of the second trimester. Olfactory receptor cells are evident by 11 weeks and fetal olfactory receptor cells are stimulated by odor compounds by at least 26 to 28 weeks gestation. The nasal plugs, which the block the openings of the nasal passages, dissolve in the third trimester, thereby allowing the nasal passages to be bathed by amniotic fluid. The fetus both inhales and swallows significant amounts of amniotic fluid by late gestation. The amniotic fluid contains many constituents, ranging from nutrients (such as glucose and amino acids) to the flavors of the mother's dietary and environmental exposures [9, 10]. For example, Mennella *et al.* [10] obtained amniotic fluid from women in their second trimester of pregnancy after ingestion of garlic capsules or a placebo. The odor of garlic on pads containing amniotic fluid was discernible from those women who ingested the garlic capsules.

The main determinant of what an individual selects to consume is whether he/she likes the flavor of the food or beverage. Flavor is dependent upon the perception of smell and taste. The fetus swallows and inhales significant amounts of amniotic fluid by late gestation. Although the chemical senses of taste and smell are operational *in utero*, what evidence is there that the fetus experiences these sensations? It was shown that injection of a sweet-tasting stimulus into amniotic fluid stimulated fetal swallowing, whereas injection of a bitter stimulus inhibited fetal swallowing [9]. What evidence is there that an infant develops cravings for pleasurable food items experienced prenatally? Mennella *et al.* [12] studied pregnant women who consumed either carrot juice or water for 4 days/week for 3 consecutive weeks during the last trimester of pregnancy. Subsequently, their infants, at about 6 months of age, were fed plain cereal and cereal amended with carrot juice flavor. The infants were videotaped as they were fed cereal with/without carrot juice flavor. Videotape analyses were directed on the frequency of negative facial responses (*e.g.*, gaping, head turning, nose wrinkling, upper lip raising, brow lowering) in response to each spoonful of ingested cereal. In addition, immediately after each videotape session, the mothers rated their infants' enjoyment of the food. As evaluated by their mothers, infants exposed prenatally to carrot juice appeared to enjoy the carrot juice flavored cereal more than the plain cereal and exhibited less negative facial responses to the carrot juice flavored cereal than did the control group not prenatally exposed to carrot juice. Prenatal experiences with food flavors transmitted from the diet of the mother into the amniotic fluid lead to greater acceptance and enjoyment of these foods during weaning. Hepper *et al.* [13] evaluated whether prenatal experience influenced dietary preference in two groups of children (8 to 9 years old). One group of children was from mothers who consumed garlic during pregnancy, whereas the other group, the control, was from mothers who had not consumed garlic during pregnancy. The dietary test consisted of meals which included garlic-flavored potatoes. Children prenatally experiencing garlic ate more garlic-flavored potatoes than did the control group. Apparently, Rashi (Yoma 82a) was correct, in that *in utero* the fetus experiences flavors sensations, which, if pleasurable, can lead to cravings for specific food items.

Snake gestation

After mating, some female animals store sperm. For example, in Genetics (BIOL 3513) the class works with fruit flies (*Drosophila melanogaster*). Suppose an assignment was to mate wild-type red-eyed male flies to mutant white-eyed female flies. Students are provided with vials of both strains; each vial contains populations of adult male and female flies, pupae (cocoons), larvae, and eggs. All adult flies in the vial

of white-eyed flies cannot be used in the study: the white-eyed males are not needed for the mating and it can be assumed that the white-eyed females have already mated with white-eyed males in that vial. Isolating these white-eyed female flies for use in the mating is pointless, as female *Drosophila* store sperm. The technique calls for removing all adult male and female white-eyed flies from the vial and then waiting for newly hatched adult flies to emerge from their cocoons; newly hatched adult flies do not mate for the initial 8 to 10 hours of adult life. The procedure then requires the isolation of virgin white-eyed female flies which are mated with red-eyed male flies. This concept of sperm storage by females also applies to snakes [14] and may explain the Talmudic passage (*Bechoros* 8a) that the gestational period of a snake is 7 years. A different version of this passage is presented in the *Yalkut Shimoni* (*Bereishis* 3, os 30), in which a gentile philosopher viewed snakes mating, captured females, placed them in a vessel, and fed them. After 7 years of captivity he noted that the female gave birth. As a 7-year gestational period for a snake is highly improbable, this incident may refer to the ability of female snakes to store sperm, thus, explaining the current observation that some female snakes give birth several years after mating [15].

An article in the Science Section of the N.Y. Times [16] described an annual mating evident that occurs between male and female red-sided garter snakes in Narcisse, Mantiboa. Around April/May of every year thousands of these snakes "awaken from an 8-month nap in their subterranean limestone lairs. They tumble about the craggy landscape in tangled knots with a singular focus: reproduction. The males pour out of the dens first and wait for the females to slowly trickle out of the course of a few weeks." The female secretes pheromones that attract dozens to hundreds of males that try to mate with the lone female. One selected male mates and leaves a stinky plug inside the female which serves to ward off other males. "A female can store sperm until she's healthy enough to reproduce." The researcher, Robert Mason, "documented a female snake that gave birth seven years after mating." Apparently, this female stored sperm for several years, eventually resulting in birth of offspring seven years after mating. In addition, Magnusson [17] observed a captive Australian file snake (*Achrochordus javanicus*) that gave birth to a single young after seven years of isolation, suggesting that this species of snake was capable either of prolonged storage of sperm or of parthenogenesis (in which the female gamete develops into a new individual without fertilization by a sperm).

As the society in the era of the Talmud was basically agriculturally-based, *Chazal* obviously were cognizant of the botany and zoology relevant to their environments. From every day observations, they were aware of various species of snakes, noting that some gave birth by laying eggs and others by live birth. It would be incorrect to assume that *Chazal* meant the seven year gestational period to be applicable to all species of snakes. Rather, apparently, they noted an unusual event, a snake which appeared to have a gestational period of 7 years. This seemingly impossible event may have been due to prolonged sperm storage by the female snake, as suggested in the *Yalkut Shimoni.*

Bishul* on *Shabbos

Bishul, the 11th of the 39 *melachos*, is loosely defined as "cooking." As related to Shabbos, *bishul* is the use of the heat of fire to alter the quality of an item, and includes activities as cooking, boiling, frying, baking, and roasting. In the *Mishkan, bishul* was the activity employed to cook ingredients to produce the dyes used to color the wool curtains and tapestries [18]. Fuels for *bishul* were logs and wood-derived coal; during the era of the *Bais HaMikdash*, wood from the fig tree, a nut tree, or an oil tree was preferred (Zevachim 58a). The logs were used in the pyre of the Alter (*Miz'ba'ch*) for burning the sacrifices and the hot coals were used for the incense pyre (Tamid 29a). In the *Mishkan* and *Bais HaMikdash, bishul* was accomplished by fire, scientifically defined as the rapid oxidation of a material in the chemical exothermic process of combustion, releasing heat, light, and various reaction products. The source of the fire in the *Mishkan* and *Bais HaMikdash* was organic matter.

Several passages in the Talmud (*e.g.*, Shabbos 39a, 146b; Pesachim 39a) note that *bishul* on Shabbos was permissible with direct radiant heat from the sun. Rashi (Shabbos 39a) explained that the use of solar radiation is an unusual mode of *bishul* and, thus, was not included in the Biblical prohibition of cooking on Shabbos. Furthermore, the Rabbis saw no reason to prohibit this type of cooking using solar radiation, as nobody would confuse cooking directly in the sun with cooking on a fire. Only the ordinary methods of cooking used in the *Mishkan* were defined as *bishul*;

any other mode of cooking that was not similar to the method employed in the *Mishkan* was not considered to be *bishul* [18].

It is interesting to note a basic difference between *bishul* considered to be a *melacha* and forbidden on Shabbos and *bishul* utilizing solar radiation which is permitted on Shabbos. *Bishul,* as derived from the work in the *Mishkan*, involved the usage of heat released from combustion of organic fuels (logs), whereas *bishul* utilizing solar radiation involves the usage of heat generated from nuclear fusion reactions. The sun, like most stars, is composed of the elements, hydrogen and helium, occurring as plasma (*i.e.*, a hot, ionized gaseous state); by mass, 75% of the sun is hydrogen and 25% is helium. Solar energy is generated by nuclear fusion reactions, in which hydrogen nuclei separate from their electrons and fuse to form helium atoms. During the fusion process, radiant energy is released. Solar energy is a combination of infrared, visible, and ultraviolet light and heat [19].

Between the Earth and the sun, there is a vast vacuum expanse, with no molecules present, which means that solar heat has to be transferred without a medium. Of the three forms of heat transfer, conduction, convection and radiation, conduction and convection require the presence of a medium to transfer heat. Only radiation does not require the presence of molecules to transfer heat and, hence, it serves as the mode of heat transfer from the sun. Of the various wavelengths within the electromagnetic spectrum, it is infrared radiation that can transmit the most heat. This heat warms the planet Earth [19] and it is this heat that can be used for *bishul* on Shabbos.

Ancient civilizations viewed the sun as a giant ball of fire lacking a solid surface [19]. *Chazal*, apparently, were knowledgeable of the difference in the source of heat derived from the sun versus that derived from fire combustion, thereby allowing cooking on Shabbos by heat derived from solar nuclear fusion reactions and prohibiting cooking by heat from the combustion of wood.

Soil volatiles and *kilayim*

A passage in tractate Pesachim (25a) discusses the laws of *kilayim*, loosely defined as "forbidden mixtures," which includes cross-breeding or side-by-side planting of certain food crops and mixtures of the vineyard. "Rav Shemayah cited the Mishnah (Kilayim 7:8) regarding one who transports a perforated pot containing a blooming plant through a vineyard. If it increased a two-hundredth part during the passage, it is forbidden." This is explained as follows: "If the perforated flowerpot has a hole large enough to permit the passage of a small root, the plant inside the perforated obtains nourishment through the air from the ground below and is regarded as having been planted in that ground. Accordingly, if one carried such a perforated pot through a vineyard, it is as if he planted it directly into the ground, thereby creating *kilayim* of the vineyard" [20].

The obvious question concerns how roots emerging from a perforated flowerpot can obtain nutrients from the underlying soil when the flowerpot is carried over a vineyard. The answer may be through gaseous absorption of biogenic volatile organic compounds (VOCs) emanating from the above-ground soil and the grape plants. Apparently, there is an invisible wall (*i.e.*, the atmosphere) of volatile chemicals that connects the ground soil with the soil in the perforated flowerpot. Soil microbes, both bacteria and fungi, and plants, including their roots, stems, leaves, and flowers, undergo many biochemical pathways to produce intracellular chemicals that are released as organic gases, or volatiles. The majority of biogenic VOCs are lipophilic, have a small molecular weight, and a high vapor pressure - all physicochemical features that support evaporation. Biogenic VOCs are released directly into the above-ground atmosphere and within the soil, in which case the gases permeate through air-filled spaces. The most well-known scent emitted by soil bacteria, primarily species of *Streptomyces* is geosmin, which emanates from forest soil to produce the typical earthy odor after a rain. Biogenic VOCs serve many biological functions, including acting as repellants, stimulants, and nutrient sources. For example, root-derived VOCs may (a) serve as carbon and energy sources for neighboring soil microbes; (b) play a role in insect and nematode interactions; and (c) inhibit root growth of competing plant species [21-23]. It would seem that this Talmudic passage is referring to biogenic VOCs released from the above ground soil and grape plants that diffuse into the atmosphere to provide nourishment to the roots of the potted blooming plant being transported over a vineyard.

Concluding remarks

The scientific explanations for the various Talmudic passages cited above are intended to satisfy the curiosity of a *daf yomi* student with a science background. These explanations are neither intended to challenge a specific Talmudic passage nor to contradict a statement of *Chazal*. Rather, these scientific explanations are presented to provide some limited insight into the materials presented in the Talmud. In fact, these observations draw us to a conclusion that *Chazal* had an extraordinary level of scientific knowledge beyond the general science knowledge of the time.

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