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The "*Bitul B'shishim (one part in sixty)*": is a Jewish conditional prohibition of the Talmud the oldest-known testimony of quantitative analytical chemistry?

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Abstract. Accomplishments of Hellenistic science and technology in some fields, such as mathematics, physical cosmology and engineering, has recently been re-evaluated and can be considered as of the same level that the scientific revolution in Western Europe reached at the beginning of the XVII century CE. Information on the level of chemical science is scanty; however, independent ancient sources such as the Jewish Talmud can yield significant clues. The still existing dietary laws include a practice to assess the acceptability of food mixtures with two complementary assessment techniques. One enforces a specific minimum mixing ratio (1:60) of unacceptable-to-acceptable ingredients, the other uses a sensory assessment to exclude the presence of a tasty unacceptable ingredient. This practice is likely the first historical example of quantitative analytical chemistry. This article collects clues that this approach is rooted in the implicit acceptance by Hellenistic chemical science of an atomic paradigm and on the awareness that interaction of different matter yields product that are different from the starting ones. Quantitative assessment of the presence of unacceptable ingredients by sensorial assessment or by mixing ratio likely points to a forgotten practice of Hellenistic experimental pharmacology and physiology to test the efficacy of drugs and poisons, that was performed in animals, with the use of a control group, and on human subjects.

Keywords. Dilution, food contamination, halacha, Hellenism, Jews, kasherut, mixture, Talmud.

1. MUCH EARLIER ANALYTICAL CHEMISTRY THAN ANTICIPATED?

Humankind practiced empirical chemistry since the farthest of times to produce food, materials and market goods,[1] and documental sources report a good deal of recipes since ancient Near Eastern civilizations.[2] Studies of paleo-chemistry and ancient chemistry however suffer from several sources of difficulty. One is the fragmentation and obscurity of documental sources, and the inherent limitation in reconstructing technological achievements of

different cultures over time. However, when the contemporary researcher re-considers and follows in detail ancient recipes, such as those reported in Early Modern "alchemical" documents, the obtained results closely approach the descriptions given by the original Authors, as has been recently documented.[3-7]

Paleo-chemistry (and contemporary chemistry) was more often concerned with manufacturing goods, such as metals and alloys, dyes, medicinal drugs and poisons,[1] rather than with the intellectual effort to understand the properties of matter. Miners often performed assays for metals in ores and alloys, and the composition of ancient pharmaceutical preparations manufactured from mixtures of individual ingredients (each of which needed to be authenticated, especially when it came from remote locations) is often reported in quantitative terms [8]. However, very little is known on the assays, if any, that were employed to identify raw materials and to check their adequacy to specific purposes, such as the integrity of metals, the composition of alloys, of food, drugs, dyes and perfume, an activity that tantamount to analytical chemistry. Among the few reported "analytical" methods is the assay of metal ores by cupellation. This technique allows to concentrate precious metals, such as gold and silver, from ores by a solid-liquid extraction into low-melting lead, followed by recovering the precious metal(s) from the latter, more easily oxidized metal, by ashing the metal button in air.[9] The described "analytical" method thus essentially corresponds to a small-scale preparation, and weighting in a scale is the final method of measurement.[10]

Seldom are a very small number of material documents, such as the residues of old-time equipment, vessels, raw materials and preparations found in archeological studies and only very recently some could be compositionally characterized.[11-13] The only clue that in the Antiquity an assay was used to detect a specific component in a mixture is the detection of Iron in biological fluids with the use of the extract of oak gall.[14,15]

The lack of information on other chemical analyses is not surprising, since also the contemporary discipline of analytical chemistry achieved a distinctive status within chemical sciences much later than the traditional branches of mineral (inorganic) and organic chemistry, and of *materia medica*, the forerunner of pharmacology, toxicology and medicinal chemistry. Methods for chemical analysis of minerals, *i.e.*, to distinguish the different simple constituents and to identify new chemical elements were published as early as the early XVII century, even in the lack of a consistent theory on the composition of matter and of an operative definition of what a "simple" chemical body, *i.e.*, a chemical element is. It is only in 1861 that the renowned independent analyst Carl Remigius Fresenius founded the first scientific journal specifically dedicated to analytical chemistry as an independent discipline.[16] Only in the 1940s the most authoritative of contemporary scholarly journals of analytical chemistry, the Analytical Chemistry of the American Chemical Society, gained an independent status, formerly being since 1929 a supplementary issue of the Society's magazine of industrial chemistry.[17]

2. A REAPPRAISAL OF HELLENISM: THE BOOM AND THE DOOM.

Hellenism is the period of Mediterranean history that stands between Alexander the Great's death in 323 BCE and the battle of Actium in 31 BCE that ended the Ptolomean rule of Egypt. Historians have long considered this as a ripe age with little real intellectual achievement, when compared, on arbitrary terms, with the previous Classical period of Greek history that established as paradigm of Western European culture. Among prejudices on this period is that according which abundance of human slave workforce caused a limited interest in mechanization of work, and the consequent lack of a developed production economy. The Old Mediterranean and Greek-Romans thus failed to understand and exploit the natural world. The missed opportunity to develop the budding knowledge into a "modern" framework also led to the withdrawal of some intellectual achievements of early Hellenism that actually foreran those of the Early Modern age. In particular, this is exemplified by the fact that Ptolemaic model of geocentric universe overcame the Aristarchus' heliocentric one, Galenic medicine mostly cancelled Herasistratus' physiology, and Archimedean mechanics only found limited exploitation in devices, such as those later described by Heron.[18]

On the contrary, a very recent re-interpretation of the surviving Hellenistic and later texts and of material artefacts indicates that the intellectual development, scientific and technological advancement at the peak of that period was at the same level that Modern Western Europe only reached in late Renaissance and Early Modern age. One main scholar to initiate this innovative interpretation, Lucio Russo, reconstructed some parts of the "lost knowledge", mainly in the fields of geographical physics, cosmology and astronomic navigation.[18-20]

A real intellectual *Boom* occurred between the III and II centuries BCE with the establishment in the recently founded Alexandria of the Museum and Library by Tolomy II Eupator.[21] Other Hellenistic kingdoms followed, such as the Attalids in Pergamon (to tackle an

ante-litteram embargo to the export of papyrus as the substrate for writing, the use of parchment was locally boosted), the Seleucids in Syria and Babylon, and elsewhere in the *koiné*, for which information is much more limited.

The abrupt geo-political *Doom* of the Hellenistic civilization occurred in the mid-II century BCE, with the almost contemporary destruction of Corinth and of Cartago in 146 BCE. Just a few years later, the anti-Greek Alexandria *pogrom* sponsored by Ptolemy III Euergetes in 137 BCE caused the migration of the luckiest scholars to safer remote places. The wholesome destruction of the main intellectual centers of the time determined a break in the transmission of knowledge, surviving scholars relocating to safer areas in the Eastern Mediterranean, in Syria and further eastwards to Bactria and Maurya India. Scholars in the quieter I century CE and later strove to revive the mostly interrupted intellectual activity, but were no more able to recover the loss, and most scientific advancements in applied mathematics, astronomy, geography and navigation, in natural sciences and medicine faded into oblivion, due to the inability to reconstruct the underlying methodological and theoretical framework.[22]

Ancient knowledge in "empirical sciences", such as in medicine and chemistry, cannot be as easily reconstructed, due to the loss of most original sources, and to the corruption of residual information that could not be understood any more in *post-Doom* times.[22] In the field of chemistry, Greek and Hellenistic scholars had conceived a rationally based precursor of the current atomic-molecular model of the composition of matter as early as the V century BCE, building on the first intuitions of Democritus, and progressively developed by Aristotle, the Epicurean school, Crisippus and the Stoic school.[22] After the *Doom*, the tenets on which the budding theory of matter composition had been developed were abandoned, purportedly for their sheer materialistic content. As in other disciplines, such as the drift of Hellenistic physical astronomy into astrology, the remnants of that knowledge merged with other philosophical and religious traditions, and evolved into alchemy.[23,24] Likely, the practical contents that dealt with manufacturing high-tech materials, such as imitation gems and gold-looking alloys, dyes, pigments, perfumes, pharmaceutical drugs and poisons, faded into the practical recipes which artisans transmitted through oral tradition, in a social environment that now was well detached from the shrinking population of educated scholars.

However, it is conceivable that some "fossil" knowledge of the *Hellenistic boom*, and especially its quantitative applications, was already embedded as common discourse in sources that have been so far untapped, and that their exploration can yield new insight on their knowledge in the other fields.

3. "FOSSIL" INFORMATION FROM AN OLD MEDITERRANEAN PEOPLE.

One possible, and so far little examined, source of information is the Talmud, a written compilation of discussions in the application of Hebrew religious Law (*halacha*) to everyday affairs that was elaborated in Roman Palestine (*Talmud Jerushalmi*) and in Parthian Babylonia (*Talmud Bavli*)[25] from the III to the VI century CE. *Halacha* developed from the normative books of the "written Torah" (*Torah she-bi-khtav*, the Pentateuch of the Old Testament) and on the "oral Torah" (*Torah Sheba'al Peh*), the sources of which were rooted at least four centuries earlier.[26,27] The exploration of Talmud unveils earlier knowledge science and technology, encompassing – in contemporary terms – animal and human anatomy and physiology, chemical technologies,[28,29,30] statistics[31,32] (including the earliest-known description of random sampling: Chullin 4a), risk prevention and management.

One peculiar aspect of *halacha* is the enforcement of several alimentary *taboos*, some of which – such as abstinence from pig – are so well known as to become symbolic and even a synecdoche of the Jewish identity to the other peoples. The main primary sources of information for the Jewish dietary rules are the Torah (in particular, Deut. 14:1-26 contains the well-known compilation of allowed and forbidden animals for food), the Talmud and a much later compilation, the XVI century CE *Shulchan Aruch*.[33] that summarized halachic rules as enforced by Sephardi Jewry in the Mediterranean area. Several treatises of the Talmud report the very complicated rules on inacceptable (*issur*) and acceptable (*heter*) food and on mixtures, such as in *Chullin* (most *loci* that are especially pertinent to this essay are between 82a and 98b; *v. infra*), and related information occurs in treatises that discuss other sources of material impurity. The topic is of a great importance to practicing Jews down to present times.[34]

Among the lesser-known food regulations are discarding the sciatic nerve (*gid hanasheh*) from the thigh of ritually slaughtered animals, completely removing fat from the slaughtered carcass, and completely draining meat from blood, the ban to mixing meat and milk in food (*basar be chalav*). In particular, the Torah states thrice the *basar be chalav* prohibition (Es. XXIII, 19 and XXXIV, 26; Deut. XIV, 21), that was unknown before

Moses' Covenant was established (in the Book of Exodus), since Abraham offers to the three Visitors meat cooked in sour milk (Gen. XVIII, 7-8).

> Es. XXIII, 19. "Bring the best of the firstfruits of your soil to the house of the LORD your God. "Do not cook a young goat in its mother's milk.
> Es. XXXIV, 26. "Bring the best of the firstfruits of your soil to the house of the LORD your God. "Do not cook a young goat in its mother's milk."
> Deut. XIV, 21. [21] Do not eat anything you find already dead. […] Do not cook a young goat in its mother's milk.
> Gen. XVIII, 7-8. [7] Then he ran to the herd and selected a choice, tender calf and gave it to a servant, who hurried to prepare it. [8] He then brought some curds and milk and the calf that had been prepared, and set these before them.

The *gid hanasheh* prohibition comes earlier in the Torah, since it links to Jacob-Israel's fight with the Angel, who left him lame for life (Gen. XXXII, 22-31).

> Gen. XXXII, 22-31. . […] [25] When the man saw that he could not overpower him, he touched the socket of Jacob's hip so that his hip was wrenched as he wrestled with the man. […] and he was limping because of his hip. […]

The *basar be chalav* prohibition had no apparent explanation since the most ancient times of Jewish culture, and therefore the religious authorities expanded its application in order not to infringe the ban.[35] In general, to avoid cross-contamination of mutually incompatible food ingredients, separate sets of pots are used, and ritual cleaning with water or on fire is performed.[34]

These food-mixing bans, however, admit an exception to thrashing the forbidden food mixture, in the case mixing of forbidden ingredients occurred by accident. In this case, to test whether the mixture is still admissible as food, two complementary routes are available. One states that if the contaminating ingredient is present in a proportion that is less than one-sixtieth of the main one (*bitul b'shishim*: one part in sixty), the food is still *kosher* (ritually acceptable). Another possibility is that if the contaminant does not impart to the mixture its distinctive properties of taste (*ta'am k'ikar*: the taste is equivalent to the substance), the food is still acceptable.[34]

Both approaches are so familiar to a present-day regulatory chemist or toxicologist, as to remind other similarly "modern" Hellenistic accomplishments that are considered as "anticipating" contemporary views in mathematics, in astronomy, in mechanics, in natural sciences.

The *bitul b'shishim* "*one part in sixty*" approach closely resembles the contemporary practice of toxicological risk assessment, whereby the presence of a contaminant is compared to an enforced lower limit, and decision upon acceptability is taken consequently.

The *ta'am k'ikar* "*the taste is equivalent to the substance*" approach corresponds to the use of a sensorial assay, and is similar in principle and setup to what is nowadays performed for similar applications. In particular, it is requested that an unaware, extraneous assessor (the *akum*, a Gentile) taste the mixture for absence/presence of the undesired ingredient (in modern terms, a *blind test*). The use of a *biological response as endpoint* foreruns the now abandoned approach to limit setting for airborne industrial solvents that was in use in the former Soviet Union, based on the measurement of evoked electrophysiological potentials triggered by body exposure to exogenous substances.[36] The criterion whereby acceptability comes when the unacceptable component is *no longer perceived* is again a forerunner of the ALARA (As Low As Reasonably Achievable) principle that is adopted in radio-protection and in the management of environmental and occupational risk from carcinogenic chemicals.[37] *Nihil sub sole novi* (Qohelet, 1,9).

The Jewish normative texts (several *loci* in *Chullin*, *e.g.* especially between 89b and 120a; *Shulchan Aruch's Yoreh De'ah*, several *loci*; *see* Appendix) describe in much detail the transmission of the off-flavor of unacceptable substances from a contained liquid or solid-in-liquid to the container, or from an unexpected and not allowed contaminant to the bulk of food. Both ancient texts correctly identify as the determinants of the process: temperature, contact time, the nature of the liquid, that of the material and the surface-to-bulk ratio of the immersed solid and the material of the container, and enforce consequently the halachic rules. Those reported below are just a few examples that describe both assessment strategies.

> **Ch. 89b chap. VII:** […] If a thigh was cooked together with the sciatic nerve it is forbidden if it imparts a taste [into the thigh]! (Note 11: I.e., if the thigh that was cooked was not sixty times greater than the forbidden nerve; for the Rabbis have estimated that if there were more than sixty parts of permitted matter as against one part prohibited, the latter cannot impart a flavor unto the former.) […]
> **Ch. 96b chap. VII:** MISHNAH. IF A THIGH WAS COOKED TOGETHER WITH THE SCIATIC NERVE AND THERE WAS SO MUCH [OF THE NERVE] AS TO IMPART A FLAVOUR [TO THE THIGH], IT IS FORBIDDEN. HOW DOES ONE MEASURE THIS? AS IF IT WERE MEAT [COOKED] WITH TURNIPS (Note 7: It is estimated by the Rabbis that meat cannot impart its taste to any substance that is cooked with it if the latter is sixty times as large in bulk as the meat.).

Ch. 97a,b: […] the Rabbis ruled that one may rely upon a [gentile] cook, and yet [in other cases] the Rabbis ruled that the test is sixty [to one]. Therefore we say, where substances of different kinds, each kind being permitted by itself, were mixed together, the test is whether or not one imparts a flavor to the other; 1 and if one of the substances was forbidden 2 then we rely upon the opinion of a gentile cook. […]
Ch. 97b: […] R. Nahman said: The [sciatic] nerve [is neutralized] in sixty-fold, but the nerve itself is not to be included to make up this number. (Note 14: I.e., there must be sixty times the volume of the forbidden nerve.) The udder is neutralized in sixtyfold, but the udder itself is to be included. (Note 15: If an udder which was not emptied of its milk was cooked together with meat, the entire contents of the pot would be forbidden unless there was in the pot sixty times as much as the milk of the udder. (The quantity of milk in the udder is regarded as equal to the volume of the udder). Now the udder can also be included to make up this sixty-fold since it is not the udder that is forbidden but only the milk contained in it. In other words, there must be in the pot fifty-nine times the quantity of the udder; v. infra ***109a***.) An egg (Note 16: Of an unclean bird which was boiled with eggs of clean birds.) is neutralized in sixty-fold, but the egg itself is not to be included.

……..

It is apparent from the reported excerpts that both assessment practices: *bitul b'shishim* (one part in sixty), and *ta'am k'ikar* (the taste is equivalent to the substance) correspond to the likely earliest example of a quantitative analytical chemical assay. It is worth considering that no information on a corresponding quantitative approach is anywhere found in survived texts of Greek, Hellenistic and Greco-Roman technology.

The particular dilution factor most commonly considered as upper limit for halachic acceptance, 1/60 (*approx.* 1.6%, or 98.4% pure), matches that which is also nowadays a useful threshold for the presence in a "technical grade" product of undesired contaminants or off-products, which are devoid of particular concern such as toxicological or microbiological health risk. This level is also close to the minimum detectable amount of some tests designed for the detection of adulterants in food, such as the late XIX-century Villavecchia-Fabris test that discriminates edible from industrial vegetable oils purposely adulterated with 5% sesame oil.[38]

It may thus be of an interest to understand whether this approach to quantitative chemical analysis might come into the Talmud deriving from Hellenistic chemical conceptions, to fulfill a specific halachic task. In a complementary way, this notion, which is contained in an early-CE text and the roots of which may well extend several centuries before, may be a clue to reverse-understand the nature and level of Hellenistic concepts on the composition of matter and on the relationship with other fields of natural science. As such, this interpretation suffers from lack of sufficient internal evidence, and may generate a circular argument. However, even if the practice of "alternative history" may quickly lead to fictionalized accounts, nevertheless by adopting some rules to control the construction of scenarios the voids in documentation can be credibly filled to re-create plausible descriptions of past events.[39]

4. ALEXANDRIA, ANTIOCHIA AND PERGAMON: MEDITERRANEAN BRIDGES BETWEEN HELLENISM AND JUDAISM?

A significant cultural interaction of Greeks and Jews developed starting in the IV century BCE, encompassed the early and late Hellenism, the Roman suzerainty and final conquer of Palestine, the Diaspora and continued after the fall of the Roman Eastern and Byzantine Empire to the Parthians and the Sassanids.[40,41] Briefly, and to the aim of this reconstruction, it is conceivable that some elements of Hellenistic knowledge in natural science and medicine outpoured into Hebrew halakhic discourse that developed in the "oral phase", even before the discussions started to be registered in writing as the Mishnah and Gemara, at the beginning of the III century CE. The Talmud and its earlier Judaic sources in fact contain several items that have long been recognized as of a likely Hellenistic origin.[42] Some Talmudic knowledge may thus represent one of the few remnants of lost Hellenistic science and technology that developed and was commonplace *before the Doom* in Ptolemaic Egypt, in Seleucid and Hasmonean Palestine, and in the Hellenistic kingdoms of Anatolia, mainly those of Pergamon and of Bythinia, and did not survive in the transmitted body of text of the Greco-Roman world.

As for the plausibility of this scenario, it is widely accepted now that, in several fields, Jews who were in contact with the Greek and Hellenistic environment reinterpreted Greek and Hellenistic knowledge, or just the cultural suggestions that their neighbors spread.[43]

There were one thousand young men in my father's house, five hundred of whom studied the Law, while the other five hundred studied Greek wisdom.

To further appreciate the possible degree of interaction of Palestinian Jews who had a role in setting the *halacha* with the contemporary Hellenistic culture, we may recall a famed Talmud episode (Shabbat, 31a). As known, the rigorous Talmud Master Shammai […] *repulsed him* (the curious Gentile who sought for instant

information on the intricacies of the Jewish faith) *with the builder's cubit, which was in his hand* […]. Shammai was a wealthy architect in I century CE Palestine, the cubit was in fact a measuring ruler, a rather sophisticated professional device akin to those in use by technicians and calculators as far as the 1980s, and his professional training very likely included elements of knowledge that was of Hellenistic derivation.

A clue that Greek and Hellenistic philosophy was at least known to educated, if observant Jews of the early Talmudic era is the use of the term "*apikoros*" to grossly indicate a secular thinker who negates most or all the tenets of Judaism, or of any revealed religion for the good. This word first occurs in rabbinic literature in the Mishnah (Sanh. 10:1),[44] and derives from the IV century BCE Greek philosopher Epicurus, who advocated a materialistic explanation of the world and the pursuit of a quiet happiness through vegetarianism and abstention from greed and violence.[45]

> Q. Horatius Flaccus, Epist., I, 4, 10. […] Me pinguem et nitidum bene curata cute vises, / cum ridere voles, Epicuri de grege porcum. (*If you ask of myself, you will find me, whenever you want something to laugh at, in good case, fat and sleek, a true hog of Epicurus' herd*.)
> D. Alighieri, Commedia, Inf. X 13-15. Suo cimitero da questa parte hanno / con Epicuro tutti suoi seguaci, / che l'anima col corpo morta fanno. (*In this place Epicurus and all his followers are entombed, who say the soul dies with the body.*)

Epicurus is the only Greek philosopher who is explicitly mentioned in the Talmud, while there is no mention of the competing Stoic school.

> **Sanh. 10:1.** […] But the following have no portion in the World to Come: He who says that resurrection is not a Torah doctrine, the Torah is not from Heaven, and an apikoros [who denigrates Torah and Torah scholars] . Rabbi Akiva adds: One who reads from heretical book […] http://www.emishnah.com/PDFs/Sanhedrin%2010.pdf

During the Hellenistic period, there was an increased opportunity for Jews to spread, especially in Anatolia, where Attalus III and Mithridates VI favored the transferred of a large body of Jewish settlers.[46] It is conceivable that some immigrants belonged to socially educated strata[47] and may transmit knowledge and suggestions to the still vital Jerusalem center, possibly in the occasion of pilgrimages to the Temple.[40] Given the advancement of agricultural, pharmacological and toxicological studies of natural substances in the Anatolian Hellenistic kingdoms, in Seleucid Babylon and in Ptolemaic Egypt,[48,49,50,51,52,53] it is conceivable that such information may reach Palestine through multiple routes.

5. AT THE CORE OF THE ISSUE: FROM DRUG TITRATION TO ISSUR ESTIMATION … AND BACKWARDS.

That the late Egyptian Pharaoh's court was likely interested in experimentation at large is witnessed by the Greek historian Herodotus (?485-425 BCE). As reported (*Historiai*, Part 1, Book 2, paragraph 2) Psammetichus I (664-610 BCE) had a baby raised without hearing any spoken language, in the earliest recorded psychological experiment, to determine whether human beings have an innate capacity for speech, and if so, which particular language is innate.

Medical studies flourished in Hellenistic Alexandria and in other cities, and eventually developed into "research-oriented" anatomical and physiological studies.[54] Reportedly, Herasistratus was the first able to differentiate motor from sensor nerves by experiments that would not be possible to perform in animals or in dead human bodies, but only in living humans.[55,56] The argument of their cruelty was used by early Christian polemists, such as Tertullian, against paganism;[57] however, the *querelle* over whether Herasistratus really performed such experiments continues.[58]

A little exploited information to support the likeliness of the information comes from the Talmud treatise on womanly issues (Niddah, 30b), which reports that Cleopatra VII of Egypt performed systematic experiments on human fertilization, likely including the use of contraceptive drugs, forced timed intercourse mating and surgical abortion.

> **Niddah 30b.** […] A story is told of Cleopatra the queen of Alexandria that when her handmaids were sentenced to death by royal decree they were subjected to a test (note 23: Fertilization and subsequent operation) and it was found that both [a male and a female embryo] were fully fashioned on the forty-first day. […] They were made to drink (note 31: Before they were experimented on), a scattering drug (note 32: i.e., destroying the semen in the womb) […]. A story is told of Cleopatra the Grecian queen, that when her handmaids were sentenced to death under a government order they were subjected to a test and it was found that a male embryo was fully fashioned on the forty-first day and a female embryo on the eighty-first day.

As for the availability of the needed experimental tools, detailed knowledge of human fertility is well documented in Pharaohs' Egypt. The Berlin Papyrus of 1.350 BCE witnesses the knowledge and application of tests to assess pregnancy, based on the stimulating effect of pregnancy hormones excreted in urine on the germination of corn and barley seeds,[59,60] and a later

one (papyrus Kahun[61,62]) uses swamp canes to the same purpose. There is clue that those ancient claims are even supported by empirical evidence.[63,64]

Due to the use of deliberate poisoning as a weapon in political struggle in the Hellenistic period (and later), efficacy studies on drugs and poisons were much developed, especially in the kingdoms of Bithynia (by Mithridates IV) and Pergamon (by Attalus III).[48-54] The high level of knowledge on toxic poisons and their antidotes calls for the use of systematic experiments, reportedly performed even on humans, such as slaves and convicted criminals, as witnessed by several nearly contemporary testimonies, especially regarding the former character.[39] It is conceivable that an assessment of the desired level of activity of concoctions (deadly toxic, or sub-toxic, "*Mithridatic*") should be performed, if the preparations were to be reliably used to their intended purpose. The II century CE pseudo-Galen text *Theriaca ad Pisonem* contains an important testimony to this practice, whereby the efficacy of a preparation against venomous animals is tested on animals, with use of a control group, but there is no clear indication that specific doses of the *pharmakon* were administered.

> 10R […] we being unable to test it on men do the same on certain other living beings and try to arrive at a true verdict on the drug. So we take cocks – not those that live with us under the same roof, but rather wild ones, and with a rather dry constitution, and we put poisonous beasts among them, and those who have not drunk theriac die immediately, but those who have drunk it are strong and stay alive after being bitten. […] (*Theriaca ad Pisonem*, ch. 1;10)[8]

It is here that the knowledge embedded in the Talmud's *bitul b'shishin* likely comes forward as a neutral witness.

It is conceivable that activity titration of *pharmaka* was possibly performed by testing the effects of progressive ("scalar") dilutions according to definite proportions,[65,66] an approach that would eventually re-surface in the XIII-XIV century CE, when the Montpellier medical school re-discovered the same principle from the al-Kindi treatise *Quia primos*.[67]

The measurement systems in the ancient world are difficult to reconstruct, since there were differences among regions and over time.

As witnessed also in the Talmud, several different scales were simultaneously in use, in particular the sexagesimal, decimal and binary ones. The binary, harmonic or Pythagorean scale ($1/2^n$, *i.e.* denominators in the sequence 1:2:4:8:16:32:64, and so on; Figure 1) is used still today for the same purpose. Dilutions with this scale are very easy to prepare and ensure a tight control over the concentration of the proband substance, since variation occurs by halving the preceding dilution. Moreover, such relative scale allows comparing the strength of different preparations, even when the actual quantity of the active material in a complex mixture is unknown and consistent units of measure may not be available. In fact, this is the case of natural extracts, and until the very recent advent of physico-chemical techniques for separation, identification and quantification of complex mixtures, this was the way to titrate biological drugs such as insulin.[68]

The actual correspondence to contemporary standards of the Talmudic units of measure and their mutual conversion is a matter of current controversy, since it occurs not only the realm of antiquary sciences and archeology, but also has a value for the enforcement of *halacha*. Not only the names and size of units changed over time and varied between different places, but also the scales used to build multiples were heterogeneous and often ill defined. The Talmud reports different and partially overlapping measures of volume for liquids and for dry (grain).[69] The *kav* (around 1,22 L; used for both dry and liquid) is the basic unit from which others are derived. The *log* (around 0.306 L; Lev. 14:10)

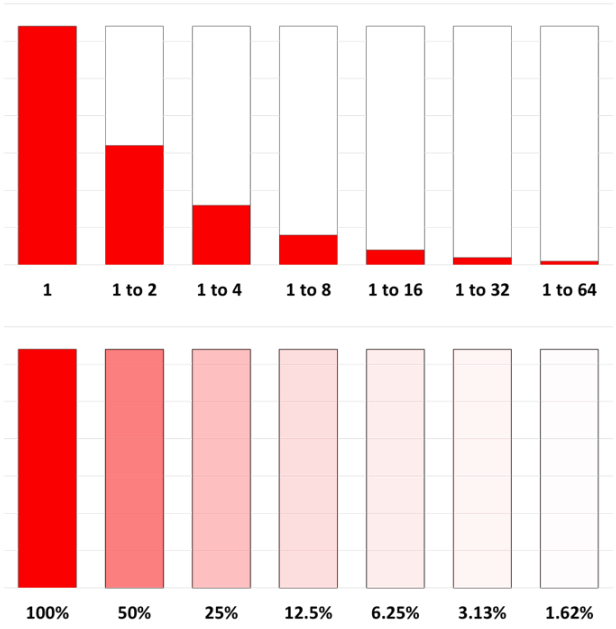

Figure 1. Scalar dilution of a concentrate (red) active substance in a solvent (white). Seven progressive dilutions are shown, starting from the mother liquor and ending with the sixth (1/64). The panel above shows the exponential decrease of the concentration form the arbitrary level of "one unit" to that corresponding to the sixth dilution. The fading of color of a solution subject to the progressive 1:2 dilution is exemplified in the panel below.

corresponds to the Babylonian *mina* and the Talmud mentions half-logs and quarter-logs, as well as eighths, sixteenths, and sixty-fourths of a log (a *kortov*). Liquid measures include a *hin* (around 3.67 L), ½ *hin*, 1/3 *hin*, ¼ *hin*.[70]

As for the dilution factor of one to sixty that is reported in the Talmud (only a slight difference, in real terms, from 1/64), it may be recalled that the number 60 is the base of the Babylonian sexagesimal system, the one that is still tenaciously in use to divide time and to measure angles. The Babylonian *maris* has multiples by the factors of 12, 24, 60, 72 (60 + 12), 120, 720, and a sub-multiple, the *shekel*, as 1/60 of a *mina*.

The number 60 has prime factors $2^2 * 3 * 5$ and 12 integer divisors; it is also the product of the numbers of the fundamental Pythagorean triplet (*i.e.*, $3 * 4 * 5 = 60$, and $3^2 + 4^2 = 5^2$). A 3:4:5 Pythagorean triangle has a perimeter of (3+4+5=12) units, and the sides differ from one another by one unit (5-4 = 4-3 = 1). Early Babylonian calculators knew the arithmetic properties that make this device among the most useful for field measurement. It is held that Pythagoras only reported and possibly demonstrated as a theorem what amounted to a long known empirical practice that had found wide application in land allotment and building (Figure 2).[71]

Given the possibility of Hellenistic technology to build finely machined devices, such as the Antikythera astronomical clock,[72] it is as well conceivable that a Pythagorean triplet might be used as reference to manufacture or carve a matching pair of containers, the larger of which exactly contains 60 times as much as the smaller one, as illustrated in Figure 3.

What may be conceived from the specific value of "*sixty*" for the denominator in the Talmudic criteria of *bitul b'shishim* is that, in the early Ptolemaic times, some Alexandrian experimental physicians performed pharmacological activity tests of medicinal preparations through scalar dilution in the geometrical proportion.[65] Some of Herophilus' disciples and followers, such as Mantias and Apollonius Mys, were reportedly pharmacologists,[54] and Galen recognized the former as being the father of the "compound drug" tradition, while the latter is the main source of Galen's *On the Composition of Drugs according to Places* (XII Kuhn). Dioskorides Phakas, allegedly a relative of Cleopatra VII Philopator, is credited as the first to use a color test to detect iron in biological fluids.[15]

At some time, *poskim* (Jewish assessors) who were acquainted with this method started to apply it to the assessment of food according to *halacha*. They came to determine that an eight-fold scalar dilution ($1/2^6 = 1/64$, or » 1,6%) was sufficient to lose the taste of some tasty, yet unacceptable ingredient, such as *chalav* (milk) in *basar* (meat) and vice-versa, and *gid hanasheh* (sciatic nerve in halachically slaughtered calves; *see* above).

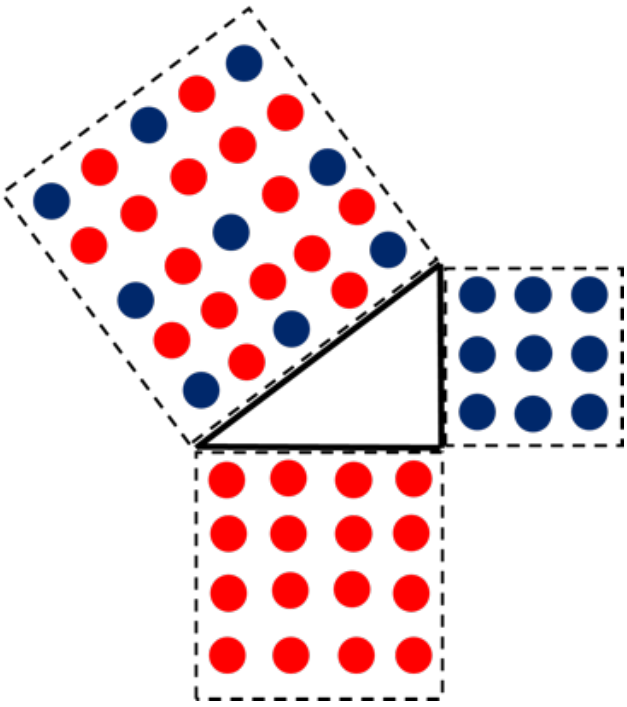

Figure 2. A chessboard that shows the empyrical derivation of the so-called Pytagora's theorem on right triangles and the existence of the Pytagoric triplet 3,4,5.

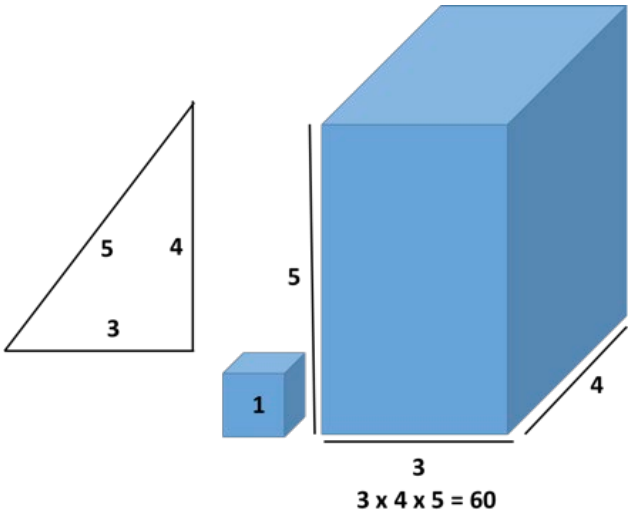

Figure 3. Relationship of two solids (containers), the larger exactly 60 times as much as the smaller, built as a unit-side cube (the smaller, acting as the unit-volume) and as a rectangular prism with sides in the 3:4:5 ratio of the fundamental Pythagorean triplet (the larger).

The detailed intellectual basis of this method might go lost at the time of the *Hellenistic Doom*, or even later, due to the loss of the trans-generational continuity of knowledge transmission in science and technology. What possibly resisted within the halachic tradition was the recollection of the use of a sensorial assessment to test for unacceptable food mixtures (*taam k'ikur*), and an approximate appreciation of a generic acceptance threshold value (*bitul b'shishim*). The one-to-sixty ratio was the closest when the 1:2 geometrical scalar dilution and the Babylonian system of multiples of the *mina* were compared, and so this specific value was consolidated some time during the formation of the Talmud. Such consolidation might occur in Palestine or in Babilonia, due to the exchange of scholars since the most ancient Hillel and Shammai time [73], but only in the *Bavli* there is a *Chullin* treatise concerning food. The Jewish community of Alexandria did not develop an autonomous halachic tradition and referred to Palestine (Niddah 69b) until its dissolution following the 115-117 CE revolt under Trajan. However, they shared with the Palestinian Masters several intellectual skills in the field of textual interpretation[74] [*e.g.* p.66] and in mechanical technology[74] [*e.g.* p.66].

> **Niddah 69b:** Our Rabbis taught: Twelve questions did the Alexandrians address to R. Joshua b. Hananiah. (Note 33) Three were of a scientific nature, (Note 34: Lit., 'the way of the earth', worldly affairs) three were matters of aggada, three were mere nonsense and three were matters of conduct.

This explanation can be strengthened by considering that the Talmud Masters did not always accept as such any of the two possibilities to enforce *kasherut* on mixtures, and in particular highlighted the difference between mild-tasting prohibited ingredients (the *basar b'chalav*) and strongly tasting ones, such as spices (*tavlin*), some of which may be halachically prohibited[34] [*passim*].

6. SENSORIAL ASSESSMENT AND SENSORIAL THEORY: AN IMPLICIT ACCEPTANCE OF ATOMISM?

The criteria of *bitul b'shishim* (*one part in sixty*) and of *taam k'ikar* (*the taste imparts identity to the substance*) represent two coordinate and complementary strategies for halachic food assessment that closely resemble contemporary approaches to regulatory food toxicology. As highlighted above, the first option is more akin to "*assessment by modelling*" in that estimation and calculation is employed to decide the *heter vs. issur* issue. The second option necessarily resorts to "*assessment by measurement*" and employs a biological sensor as the measuring device of a physico-chemical phenomenon: such is, in fact, the action of tasting. That chemical analysis owes to sensorial assays its beginnings is apparent from the etymology itself of the terms employed to describe its operations. *Test*, *saggio* (in Italian), *assay*, all derive from the sensorial assessment performed through the mouth: to taste, *assaggiare*; the wise (il *saggio*) is the man who knows by personal appreciation, who has learnt to distinguish the taste of salt, il *sapore di sale*, from that of other substances.

The very possibility to use taste as an assessment technique, as in the case of food *halacha* by *taam k'ikar* is not only rooted in human common sense, but is implicitly founded on a sensorial theory, and in turn on an underlying theory of matter. It is here that *halacha* shows its likely derivation from previous (*i.e.*, Old Mediterranean) methods of assessment of the strength of preparations with sensorial or biological activity, such as of tasty spices or pharmacologically active preparations. Information in the Talmud may thus shed light on the prevailing theory of matter in Hellenistic time, and possibly on its evolution or transformation over time, down to the Late Middle Age.

It is generally accepted that non-atomistic theories developed by Aristotle and his successor Theophrastus, were largely prevalent, while Democritean atomism did not develop beyond the imaginative level depicted in the Epicurus-Lucretius tradition. The Aristotelian four-element, four-quality theory was fully exploited in several branches of knowledge, in particular as the foundation of the four-humor physiological model that was the mainstay of the Galenic medical thought for the best of the following fifteen centuries.[75,76] In turn, its application to *materia medica* classified remedies, such as spices and herbal medicines, according to their purported qualities (hot-cold, humid-dry) and attempted to assign to each herb the nature of the qualities and a semi-quantitative appreciation of the respective strength, as "grades" in a cardinal scale.[4]

The overall Aristotle-Theophrastus sensorial theory (*de Sensu*; *de Sensibus*)[77,78,79] classifies the five senses into three groups. The first group of senses includes sight and hearing, and, in both cases, no physical contact occurs between the sensing organ and the object from which the stimulus originates. The second group includes touch, for which the interaction of the receptor with the stimulus is of direct physical contact. The third group includes smell and taste, the nature of which is somewhat ambiguous, and the interpretation of which by Aristotle and Theophrastus is uncertain, but like-

ly foreruns the contemporary, physiologically correct receptor-agonist theory and identifies the transporters of the stimuli of taste and smell as material entities that diffuse from the object to the organs of sense [80,81,82]. Although Aristotle and Theophrastus did not adhere to atomism, nevertheless, the sensorial theory of smell and taste as such is only justified as long as the transporters of the stimulus are of a material constitution (and so are the matching receptors).[83,84] Furthermore, a law according to which the strength of the stimulus is directly proportional to the quantity of the transporters of the stimulus holds, and by consequence the weaker the stimulus, the weaker is the presence of the substance.

It is thus conceivable that the logical bases for halachic rules such as *bitul bitushin* stem by a more or less direct intellectual route from familiarity with, and the acceptance of Greek or Hellenistic knowledge by the Masters of the Talmud, in a field that we may now consider at the merge of physical chemistry and physiology. Several *loci* of the Talmud where medical knowledge is instrumental to solving halachic issues show that Greek-Hellenistic medical theory was pragmatically accepted and re-elaborated according to need.[85,86,87]

Another strong clue that the theory of matter implicitly accepted by the Masters of the Talmud is corpuscular and atomistic is the strong attention that the Talmud gives to the regulation of the halachic status of (food) mixtures. This includes the transport of the status of substances to vessels and through vessels to other (food) substances, caused by absorption-desorption phenomena (*ta'am balua*, absorbed taste). In particular, the transmission of taste is fastidiously related to parameters of time (one day, *ben yomo*, or more than one day, *eino ben yomo*), temperature (sparking hot, *libbun gamur*), physical condition and comminution of the interacting substances (*chaticot*, pieces or *lach*, liquid mixture) and the material of the containers (essentially pottery, metal or glass). To get rid of the prohibited *ta'am*, decontamination with either hot water (*hagala*) or with fire (*libbun*) is prescribed, according to the nature of the *issur* and of the container.[34 [*passim*]]

The XVI century CE *Shulkan Aruch* treatise summarized most food-related *halacha* in the *Yoreh De'ah* section (*see* Supplementary), with reference to the original Talmudic source and to the later elaboration of the main Middle Age commentators (according to the Hebrew time scan, the Geonic and Rishonic period). The closest earliest similar observation to that reported in the XVI century *Yoreh De'ah* occurs in Vannoccio Biringuccio's treatise on metals (*De la pirotechnia*, 1540), with just the plain observation that bulk metal takes more time to dissolve than comminuted one. More strikingly, the phenomenological basis and fundamental laws of mass-transfer and chemical kinetics only became apparent in the late XIX century (CE!), when investigation on catalysis in organic chemistry started and the laws of absorption-desorption, enzyme kinetics and dose-response were rationalized.

There is an even more sophisticated issue in the Talmud that may hide a fossil notion of a Hellenistic theory of matter transformation (*i.e.*, of modern chemistry).

Cooking entails the (irreversible) transformation of some components of food into others with different characteristics, such as taste, smell or texture, and halachic status, as well. In particular, a regulation considers that two different (food) substances, each with its own halachic status, can combine to produce another, with an individual, specific halachic status, usually from allowed to forbidden (*chaticha na'aset neveila*) [34, *passim*].

The Avodah Zarah of the Mishnah (2:6) and of the Talmud (37b) contain a regulation, *bishul Yisrael*, according to which Jews can only eat food that is prepared by Jews (or under supervision of a Jew).

> **Avodah Zarah 37b.** […] A comparison is to be drawn with water — as only water which has undergone no change [is permitted to Jews] so also must the food have undergone no change [at the hand of heathens]. […] ears of corn should also be prohibited when roasted by them […] wheat should be prohibited when milled by them […]

However this law applies only to those foods that, according to the Talmud, are "fit for a king's table" (*oleh al shulchan melachim*) and/or are not usually consumed raw (AZ 38a).

> **Avodah Zarah 38a.** […] Whatever is eaten raw does not come within [the law of what is prohibited] on account of having been cooked by heathens. […] Whatever is not brought upon the table of kings to serve as a relish with bread does not come within [the law of what is prohibited] on account of having been cooked by heathens. […]

It is thus conceivable that its formulation by the Masters of the Talmud reflects their knowledge of, and the agreement on, a theory of matter according to which forms of matter irreversibly become (transform) into a different one (*davar hadash*) by natural or voluntary human means.[88] The same is likely to apply to the Talmud commentators and *halacha* regulators who lived in the West European Middle and early Modern Age, since no substantial theoretical change in the theory of matter occurred until truly atomistic theories developed in the late XVII century CE.[89].

Thus, if this chain of reasoning could be retrieved from the ancient Jewish sources, it would strengthen

the possibility that the Hellenistic theory of matter already distinguished physical mixtures (*myxis*) from the product(s) of chemical reactions (*krasis*) that occur between mixture components.[20 [pp. 157-167]] Such processes were already common in the antiquity and led to new materials that do not exist in nature (such as soft glass), to dying products (the reversible air-induced reduction-oxidation reaction of indigo and of purple mussel extracts that originates the two famous colors), and to other artificial goods.

As a recent example, the halachic status of mono- and di-glyceride emulsifiers that derive from natural fats, has been assessed by considering their relationship to the starting products. Some contemporary Jewish religious authorities in the USA decided that the meaning of "*fit for a king's table*" is that the product should stay edible throughout the process that transforms a raw, inedible (or halachically forbidden) food into the finite product. Since one of the preparation steps of glyceride emulsifiers entails the formation of an inedible, even caustic, mixture of fat with strong acid, this event breaks the edibility chain, since now the concoction is no more *oleh al shulchan melachim* (or for anyone's mouth, really).[90]

7. CONCLUSIONS, AND A ROADMAP FOR FURTHER STUDY.

The several, however far from exhaustive, nuggets of Talmudic information reported here suggest that the elaboration and incorporation of Greek, Hellenistic and later knowledge into the Hebrew Talmud occurred very early, and continued through the centuries. Such cultural event was likely occasioned by the proximity of Jewish scholars, who also were the earliest Talmud Masters, to Gentiles who practiced Hellenistic science and technology, especially in large cosmopolitan cities. The cultural melting pot of Alexandria is one likely candidate, yet in several other areas of the Hellenistic and Roman world, and in Parthian Babylonia, occasions of interaction between learned individuals may have played a similar role. Such interaction, direct or mediated as it might develop, would induce Hellenistic advances in science and technology into the halachic discussion of the time, and this embedded knowledge survived the *Hellenistic Doom* and was preserved as a component of Talmudic knowledge even when its Hellenistic roots had been severed.

This cultural phenomenon may not be unique in the history of Western Judaism. As Ptolemaic Alexandria might be the cradle of the Hellenistic-Judaic interaction in the III to II century BCE, as well Islamo-Judaic *al-Andalus-Sepharad* visited by Christian post-docs in the X-XII centuries CE was where quantitative studies of the pharmacology of simple and mixed *remedia*[65,67] could be re-appraised through the inherently quantitative approach of *halacha*. The intellectual pathway towards quantitative pharmacology traced by the al-Kindi – Gerard of Cremona – Arnald Villanova – Jordan de Turre connection of the Montpellier medical school[66] in fact developed at the same time of the flourishing Catalan-Provençal Geonim. Even the converted Jew who took part in the Gospel *vs.* Talmud polemic debates at least until the Paris Talmud fires of 1240 CE might play a yet unconsidered role in highlighting to the Christian scholarly world some unsuspected sides of Talmudic thought.[91,92]

Later, throughout the Humanism, Renaissance and until the Counter-Reformation, there was a surge of interest among educated Gentiles on studying Hebrew to meddle into their texts, such as the Hebrew source of the Septuaginta and the *Kabbala*,[93] as a source of *prisca sapientia*. In addition, "court Jews" were among the first to get involved in chemical manufacturing of high-tech commodities, such as dyes, drugs, gunpowder.[94] Due to the perceived complexity of the operations, chemical manufacturing was long known as "practical alchemy" or "white witchcraft", and a then current (and still lasting) prejudice[23,40,93,95] considered Jews in general as particularly suited, for the good and for the evil, in the "esoteric" science of transformation of matters.

In all cases, geopolitical events beyond the pale of individuals would close the short "windows of opportunity", and in general, the Jewish intellectual world contributed much less than deserved to the development of Western culture at large. The recently started preparation of a version of the Talmud in Italian[69] is expected to facilitate data mining of this huge text by means of Information Technology, independent from halachic studies and from knowledge of the specific Hebrew language. Furthermore, availability of an increasing volume of related information through computer-aided translation will prompt investigations on the possible (and even likely) transmission of Ancient Mediterranean knowledge in the Hebrew Talmud, and through this text, its comments and other Hebrew sources into that of the reawakening Western Europe: *if not now, when?*

REFERENCES

1. S. C. Rasmussen (Ed), *Chemical Technology in Antiquity. ACS Symposium Series Vol. 1211* **2015**, American Chemical Society.

2. M. Levey, *Osiris* **1956**, 12: 376-389.
3. L. M. Principe, *Ambix* **1987**, 34: 21-30.
4. L. M. Principe, *The Secrets of Alchemy*. University of Chicago Press, 2013.
5. H. Fors, L. M. Principe, H. O. Sibum, *Ambix* **2016** May; 63(2): 85-97.
6. L. M. Principe, *Ambix* **2016** May; 63(2): 118-44.
7. H. Robertson, *Ambix* **2016** May; 63(2): 145-61.
8. Galen, Kuhn Ed. vol XII, XIII, XIV at: https: // archive.org/details/hapantaoperaomni13galeuoft; an English translation of *Theriaca ad Pisonem* (Kuhn, XIV) is: Robert Adam Leigh, On Theriac to Piso, Attributed to Galen. PhD thesis, University of Exeter, 2013: https: //ore.exeter.ac.uk/repository/bitstream/handle/10871/13641/LeighR.pdf?sequence=1; (access 2017).
9. F. Téreygeol, N. Thomas, *Revue d'Archéométrie* **2003** 27, 171-181.
10. B. Vannoccio, Tr. Eng. *The Pirotechnia of Vannoccio Biringuccio* / translated from the Italian with an introduction and notes by Cyril Stanley Smith & Martha Teach Gnudi. **1942** The American institute of mining and metallurgical engineers, New York.
11. M. Ciaraldi, *Veget Hist Archeobot*. **2000** 9, 91-98.
12. M. R. Guasch-Jane, M. Ibern-Gomez, C. Andres-Lacueva, O. Jauregui, R. M. Lamuela-Raventos, *Anal. Chem*. **2004** 76: 1672-1677.
13. D. Namdar, A. Gilboa, R. Neumann, I. Finkelstein, S. Weiner, *Mediterranean Archaeology and Archaeometry* **2013** (12)3: 1-19.
14. M. Nierenstein, *Isis* **1931** 16,2 (Nov.), 439-446.
15. M. Nierenstein, *Bristol Med Chir J (1883)* **1946** Summer; 63(226): 75-81.
16. W. Fresenius, *Fresenius J Anal Chem* **2001** 71: 1041-1042)
17. R. Murray, *Anal. Chem*. **2011** 83(23): 8825.
18. L. Russo. *La Rivoluzione dimenticata*. 2° ed. **2013** Feltrinelli, Milano,; chapp. 4, 9
19. L. Russo. *L'America dimenticata*. **2013** Mondadori, Milano,
20. L. Russo. *Stelle, atomi e velieri. Percorsi di storia della scienza*. **2015** Mondadori Scuola, Milano,
21. P. M. Fraser. *Ptolemaic Alexandria*. 3 vols. **1972** New York: Oxford University Press.. Ch. xx
22. L. Russo. *La Rivoluzione dimenticata*. 2° ed. **2013** Feltrinelli, Milano; chap. 10.8
23. R. Patai. *Jewish Alchemists: A History and Source Book*. **1995** Princeton University Press.
24. L. M. Principe, **2013** *cit.* chap. 1, 2
25. Anon. (III-VI sec. CE) *Talmud Bavli*. English translation (only Mishnah and Gemara): www. https: // ia800501.us.archive.org/1/items/TheBabylonianTalmudcompleteSoncinoEnglishTranslation/The-Babylonian-Talmud-Complete-Soncino-English-Translation.pdf (last accession 2017); some treatises also at: http: //www.come-and-hear.com/talmud/ (last accession 2017)
26. A. Steinsaltz, *The Essential Talmud*. **2006** Basic Books (New York, USA).
27. H. Freedman, *The Talmud: A Biography*. Tr.It. Storia del Talmud. **2016** Bollati Boringhieri.
28. A. Steinsaltz, *Isis* **1977** 68(1): 104-105.
29. N.L. Rabinovitch, G. Nàdor, *Isis* **1976** 67: 103-105; *ibid.* **1977** 68: 104.
30. M. E. Singer, *J. Halacha Contemp*. Soc. 42, Sukkot 2001.
31. M. Hasofer, *Biometrika* **1967** 54(1/2): 316-321.
32. N.L. Rabinovitch. *Biometrika* **1969** 56(2): 437-441.
33. Caro I. (XVI sec. C.E.) *Shulkan Aruch (Yoreh Deah)*. Tr. Eng. (partial) in: https: //en.wikisource.org/wiki/Translation: Shulchan_Aruch/Yoreh_Deah; *see* also http: //www.yonanewman.org/kizzur/ (last accession 2017).
34. D. Brodsky (Rav). *The Laws of Kosherut*. **2017** At: http: //etzion.org.il/en/topics/laws-kashrut (access 2017).
35. J. M. Sasson, *in:* U. Hübner, E. Axel Knauf (Eds.) *Kein Land für sich Allein: Studien zum Kulturkontakt in Kanaan, Israel/Palestina und Ebirnâri für Manfred Weippert zum 65 Geburtstag*, **2002** Orbis Biblicus et Orientalis 186 Freiburg Universitätsverlag 294-308.
36. V.A. Ryazanov, *Arch Environ Health*. **1962** 5: 480-94.
37. S. J. Walker, *Permissible Dose: A History of Radiation Protection in the Twentieth Century*. 1st Ed., **2000** University of California Press. Review: A. Colombi, F.M. Rubino, *Med. Lav. (Milano)* **2003** 94(3): 334-336.
38. V. Villavecchia, *Trattato di Chimica Analitica Applicata*. 2°ed., **1922** vol. II. U. Hoepli Ed. (Milano).
39. Mayor A. *The Poison King. The life and legend of Mithridates, Rome's deadliest Enemy.* **2009** Princeton University Press. Tr. it. *Il Re Veleno*, **2010** Einaudi, Torino, and references therein.
40. V. Tcherikover, *Hellenistic Civilization and the Jews* (translated by S. Applebaum) **1959** Jewish Publication Society of America.
41. S. T. Katz (Ed.), *The Cambridge History of Judaism, Volume 4. The Late Roman-Rabbinic Period* (**2008**).
42. D. Boyarin, in: *The Cambridge companion to the Talmud and rabbinic literature*. **2007** Charlotte Elisheva Fonrobert, Martin S. Jaffee (Eds.), Cambridge University Press, 336-364.
43. S. Lieberman, *Greek in Jewish Palestine*. (5702-**1942**) New York, The Jewish Theological Seminary of

America.
44. J. R. Labendz, *Hebrew Union College Annual*, **2003** 74: 175-21
45. A. Keimpe (Ed.), *The Cambridge History of Hellenistic Philosophy* **2008** Cambridge Histories Online. Cambridge University Press.
46. M. Rostovtsev, *The American Historical Review* **1921** 26(2): 203-224; p.221.
47. R. Buitenwerf, *Book III of the Sibylline oracles and its social setting*. With an Introduction, Translation, and Commentary. **2003** BRILL, Leiden 304-320 (https: // books.google.it/books?isbn=9004128611).
48. J. Scarborough, *Studies on Ancient Medicine* **2008** 138-156.
49. L. M. V. Totelin, *Early Science and Medicine* **2004** 9: 1-19.
50. S. Norton, *Molecular Interventions* **2006** 6: 60-66.
51. L. Totelin, *Phoenix* **2012** 66(1-2) 122-144.
52. P. Schneider, *Phoenix* **2012** 66(3-4) 272-297.
53. A. J. Marshall, Phoenix 29(2): 139-154 (1975)
54. H. von Staden, *Herophilus: The Art of Medicine in Early Alexandria* **1989** Cambridge.
55. H. von Staden, in: *Alexandria and Alexandrianism*. Kenneth Hamma (Ed.) The J. Paul Getty Museum 85-106 (1996)
56. L. Russo, *La Rivoluzione dimenticata*. 2° ed. **2013** Feltrinelli, Milano; chap. 5.
57. Quintus Septimius Florens Tertullianus, (155-230 CE) http: //www.tertullian.org/anf/anf03/anf03-22.htm (access: 2017)
58. J. Ganz, *Istoriâ mediciny* **2014** 4(4): 5-12.
59. H. P. Bayon, *Proc R Soc Med*. **1939** 32(11): 1527-1538.
60. P. Ghalioungui, S. Khalil, A. R. Ammar, *Med Hist* **1963** 7: 241-46.
61. J. M. Stevens, *Med J Aust*. **1975** 2(25-26): 949-52.
62. L. Smith, *J Fam Plann Reprod Health Care* **2011** 37(1): 54-5.
63. R. Haimov-Kochman , Y. Sciaky-Tamir, A. Hurwitz, *Eur J Obstet Gynecol Reprod Biol*. **2005** 123(1): 3-8.
64. http: //gifh.wordpress.com/2012/02/19/la-travagliata-storia-del-test-digravidanza/; ; http: //www.laprovinciadicomo.it/stories/cultura-e-spettacoli/292109_test_di_gravidanza_egizio_funziona_dopo_4_mila_anni/ (last access 2017)
65. M. R. McVaugh, *Bull Hist Medicine* **2017** 91(2): 183-209.
66. J. Ricordel, *Revue d'histoire de la pharmacie*, **2001** 89e année, n°330, 135-148.
67. Arnaldus de Villanova. *Aphorismi de gradibus*. Edidit et praefatione et commentariis anglicis instruxit Michael R. McVaugh. **1975** Granada; Barcelona.
68. C. Sinding, *Bull Hist Med*. **2002** 76(2): 231-70.
69. R.S. Di Segni (Ed.) *Talmud Babilonese - Trattato Rosh haShanà*. **2016** Giuntina, Milano.
70. *Encyclopedia Judaica. Units of measure*. At: http: // www.torahcalc.com/info/biblical-units/; https: //www.sil.org/system/files/reapdata/.../silewp2014_003.pd; http: //www.ajdler.com/jjajdler/Talmudic3.pdf; *also:* http: //www.jewishencyclopedia.com/articles/14821-weights-and-measures; www.dafyomi.co.il/general/info/units-of-measurement.pdf; dafyomi.shemayisrael.co.il/general/.../units-of-measurement.pdf (last access 2017)
71. L. Russo. *La Rivoluzione dimenticata*. 2° ed. **2013** Feltrinelli, Milano, ch. 2, 52-53.
72. *Antikythera Mechanism Research Project* at: https: // www.antikythera-mechanism.gr/ (Access 2017)
73. Y. Z. Eliav, in: *The Archaeology and Material Culture of the Babylonian Talmud*. **2015** (Markham J Geller, Ed.), Brill, Leiden 186-224.
74. S. Lieberman. *Hellenism in Jewish Palestine*. (5722-**1962**) New York, The Jewish Theological Seminary of America; *passim*; p.66; p.94.
75. E. Nicholas. *The Alphabet of Galen: Pharmacy from Antiquity to the Middle Ages: A Critical Edition of the Latin Text*. **2012** Univ. of Toronto Press.
76. P. Holmes, *J Amer Herbalist Guild* **2002** Spring/Summer: 7-18.
77. Aristotle. *De Sensu et sensibilibus*. Tr. It. A. L. Carbone in: *L'anima e il corpo, Parva Naturalia*. II Ed. **2015** Bompiani (Milano).
78. Aristotle. *De anima*. Tr. It. G. Movia in: *L'anima*. VII Ed. **2015** Bompiani (Milano).
79. Theophrastus of Erebus. *De Sensibus*. Tr. It. L. Torraca in: *I Dossografi Greci*. **1961** CEDAM (Padova).
80. R. Sorabji, *The Philosophical Review* **1971** 80(1): 55-79.
81. T. K. Johansen, *Phronesis* **1996** XLI/1, 1-19.
82. J. Ellis, *Phronesis* **1990** XXXV/3, 290-302.
83. J. Mansfeld, *Phronesis* **1996** XLI/2, 158-188.
84. B. Stansfield Eastwood, *Rheinisches Museum für Philologie, Neue Folge*, 124. Bd., H. 3/4 268-290 (1981)
85. S. T. Newmyer, *Aufstieg und Niedergang der römischen Welt II* **1996** 17(3): 2895-2911.
86. S. S. Kottek, *Aufstieg und Niedergang der römischen Welt II* **1996** 17(3): 2912-2932.
87. F. Rosner, *Aufstieg und Niedergang der römischen Welt II* **1996** 37(3): 2866-2887.
88. K. Abelson, M. Rabinowitz (Rabbis), *Proceedings of the Committee on Jewish Law and Standards* I **1980-1985** 187-190. Rabbinical Assembly, **1988** http: // www.rabbinicalassembly.org/yoreh-deah (last access 2017)

89. B. T. Moran, *Distilling Knowledge: Alchemy, Chemistry, and the Scientific Revolution*. **2005** Harvard University Press.
90. K. Abelson (Rabbi), *Proceedings of the Committee on Jewish Law and Standards* I **1980-1985** 181-185. Rabbinical Assembly, **1988** http: //www.rabbinicalassembly.org/yoreh-deah (last access 2017)
91. A. Fidora, *J. of Transcultural Medieval Studies* **2014** 1(2): 337-342.
92. A. Fidora, *J. of Transcultural Medieval Studies* **2014** 2(1): 63-78.
93. G. Scholem. *Kabbala e Alchimia* [tr.it.] **2015** SE.
94. D. Jutte, *Isis* **2012** 103: 668-686.
95. G. Ferrario, in: *Chymia: Science and Nature in Medieval and Early Modern Europa*. **2010** M. Lopez Perez, D. Kahn, M. Rey Bueno (Eds.) Cambridge Scholars Publishing, 19-29.

Supplementary Materials

Shulchan Aruch Part II: Yoreh De'ah (http://www.torah.org/advanced/shulchan-aruch/archives.html)

	Loci
Yoreh De'ah Chapter 7a - ABSORPTION	
If forbidden food (or an object that has absorbed forbidden food within the past 24 hours) is in contact even momentarily with hot liquid in a utensil that has been on a fire, or with salty liquid for 18 minutes, or with any liquid for 24 hours, permissible food that was in contact with the liquid for that period of time becomes forbidden unless the forbidden components are less than 1/60 of the total.	(69:1,9,11,15,18;70:6;98:4; 104:1-2;105:1-3)
In estimating 1/60 only food below the surface of the liquid is considered	(see 94:1; 98:4; 99:1,4; 105:1).
If the utensil has not been on a fire, but a hot component comes from such a utensil	(see 68:10-11, 13,15),
the surface of the permitted food must be peeled off where it comes in contact with the liquid	(105:3).
Even if the components are hot, if they do not come from utensils that have been on a fire and the liquid is not salty	(see 69:9 and 91:7)
and the permitted food remains in it for less than 24 hours, the food need only be washed off and the liquid is permitted	(91:1-4;105:2-3).
These and the following rules also apply to contact between milk and meat products	(87:10;91:4-6; see 92:1,4-6).
On absorption from a forbidden egg that is still in its shell	see 86:5-6.
If the components are near a fire and hot but not in contact with liquid, and an object that has absorbed forbidden food touches permitted food, it becomes forbidden unless the forbidden components are less than 1/60 of the total; and the same is true if forbidden food of a type that sometimes contains fat touches permitted food, even if the forbidden food is absorbed in other food; but if the forbidden food is of a type that never contains fat, the places where it touched the permitted food need only be removed to a depth of a fingerbreadth, and this must be done in any case if the places where it touched are known	(see 68:4,9;105:4-5,7-8).
If the components are not near a fire and a hot component that has been on a fire is added, the places where the permitted food touches a forbidden component need only be peeled	(68:10-11,15;92:7;94:8;105:6).
If no component has been on a fire only washing is needed, and nothing need be done if the components are dry	(91:1-4).
If the components are not near a fire, but a forbidden food component is heavily salted	(see 69:8;70:6)
and not entirely dry	(see 91:5;95:7),
the places where a permitted component touches it even momentarily must be peeled;	(see 69:8,18;70:6;105:1)
and if the forbidden food is of a type that sometimes contains fat, the permitted food that touches it becomes forbidden unless the forbidden components are less than 1/60 of the total, and it must also be peeled if the places where it touched are known	(64:16,20; 65:1; 69:9,16,18,20;70:1-4; 72:2;105:9-11).
Salt causes absorption even in an object	(see 69:16-17),
but it does not draw out forbidden food that has been absorbed in an object	(69:16;70:2;105:12-13).
If the forbidden food is meat from which the salt is drawing blood, and the salt is also drawing juices out of the permitted food, or the permitted food is on top, it does not absorb the blood and need only be washed	(70:1-4);
or if the permitted food is meat that still contains blood, any blood that it absorbs in this way can be extracted together with its own blood, though other blood that it absorbs cannot	(69:2;70:2,6;72:2).
Similarly, the blood that a fire draws from meat is not absorbed in other meat that is near the fire, but other blood is	(69:4,20;76:1-2;77:1).
Yoreh De'ah Chapter 7b - ABSORPTION cont'd	
Some substances absorb more easily or less easily than others; for examples	see 64:18-19;96:5;121:1.
Pressure (as in cutting with a knife or grinding in a mortar) increases the depth of absorption;	see 94:7 and 96:1-3 as well as 10:1-3;64:16;89:4.
Even in cases where the forbidden component is less than 1/60 of the total, if it can be recognized or separated it must be removed; and if it is attached to or first entered a permitted component, that component is forbidden and must be removed if it can be recognized	(69:11;72:2-3; 73:6;90:1;92:2-4;94:3;98:4; 106:1-2).
When a permitted food component becomes forbidden because of thorough mixing (see Ch.8a) or absorption it is regarded as entirely forbidden even if it absorbed an amount smaller than its volume	(92:4;98:5;99:3,5;106:1;107:2),
but if it absorbs meat or milk it is not regarded as being entirely meat or milk	(94:6).
If an object absorbs an unknown amount of forbidden food it is regarded as entirely forbidden	(see 94:2)
unless the absorption was of a type that requires only peeling	(98:4).

	Loci
If it absorbs a known amount of forbidden food it is not regarded as entirely forbidden unless it is made of pottery or it has also absorbed an unknown amount of permitted food	(98:5; see 92:5-7 and 94:6).
Permitted and forbidden foods should not be heated together in an enclosed space (such as an oven) unless one of them is covered or both of them are in containers and the oven is not completely enclosed, but if this was done the food remains permitted if the oven is not completely enclosed unless one of the foods has a sharp taste or unless a mixture containing even a tiny quantity of the forbidden food would be forbidden	(90:2;97:3;108:1-2; see Ch.8a).
Some foods absorb odors even if the source is covered;	see 108:4.
Similar laws apply to heating them one after the other if the first one causes steam to form in the oven	(108:1; see also 92:7-8;93:1; 105:3).
Tasting forbidden foods even without swallowing them is forbidden	(108:5),
but smelling them is not forbidden unless it is forbidden to derive benefit from them	(108:7).
An object that was in contact only with cold, unsalted forbidden food can be cleaned by thorough washing	(121:1),
but if it has absorbed forbidden food it should not be used even with cold, unsalted permitted food even after it has been washed unless it is earthenware	(see 69:16; 94:7;121:5).
If an object made of metal, wood or stone absorbed forbidden food in the presence of hot liquid, the absorbed food can be removed from it by immersing it in boiling water at least 24 hours after the food was absorbed in it	(91:5;108:3;121:2).
If the absorption was in the presence of heavy salt or of hot liquid that is no longer in a utensil that has been on the fire, it is necessary only to scrape off the object's surface where the food or liquid touched it;	see 92:9
. If it absorbed forbidden food by heating in the absence of liquid (this includes frying) the absorbed food can be burnt out of it by heating it to a high temperature	(97:2;121:4-6).
If it is a knife it may be used with cold food after thoroughly cleaning or grinding it down; to use it with hot food it must be heated to a high temperature or ground down and immersed in boiling water	(see 10:1-3; 64:17;69:20; 89:4;94:7;121:7).
These laws are also treated in Orach Chayim 55:1-2; see 121:3. On the procedures for cleaning utensils that were used with forbidden wine see Ch.10b.	Orach Chayim 55:1-2; see 121:3
Yoreh De'ah Chapter 8a - MIXTURES OF FOOD cont'd	
If forbidden and permitted foods are mixed together thoroughly the mixture is permitted if no one forbidden component is more than 1/60 of the total	(98:1,6,9; see 99:1-2,4).
In defining a component, things that have the same name are regarded as the same whether or not they taste the same;	see 98:2.
For some types of forbidden foods amounts different from 1/60 are required; for other types any amount makes a mixture forbidden	(see 98:7-8).
If an intrinsically forbidden component can be detected by its taste or by its effect on the mixture	(e.g., 87:11; 102:1),
or if a forbidden component can be recognized but cannot be removed	(104:1,3),
the mixture is forbidden even if the component is less than 1/60	(98:8; 105:14).
It is forbidden to mix forbidden food with permitted food to produce a permitted mixture; if this was done, the person who did it or for whom it was done is forbidden to derive benefit from the result	(94:5-6;101:6).
It is forbidden to use a utensil that has absorbed forbidden food if the utensil is sometimes used for less than 60 times as much permitted food	(99:7;122:5).
If a mixture contains less than 1/60 of a forbidden component, and more of that component is added so that the total reaches 1/60, the mixture becomes forbidden; but if a mixture contains less than 1/60 of meat (or milk) it does not become forbidden even if milk (or meat) is added to it afterwards	(99:6).
If an entire (dead) creature or (named) body part that has always been forbidden is mixed with any amount of permitted food the mixture is forbidden, but if the forbidden component can be recognized and removed the remaining mixture is permitted if the forbidden component was less than 1/60 of it	(100:1-3).
Similarly, if a portion of food that is intrinsically forbidden and is large enough to serve to guests in its present condition is mixed with any amount of permitted food, the mixture is forbidden as long as the portion may have remained intact	(69:14;81:2; 92:3; 101:1-7; 105:9;106:1).
If food that is only temporarily forbidden or that can be made permitted without much effort is mixed with any amount of permitted food of the same type, the mixture is forbidden until the forbidden component becomes permitted; but if it is mixed with permitted food of a different type, or is not intrinsically forbidden, or became forbidden only after it was mixed, or can be recognized and removed, the mixture is permitted if the forbidden component is less than 1/60 of the total	(102:1-4).

	Loci
Yoreh De'ah Chapter 8b - MIXTURES OF FOOD cont'd	
If forbidden food is tasteless or gives a mixture a permanent bad taste (or if it is a creature: itself has a bad taste) it does not make the mixture forbidden unless it is the majority ingredient, but it should still be removed from the mixture if possible;	see 81:8;95:4;100:2;103:1-4; 104:1-3;107:2;122:1;123:25.
Food absorbed in an object loses its taste after 24 hours and no prohibition results if it is reabsorbed in other food afterwards	(93:1;94:4;95:2;103:5,7;122:4,6-7),
but food adhering to the surface of an object does not lose its taste, and in any case if an object has absorbed forbidden food it should not be used with permitted food even after 24 hours until the absorbed food is removed from it	(122:2-3; see Ch.7b).
Milk or meat absorbed in an object and reabsorbed in meat or milk within 24 hours results in a prohibition, but if it is first reabsorbed in something else it becomes a "second-order" taste and can no longer result in a prohibition	(94:5,9;95:1-3).
In strong-tasting food, even absorbed tastes that are 24 hours old or second-order are not permitted	(95:2;96:1-5;103:6;122:3).
Precautions should be taken to avoid the possibility of forbidden and permitted things becoming mixed up;	see 101:8-9;110:10;123:23.
If a piece of forbidden food that is not large enough to serve to guests becomes mixed up with two or more pieces of permitted food of the same type the pieces are all regarded as permitted, but one person should not eat all of them	(109:1, and see Ch.9).
If they were cooked together the result is forbidden unless the forbidden food is less than 1/60 of the total of the food that is in doubt	(109:2, and see 111:7;
a person is allowed to add permitted food to the mixture before cooking it to ensure that the forbidden portion is less than 1/60).	
If a piece of forbidden food becomes mixed up with pieces of permitted food of a different type and cannot be distinguished, it is not regarded as permitted unless it is less than 1/60 of the mixture	(109:1);
but if it is more than 1/60 the mixture is not regarded as entirely forbidden, and if more permitted food is added to it until the forbidden portion becomes less than 1/60 the mixture becomes permitted	(92:4).
If an object that has absorbed forbidden food becomes mixed up with other objects they are all permitted	(102:3; 122:8).
If an "important" forbidden thing (for example, a living creature or anything that is counted rather than measured) becomes mixed up with any number of permitted things of the same kind the mixture is forbidden	(e.g. 86:3),
but if the things lose their importance (for example, the living creatures are slaughtered and are not large enough to serve to guests) and this was not done deliberately the mixture becomes permitted	(110:1-2),
and if one of the things is accidentally destroyed the others become permitted because we assume that the forbidden one was destroyed (this also applies to creatures, large portions, and things that are only temporarily forbidden), but they should be eaten two at a time by more than one person and they should not all be eaten at once	(110:7).
See Ch.11 on the case where the things are forbidden because of idolatry.	