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Talmudic Metrology III
Units of Measure of Volume and Capacity[1]

In the absence of precise talmudic traditions, the Rabbis used natural units of measurement, i.e. the volume of the average egg of a hen (*beitza*) and the breadth of the thumb (*etzba*). Indeed, the Talmud expresses the *revi'it* with respect to these natural sizes through the relationship: 1 *revi'it* = 10.8 e^3 = 1.5 eggs (B. Pesahim 109a and Eruvin 83a). Since the 14th century, the contradiction between these two methods of evaluation of the units of capacity has been evident. The capacities determined through the breadth of the thumb are twice those estimated through the use of the volume of eggs. A third method of evaluation, based on a passage in Y. Terumot X: 8, according to which the weight of two *zouz* of forbidden fish represents 1/960 of the weight of a pickle of two *seah*, leads, according to the traditional commentators, to capacities three times greater. This third method, however, has been considered a marginal opinion that was not taken too seriously and that could be neglected. The method of evaluating the capacities through the use of the *etzba*, leading to larger units of capacity, has gained more and more importance, while the older evaluations were founded on the principle of smaller units of capacity. Because of the link between the talmudic units of capacity and the Roman units of capacity (Mishna Kelim XVII: 11), the latter are dealt with thoroughly in this paper. Different talmudic passages connected with the use of units of capacity and units of weight are examined extensively. We demonstrate that the third method of evaluation, correctly understood, is accurate, and is in concordance with the large units of capacity found through the use of the *etzba*. It allows for a definitive definition of the talmudic units with respect to the Roman units of capacity. The use of a principle proposed in its time by Bornstein, which was neglected and not taken seriously, explains and reconciles the first two methods of evaluating the units of capacity, and allows for an understanding of the origin of the divergence between the two methods. It concerns the method of measuring a volume in eggs. Finally, we examine the metrology of Maimonides and we raise the issue of a contradiction between his estimation of the weight of the Egyptian *dirham* in his commentary of the Mishnah and his *hibur*.

* I want to thank R. Y.G. Weiss for reading this paper, and for his invaluable remarks.

1 This paper is dedicated to the blessed memory of my late parents. My father R. Eliezer Ajdler (Warsaw 1901– Brussels 1999) had a traditional education: *heder* and *beit hamidrash*.

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I. Different Units of Volume in the Talmud and their Evolution over Time

When we consider units of length, we observe a great diversity among types of the same unit. We have a cubit of five *tefah*, and a cubit of six *tefah* or 24 *etzba* (a rigorous cubit). In the entrance of the Temple Court, at the Gate of Sushan, there was a cubit of 24.5 *etzba* and another of 25 *etzba*.[2] There was also a generous cubit (which could be one of the precedents). Apparently, however, there were no geographical differences; all of Palestine used the same units of length. Furthermore, we do not hear about evolution over time of the length of these units.

In the case of the units of capacity, the situation seems to be completely different; there were different units of measurement in the main towns of Palestine. Furthermore, as we learn from the Talmud, sometimes there was also an evolution in these places over time.

In 1919, he was conscripted and enrolled at the end of that year in order to fight against Russia. He spent six months in Ostrowiec, at the house of the Admor, Rabbi Meir Jehiel ha Levi Holtzstock (1851-1928), under whom he studied *mishnayot kodashim* and *teharot*. With his benediction, he succeeded in escaping to Germany, where he joined the Yeshiva of R. Moses Schneider in Frankfurt. He was among the few young Poles to receive *semikha* from R. Solomon Zalman Breuer. But his personal pride was the *semikha* that the Rabbi of Ostrowiec later wrote for him. He was assistant rabbi in a German community for a year, but soon entered into business. He left Germany in 1933 and settled in Brussels. He married in late 1940. In late 1942, my parents concealed themselves in a gentile family's attic, and I was placed with a gentile family in the suburbs. After the war, my father continued importing plywood from Finland. He was among the founders of a Jewish day school in Brussels. For nearly 25 years, he gave a public two-hour Talmud lesson twice a week at his home. His strength was based on a deep comprehension of Rashi and *Tosafot* and, in this field, he was one of the strongest figures. His modesty rather than his qualifications was his calling card. My mother, Bianca Steinfeld (Brakha Bluma) (Antwerp 1913 – Brussels 1997), was among the first Jewish girls to receive a university education (in business). She was deeply affected by the calamities of the war. On the evening of Friday, 3 August, 1943, her father R. Israel Steinfeld (Warsaw 1885 – Auschwitz 1943), her mother, Antonia Figatner (Antwerp 1888 – Auschwitz 1943), and her brother Saul Steinfeld (Antwerp 1920 – Antwerp 1943) were carried off. Her brother died that same evening, suffocated in an overcrowded bus, together with three other boys, in front of their parents. His tomb is at the entrance of the cemetery of Mahzike ha-Dat in Putte, Holland.

תהיינה נשמותיהם צרורות בצרור החיים, עם נשמות אברהם יצחק ויעקב, שרה רבקה רחל ולאה, עם שאר צדיקים וצדקניות שבגן עדן, ונאמר אמן.

2 See Mishna Kelim XVII: 9, B. Pesahim 86a and B. Menahot 99a.

1. Units of Moses (*Midbarit*), of Jerusalem and of Tzipori

B. Eruvin 93a writes:

> תנו רבנן: סאה ירושלמית יתירה על מדברית שתות ושל ציפורית יתירה על ירושלמית שתות, נמצאת של ציפורית יתירה על מדברית שליש

The basic units of volume are called *midbarit*, or units of Moses. In Jerusalem, the units of volume or capacity[3] were increased by 20 percent (the Talmud also says by 1/6 of the new values); therefore, the units of capacity of Jerusalem are 6/5 = 120 percent of the basic units of Moses.[4] The new units of Jerusalem were increased by another 20 percent in Tzipori (1/6 of the new values), and the units of Tzipori, therefore, were 6/5 = 120 percent of the units of Jerusalem.[5]

The units of Tzipori are then 36/25 = 144 percent of the units of Moses. They have been increased by 44 percent, or by 44/144 = 0.306 of the new units. The Talmud simplifies – and writes by 1/3 (of the new units).[6] These modifications must be very old, probably before, or, at the latest, at the very beginning of, the period of the Mishnah.[7] Apparently, the older units of capacity of Tzipori were equal to the new units of measure of Jerusalem; the new units were therefore 120 percent larger than the older ones. There was, however, a special situation in Tzipori regarding the measure of muries, i.e. a brine or pickle containing fish hash, for which they were still using an old unit equal to the *log* of the desert, the unit of Moses. There is a mention of this unit in the following talmudic passage: B. Pesahim 109a:

3 In B. Eruvin 83a it speaks about the *seah*, a unit of capacity of dry stuff. But this must also be the case for all other units of capacity. See Mishna Hallah II: 6, the pastry used for *hallah* has a volume of 1.25 *kav* or five *log* of Tzipori; they are equal to 1.5 *kav* or six *log* of Jerusalem, and to 1.8 *kav* or 7.2 *log* of the desert. See also Mishna Menakhot VII: 1 and B. Menakhot 76b, Tosafot בד״ה התודה. From these references, it appears, without doubt, that the whole system of units of capacity was increased in Jerusalem and later in Tzipori. Weiss (1984), p. 291, doubts whether this increase also concerned the units of capacity of liquids. For me, it is evident that this is the case for the simple reason that many units of capacity are common for dry and liquid stuff. There is also even stronger evidence: the expression of the volume of the *revi'it shel Torah* in the Babylonian Talmud 2e x 2e x 2.7 e, and in the Jerusalem Talmud 2e x 2e x 1.833e, implies that the *revi'it* of Tzipori is 1.44 greater than the *revi'it* of the desert. See note 68.

4 See Mishna Menakhot VII: 1.

5 See Mishna Eduyot I: 2, from which we can deduce that the units of Jerusalem were already used in the time of Hillel and Shamai, and that the units of Tzipori were introduced only later.

6 B. Eruvin 83a.

אמר רבי יצחק קסתא דמורייסא דהוות בציפורי היא הוות כמין לוגא דמקדשא

2. Units of Volume of Tiberias

a. The old units of Tiberias

The old units of Tiberias were the units of Moses. Indeed, Y. Pesahim X: 1, Y. Shekalim III: 2 and Y. Sabbath VIII: 1 write:

> תני חצי שמינית טיברינית הישנה, אמר רבי יוחנן, הדא דידן הוות ולמה לא אמר עתיקתא, בגין דהוות ביומוי.

The prescribed cup of wine of one *revi'it* is 1/16 of the old measure[8] of Tiberias. Therefore, the ancient units of Tiberias were equal to the measures of Moses, and the basic unit of Tiberias was the *kav*.

b. The modern units of volume of Tiberias

The modern units of capacity were introduced in Tiberias in the second half of the third century during the lifetime of Rabbi Johanan.[9]

The units of measure of volume were diminished to 80 percent of the old value, i.e. they were diminished by 20 percent (in the Talmud it says by 25 percent of the new value).

This can be deduced by the following passage in B. Pesahim 109a:

> אמר רבי יוחנן תמניתא קדמיתא דהווה בטבריא הוות יתירא על דא ריבעה ובה משערין רביעית של פסח

This passage must be understood as follows: the eighth part of the ancient *kav* of Tiberias, or the ancient eighth part of the *kav* of Tiberias, which is equal to $^1/_2$ *log* or two *revi'it* of Moses,[10] has been diminished by 20 percent (25 percent of the new capacity). This allows us to determine the *revi'it* of the Torah, being its half.

Rashi and Rashbam believed that the *revi'it shel Torah* was found by evaluating

7 See *Dorot ha Rishonim*, Book I, p. 225. He establishes that the measure of Jerusalem had already spread by the time of Hillel and Shamai, because they used this measure. See Mishnah and Tosefta Eduyot I, 2. Actually, only the Sages, who were opposed to Hillel and Shamai, used the Jerusalem *kav*, while Hillel and Shamai still used the *kav* of the desert.

8 The old measure used was a *kav*.

9 See the passage in Y. Pesahim mentioned *supra*. Rabbi Johanan used the ancient measure, but not the antique measure, because the ancient measure was still in use during his time.

10 According to the passage of the Jerusalem Talmud mentioned above.

the difference between the old and the new measurements. The difference between the old and the new measurements is in fact equal to 2 *revi'it* – 1.6 *revi'it* or 0.4 *revi'it*. So 2.5 x the difference is equal to the *revi'it shel Torah*. But Rashi and Rashbam probably understood ריבעה, in the former passage, to mean the *revi'it* and not a quarter.

This exegesis seems difficult to accept. Indeed, the old measure was two *revi'it*, so the new measure must then be one *revi'it*, if we want the difference to be one *revi'it*. In this case, the diminution of the capacity would have been by 50 percent! And it would have been simpler to say that the new eighth of the *kav* of Tiberias is a *revi'it shel Torah*. If the new measure was 80 percent of the ancient measure, 5/4 of the new measure would be equal to the ancient measure. Therefore, the following passage – quoted in the three references in the Jerusalem Talmud mentioned above – כמה שעורן של כוסות, טיטרטון ורביע – is referring to the situation existing in Tiberias at the end of the life of Rabbi Johanan and later, when 5/4 of the new *revi'it* (*tetraton*) was equal to the old *revi'it* or *revi'it shel Torah.*[11]

II. RELATIONSHIP BETWEEN THE TALMUDIC UNITS OF CAPACITY AND THE ROMAN UNITS OF CAPACITY.

1. Introduction

Mishna Kelim XVII: 11 writes:

> ויש שאמרו במדה דקה, מדות הלח והיבש שעורן באיטלקי

It is accepted, on the basis of this Mishnah, that the talmudic units of capacity, or, more precisely, the units of capacity of Moses or of the desert (in contrast to the units of capacity of Jerusalem and those of Tzipori) were equal to the Roman units of capacity.

We find a similar statement in Tosefta Ketubot V: 7

> המשרה את אשתו על ידי שליש, לא יפחות לה מקביים חטין או מארבע קבין שעורים, וכולם במדה האיטלקי

This passage is parallel to Mishna Ketubot V: 8, and differs only by this additional remark that the units of capacity mentioned in the Mishnah, which are understood as units of the desert, are equal to the Roman units of measurement.

Based on this principle, Zuckerman (1887) proposed identifying the *log* with

11 This exceptional explanation was given by Borenstein (1887). It must be noted, however, that the *Shulhan Arukh*'s version is טטרון; it therefore refers simply to the *revi'it* of the desert.

the Greek *xestes* on the basis of the passage in B. Pesahim 109a, mentioned above:

אמר רבי יצחק קסתא דמורייסא דהוות בציפורי היא הוות כמין לוגא דמקדשא

But the objection is that it is uncertain whether this *kesta*[12] is a *xestes*. As proposed by the *Shulhan Arukh*, it could perhaps represent a certain receptacle, but it is not established that this receptacle had the capacity of a *xestes*.[13] More generally, modern authors like Benish and Weiss accept the principle of the correspondence of talmudic units of capacity with the Roman units of capacity. Benish maintains, however, that it is not possible to fix this correspondence; a doubt remains, and it is not possible to decide whether the *log* is equal to the Greek *xestes* (equal to the Roman *sextarius*) or to the Greek *kotyle* (equal to the Roman *hemina*). Weiss, on the contrary, adopts the smaller units of capacity.[14]

2. Extra-Talmudic References about the Correspondence of the Jewish Units of Capacity with the Latin and Grecian Units of Capacity

a. Septuagint

In the translation of Parashat Metzora, the *log* is translated five times as *kotyle* (half of the *kestes*). However, 2 Chronicles 4: 5 translates בתים by *metretes*.

There is a variant reading[15] of Lev. 14: 10, where the *log* is translated by *xestes*.[16] It seems that *kotyle* is clearly Septuagintal; *xestes*, in the variant reading, appears to stem from the *hexapla*.[17]

12 It is symptomatic that the names of different units of capacity are at the origin of the denominations of utensils, the *kestes*: *kesta* or *kist*; the *chous* (1/2 *kestes*): *khouza* (Mishna Tamid III: 6; B. Sabbath 33b; B. Bava Metzia 40a; B. Bava Batra 96b); the *log*: *louga* (B. Yoma 83b).

13 R. Benjamin Mussaphia (c.1602 – Amsterdam 1675) refrained from calling *kestes* a measure.

14 He called my attention to the fact that R. Abraham ben David Portaleone (1542-1612) in his *opus magnum*, שלטי הגיבורים (Mantua, 1612), writes that the weight of a *sextarius* of wine is 20 ounces (that of a chemist of about 28 gr which gives a weight similar to the weight of Grovius), the weight of a *hemina* of wine is 10 ounces (see p. 74a), and the weight of a *log* of wine is 9 ounces (see pp. 93b, 94 and 97). So he opted for the small capacities, and was not disturbed by the lack of correspondence between the *log* and the *hemina*.

15 This reference is mentioned in the *Hebrew-Aramaic Dictionary* by Prof. Ezra Melamed.

16 I thank Prof. Albert Pietersma, Professor of Septuagint and Hellenistic Greek at the University of Toronto, for this information.

17 The Hexapla is a polyglot edition of the Hebrew Bible prepared by Origen (c. 185 – c. 255 CE). It was generally printed in six columns: a Hebrew text (Masoretic?), a Greek transliteration, and four Greek versions: those of Aquila, Symmachus and Theodotion, and a revised version of the Septuagint. According to Schurer (1973) (Vol. 3, part 1, p. 493),

b. Josephus

In his *Antiquities*, Book 8; 2: 9, he translates בת by *metretes*.

In his *Antiquities*, Book 3; 8: 4, he translates הין by two *chous*.

In his *Antiquities*, Book 9; 4: 5, he writes that one *seah* is equal to 1.5 Italian *modius*.

However, in his *Antiquities*, Book 3; 6: 6, he translates עישרון by seven *kotyle*, instead of seven *xestes*.

c. Vulgate

In Metzora, the *log* is translated by *sextarius*.

d. Conclusion

Even the Jewish books of the Septuagint and of Josephus reached modern hands through an unknown route, and no confidence can be granted to the extant texts. Particularly because there are internal contradictions in each[18] of them, they cannot help us solve the problem.[19]

Aquila and Theodotion were Jewish, while Symmachus, according to Eusebius, was an Ebionite Christian. Schurer writes that the translation of the Septuagint prevailed among Jews of the Greek-speaking Diaspora as the main sacred version of the Bible until the beginning of the second century CE. The period of its predominance coincided with the golden age of the Jewish community in Alexandria. In the second century, however, this community suffered near extinction, and the translation of the Bible, which it had championed, fell into disfavor among the Jews. This process was aided by two factors: an increase of the prestige of rabbinic commentators outside Palestine, and the successful advance of Christianity. An important symptom of this change can be found in the new Greek translations of the Bible, which were intended to provide Greek-speaking Jews with a translation based on the authoritative Hebrew text. These translations are also a memorial of the struggle between Judaism and Christianity, since they provided the Jews with a polemical weapon in the battle against Christian theologians, who exploited the uncertain text of the LXX in their own interests.

18 Schurer (1973) (Vol. 3, part 1, p. 474) writes that the Septuagint was not the work of a single hand. What was brought together under this name at a later time is not merely the work of different translators, but also derives from different times. Therefore, the affirmation of internal contradiction must be considered with reservation. Schurer notes (p. 482) that a great number of "hexaplaric" readings found their way into the text of the LXX, so that the elimination of the hexaplaric additions is one of the chief tasks of septaguintal research. The Aristeas legend refers apparently only to the Pentateuch. It was reported in the Talmud: B. Megila 9b, B. Sofrim I: 8.

19 It is not impossible that the Septuagint (third century BCE) adopts the principle of the small units of capacity, while, in accordance with the prevailing opinion of the epoch of the Mishnah and later the Talmud, the Hexapla adopts the opinion of the larger units of capacity.

3. Other Evidence about the Correspondence of the *Log* and the *Xestes* or *Sextarius*

Despite the former argument, there is evidence establishing a correspondence between the *log* and the *xestes*.

It is interesting to compare two passages: B. Taanit 30a,

> כיצד ממעט, אם היה רגיל לאכול ליטרא בשר, יאכל חצי לטרא, היה רגיל לשתות לוג יין, ישתה חצי לוג

and the parallel passage in Y. Taanit IV: 6 (ed. Vilna); Y. Taanit IV: 10, p. 69a (ed. Krotoshin).

> מהו ישנה, יחלף: אין הוה יליף אכיל ליטרא דקופד ייכול פלגא, אין הוה יליף שתי קסט דחמר, ישתה פלגא

From the parallelism[20] between these two passages, it appears that *log* is translated by *kestes* in the *Yerushalmi*.

In B. Berahot 44b, Rashi explains **קייסי** as a measure containing a *log*.[21]

4. About the *Revi'it*

The *revi'it* is the fourth part of the *log*; it plays a central role in the Halakhah and the Talmud. B. Nazir 38a writes **א״ר אלעזר: עשר רביעיות הן** and enumerates these different cases: 1) the *revi'it* of wine for the *nazir*; 2) the *revi'it* of concentrated wine for the four cups of Pesah, which, after dilution, has in each of the four cups a capacity of one *revi'it*; 3) he who drinks a *revi'it* is not proper to judge; 4) he who drinks a *revi'it* of wine and enters the Temple is held culpable, and merits death; 5) the *revi'it* of blood from a death is impure; 6) a *revi'it* of oil is necessary for the preparation of the *hallot* accompanying the *korban toda*; 7) a *revi'it* of oil for the preparation of the *hallot* brought by the *nazir* at the end of his nazirate; 8) a *revi'it* of water is necessary for the sacrifice of the *metzora*; 9) a *revi'it* of impure water can make impure another liquid or a man; 10) a *revi'it* is the quantity for which one is held culpable on the Sabbath, for bringing it from the public domain to the private domain or vice versa.

20 The parallelism between these two passages is not fortuitous. One must remember that rabbis traveled between the academies of Palestine and Babylonia, which enabled these institutions to be aware of the teachings of the others. See *Dorot haRishonim* (1897-1939, reprinted 1967), Vol.7, pp. 467-73, by R. Isaac Halevy.

21 But he also equates a *log* to a *litra* in B. Eruvin 29a

If we refer to the third case, the quantity of wine that makes someone unfitting to judge and to teach the law, we find in many instances[22] the same quantity expressed as רביעית באיטלקי "the fourth expressed in the Italian measure." This undoubtedly refers to the *quartarius*, the corresponding Roman measure, which is the fourth part of the *sextarius*. If we refer to the second case, relative to the capacity of the cups of Pesah, which is one *revi'it*, and the quantity of concentrated wine necessary for the four cups together, we find in many instances[23] this quantity of one *revi'it* expressed as רביעית יין באיטלקי "the fourth of the Italian measure," referring again to the *quartarius* or the fourth part of the *sextarius*.

5. *Tetraton Ureviya* טיטרטון ורביע

The Jerusalem Talmud writes:

כמה שעורן של כוסות, טיטרטון ורביע.

In Y. Pesahim X: 1 the dictum is mentioned in the name of Rabbi Mana. In Y. Sabbath VIII: 1 and Y. Shekalim III: 2, it is mentioned in the name Rabbi Abin. This passage refers to the situation existing in Tiberias at the end of the life of Rabbi Johanan and later, when 5/4 of the new *revi'it* (*tetraton*) was equal to the old *revi'it* or *revi'it shel Torah*. This proves again that the *revi'it* was once equal to the Roman *quartarius*.[24]

6. The Quantity of Two Meals for an *Eruv*: Mishna Eruvin VIII: 2

When preparing an *eruv*, we must bring the necessary quantity of food for two meals for each participant. It is accepted that this quantity is to be considered the minimum quantity required for a meal. According to Rabbi Johanan ben Beroka, we need a bread of half a *kav*, of which the baker takes half to remunerate his work and the cost of his oven. Therefore, there remains a bread of 1/4 of a *kav*, which suffices for two meals, i.e. a bread of 1/8 *kav* per meal.[25] On the other hand, Rabbi Simeon says we need for the *eruv* 2/3 of a bread of 1/3 *kav*, i.e. for each meal we need a bread of 1/9 *kav*. The account of Rabbi Simeon deals with net quantities,

22 See the following references: Tosefta Pesahim II: 9, Y. Avoda Zara VII: 2, Leviticus Rabbah 37: 3.

23 See the following references: Y. Pesahim X: 1, Y. Shekalim III: 2 and Y. Sabbath VIII: 1.

24 The *Shulhan Arukh* deletes *ureviya* and considers *tetraton* to be the equivalent of the *revi'it*.

25 This explanation is confirmed by the Mishna Ketubot V: 8, where the wife receives two *kav* for 16 meals, i.e.1/8 *kav* for one meal. This proves that the quantity of bread is measured by the volume of the constitutive whole wheat.

after the remuneration of the baker. The difference between the two opinions is slight. The *kav* is a unit of capacity and the meaning of the *kav* in the estimation of the size of the bread is the volume of wheat used in its preparation. According to the data given by Maimonides,[26] the density of whole wheat is about 0.78.[27] Therefore, if we consider a wholemeal bread, a bread of 1/8 *kav* is made with 0.78 x 80 = 62.4 *denarius* wholemeal or 212.78 gr wholemeal, and it weighs about 274 gr, because it can be assumed that 1gr meal makes about 1.29 gr bread.[28] This data was calculated on the basis of a *kav* being equal to 4/6 *congius*. These results are likely: 274 gr bread per meal seems a minimal quantity but a quantity of bread of 137 gr per meal, which would correspond to the equalization of a *log* to a *hemina*, would not be acceptable.[29] We have thus understood that a bread of 1/8 *kav* is a bread prepared with 1/8 *kav* whole wheat, the meal being measured by its volume. Another explanation, although far-fetched, would involve bread that weighs 1/8 *kav* of water or 80 *denarius*, i.e. 272.8 gr. According to this second explanation, the unit of capacity is used as a unit of weight, representing the weight of the water contained in this capacity. It appears, in this particular case, that both explanations give equivalent results, and it is difficult to decide which of them is correct.

7. Two Meals of the Poor Person who Travels from Place to Place

In Mishna Peah VIII: 7, it writes about the poor person who travels from place to place, and to whom one must give the amount of food necessary for two meals, so that he receives bread made with half a *kav* of whole wheat, which allows him to eat two meals of bread made with 1/8 *kav* of whole wheat, taking into account the fact that half the bread has to be given to the baker. This, again, is in accordance with the opinion of Rabbi Johanan ben Beroka. The quantity to give to the poor is then the same as the quantity necessary for the *eruv*, and represents 274 gr of bread per meal. This is the minimum quantity needed to satisfy the poor person's hunger.

26 See Mishna Eduyot I: 2.

27 According to the Mishna Eduyot I: 2, the density of wheat is 21/27 = 0.78, and the density of meal is 18/27 = 0.67. As the wife of the poor worker receives corn, I have supposed that she mills the corn, just as it is, without any sifting. It is likely that poor people ate wholemeal bread.

28 See Benish (1987), p. 290 note 114*.

29 In fact, we must remain cautious in this particular case because the Sages were lenient, in some instances, in the fixation of the necessary quantity of the meals necessary for the *eruv*. The demonstration is more convincing when dealing with the quantities allowed, ensuring the subsistence of the poor or of the wife of the workman.

8. Two Meals of the Poor Person on the Threshing Floor

Mishna Peah VIII: 5 writes about the poor person who passes by the threshing floor, to whom one must give half a *kav* of wheat.[30] This allows him to eat two meals of bread made with 1/8 *kav* of whole wheat per meal, taking into account that half of the bread has to be given to the baker. This conclusion, again, is in accordance with the opinion of Rabbi Johanan ben Beroka and grants him 274 gr of bread per meal. A quantity of 137 gr of bread would be insufficient.

9. The Meals of the Wife of the Poor Person who is Away During the Week, Mishna Ketubot V: 8

We will now deal with the same Mishnah that was already considered above.

The wife receives, each week, two *kav* of wheat with which to make bread. This quantity must suffice for 16 meals: 14 meals for herself and two additional meals for her husband on Sabbath or, according to others, for the poor or for guests. Therefore, she has 1/8 *kav* of whole wheat per meal. We know that one *kav* of water weighs 640 *denarius*. Therefore, two *kav* of wheat, of a density equal to 0.78, will weigh 0.78 x 2 x 640 = 998.4 *denarius* or 3,405.54 gr.

For each meal, she has 212.78 gr of whole wheat, which enables her to bake 1.29 x 212.78 = 274 gr of bread.[31] This result is in full accordance with the conclusion of the former paragraph, following Rabbi Johanan ben Beroka, on condition that the husband provides his wife with the wood or coal necessary for baking the bread. So the baking of the bread is her responsibility, while the poor person is not able to or in a state to bake his own bread.[32] This quantity of 274 gr per meal, twice

30 In Peah VIII: 5, the Mishnah enumerates the different categories of food in an additive manner, as if the poor person had a right to all these foods: a half *kav* of wheat, one *kav* of barley and a *kav* of dried figs. Maimonides in H. Matanot Aniyim VI: 8 enumerates the same foods in an exclusive manner: half a *kav* of wheat, or one *kav* of barley, or one *kav* of dried figs, or one *mana* of pressed figs. He probably justifies his understanding of the Mishnah by the comparison with Mishna Ketubot V: 8, where the wife of the poor worker receives two *kav* of wheat or four *kav* of barley. Furthermore, she receives only a *kav* of dried figs or a *mana* of pressed figs for a whole week, corresponding to 18 dried figs for 16 meals. Maimonides has thus logically concluded that the unknown poor need not receive more than the wife of the worker. It is therefore not necessary to justify the ruling of Maimonides by a different version of the text of the Mishnah, as proposed by Radvaz.

31 In practional terms, this is her ration. She still has half a *kav* of chickpeas (0.25 of the quantity of bread) and a little more than one dried fig per meal. This is really a minimal subsistence level.

a day, without fish or meat, and augmented by a very limited quantity of vegetables and fruits, indeed represents a minimal livelihood. A quantity of 137 gr per meal, twice a day, would almost be a subsistence regime.

10. קב גרוגרות ומנה דבלה Mishna Ketubot V: 8 and Mishna Peah VIII: 5[33]

Mishna Ketubot V: 8, deals with a poor man working during the week far from his home, who entrusts another person with the responsibility of providing a living for his wife. The Mishnah enumerates the quantity of different foods that this man must provide for the former's wife. Among them are figs, dried figs, which – like the other elements – are measured by their volume, and a bread of figs, which must be measured by its weight.[34]

Mishna Peah VIII: 5 deals with the quantity of food that one must give to the poor in the barn when one distributes מעשר שני. From this enumeration, it appears

32 We have seen that the minimum quantity of bread per meal is 274 gr. This quantity can be compared with the quantity of *man* that the people received in the desert, i.e. one *issaron* a day or 7.2 *log* a day or 3.6 *log* per meal. This seems a lot compared to the quantity of bread allowed to the wife or to the poor. This question has been raised in Tosafot Rid in B. Ketubot 64b. Tosafot Rid brings the answer of R. Shalom Gaon, who says that one should not confuse the minimal quantity with the maximal quantity. Nevertheless, the minimal quantity is 1/8 *kav* while the maximal quantity is 0.9 *kav*, which gives a ratio of 7.2! A better, or at least a complementary, explanation is perhaps that the *man* was probably a substance similar to snow, with a very low density. If we consider a density of 0.1, then the weight of this meal would be 3.6 x 0.546 x 0.2 = 0.39 kg. The importance of the volume of the meal of the *man* had already puzzled Cardinal Cumberland and William Whiston, both English authors of the 17th century. In connection with the *issaron* of the desert, the following passage raises difficulties. In B. Eruvin 83a, it says: מכאן אמרו האוכל כמדה זו הרי זה בריא ומבורך, יתר על כן רעבתן פחות מכאן מקולקל במעיו. The *issaron* represents, according to Maimonides: 0.074375 x 4 x 7.2 = 2.142 dm^3. This volume of meal weighs about 1.43 kg and allows for the preparation of 1.83 kg of bread. According to the conclusions of this paper, this *issaron* is equal to 7.2 x 0.54575 = 3.93 dm^3, and this volume of meal weighs 2.62 kg and allows the preparation of 3.3 kg of bread. This seems rather a large quantity, and certainly not an average and recommended quantity. R. Jacob Emden seems to dispute this objection, and writes: certainly for average people, but evaluated according to their generation (of the Exodus) he brings some examples of their great capacity for eating. Similarly, the cakes that Abraham commanded Sarah to prepare were made with three *seah* meal, representing one *eifa*, equal to 3 x 24 x 0.54575 = 39.29 1, weighing 26.20 kg!

33 The fresh fig or תאנה, when it is dried, is called גרוגרת. It is also cut up into slices, which are dried and called קציעות. These are then pressed together in order to get a bread of dried figs, called דבילה.

34 Rashi writes explicitly in B. Eruvin 29a and in B. Ketubot 64b: לאחר שנדרסין בעיגול קרי להו דבלה ושוב אינו מוכר במדה אלה במשקל.

that both quantities should be equivalent. We know, according to the *Sillian Plebiscitum*, that the weight of the water contained in one *congius* is 10 *libra* or 960 *denarius*, and the weight of one *sextarius* is 10/6 *libra* or 160 *denarius*. If, as already seen above, one *log* is equal to one *sextarius*, then 1 *log* water = 160 *denarius* and a *kav* of water = 4 x 160 = 640 *denarius*. If we assume that the density of dried figs is about 1.2, then the weight of one *kav* of dried figs is 768 *denarius* or about 2,619 gr. These figures should be divided by about 1.5 in order to take into account the empty space between the dried figs, i.e. 512 *denarius* or 1,746 gr. Now one *mana* is equal to 100 *denarius* and weighs 341 gr. The only way to solve this discrepancy is to consider that the capacity of one *kav*, mentioned in this passage, relates to the original fresh figs, which, after drying, become considered as *grogerot*.[35]

11. The *Litra*, a Unit of Weight used as a Unit of Capacity

The *litra* is a unit of weight used in the Talmud. It is equal to 96 *denarius* and is thus very similar to the *mana*, which is worth 100 *denarius*. In the Talmud, both units are often confused.[36]

The Mishna Terumot X: 8 writes about the quantity of unclean fish that forbids a pickle of fish:

> דג טמא שכבשו עם דג טהור כל גרב שהוא מחזיק סאתים, אם יש בו משקל עשרה זוז ביהודה שהן חמש סלעים בגליל דג טמא, צירו אסור

35 In Mishna Terumot IV: 10: בדורס ליטרא קציעות על פי הבד, Maimonides writes: ליטרא משקל ידוע וקציעות התאנים היבשות ואומר כי מי שלקח ליטרא תאנים וכשתן..... Our assumption is thus likely, and is accepted by Maimonides. Now, according to B. Eruvin 80b, 18 dried figs constitute two meals. According to Maimonides, two meals represent a volume of food of three eggs (H. Eruvin I: 9 and H. Sabbath VIII: 5). According to Rashi, however, a normal meal is a volume of food of four eggs (see B. Pesahim 44a, Rashi in two places, and B. Eruvin 4a in Rashi). Rashi writes: הלכה למשה מסיני דחצי כיכר של שמונה ביצים הוא זעודה. Therefore, the volume of a dried fig is 0.44 egg. If we assume that a fresh fig has the same volume as three dried figs, then one fresh fig is 1.32 eggs and 18 figs are about 24 eggs – and correspond to one *seah*. In fact, Rashi in Menahot 54b writes that a fresh fig is at least two dried figs: דכלי המחזיק מאה גרוגרות לא מחזיק טפי מחמישים תאנים. Furthermore, some commentators who consider a normal meal to be a volume of four eggs of food also consider it a necessity to have 24 dried figs for a normal meal: see Tosefot Yom Tov on Mishna Kelim IV: 2, based on R. Ovadia of Bertinoro, on Mishna Eruvin VIII: 2.

36 In B. Sanhedrin 70a: נמצא תרטימר חצי מנה , but in the parallel passage in Y. Sanhedrin VIII: 2: אמר רבי יוסי: טרטימר חצי ליטרא הוא.

Y. Terumot X: 8[37] writes:

> כמה סאתא עבדא, עשרין וארבע לוגין, וכמה לוגא עביד תרתין ליטרין, וכמה ליטרא עבדא מאה זינין, נמצא כל זין וזין אחת מתשע מאות וששים

These passages have not been understood correctly.[38] We will show that the units of capacity quoted in this passage – *seah* and *log* – are Jerusalem units of capacity.[39] Indeed, we know that a *log* of water weighs 160 *denarius*, i.e. 160 *zouz*, not 200 *zouz*. But the Jerusalem *log* of water is 20 percent greater and weighs 192 *denarius*, i.e. two *libra* (the talmudic *litra*). The statement of the Jerusalem Talmud that a *log* is two *litra* is thus rigorously correct if we consider a Jerusalem *log*. The statement of the Jerusalem Talmud that the *litra* is 100 *zouz* is only approximate. Although the *litra* is often confused with the *mana*, here the *litra* is rigorously 96 *zouz*; therefore, the two Jerusalem *seah* (of water) weigh exactly 9,216 *zouz*, and the proportion leading to the proscription of the pickle of fish is actually 1/921.6 in weight, as long as the density of the mixture is one. If the density of the mixture is 1.04, then the weight of the Jerusalem *log* of pickle is actually 200 *denarius*, i.e. two *mana*, and the two Jerusalem *seah* of pickle indeed weigh 9,600 *denarius*. The proportion is then 1/960.

In conclusion, the *litra* is equivalent to the Roman *libra*; it weighs 96 *denarius*, and represents the weight of half a Jerusalem *log*. The units of capacity mentioned

37 Y. Terumot X: 5 in the edition of Vilna.

38 This passage has always been understood as dealing with the *seah midbarit*. R. Yom Tov Lipman Heller thought that the weights of the Jerusalem Talmud are 2.87 times greater than those of the Rambam. The truth is that the *log* of Maimonides is 4 x 74.375 = 297.5 cm^3, while the *sextarius* is about 545.75 cm^3. This gives a ratio of 1.834. The apparent ratio is 100/35 = 2.857, because the *lira* is equal to 100 *denarius* in the Jerusalem Talmud, and to 35 *denarius* according to Maimonides. Let us now take into account the following points: the *litra* is actually 96 *denarius*, the *litra* is equal to 2.4 *revi'it* and not 2 *revi'it* and, therefore, the *litra* is equal to 80 *denarius*, and not to 100 *denarius*, the *dinar* in the Talmud is about 3.41 gr and not 4.25 gr. The corrected ration will then become: (80/100) x (3.41/4.25) x 2.857 = 1.834. See Madanei Yom Tov Berahot III: 30 § 80. We see therefore that the data of Y. Terumot X: 8, if we neglect the approximation *litra* = *mana*, is rigorously exact, and gives us a full confirmation of our theory that the *log* is equal to the *sextarius*. If this passage had been correctly understood, particularly in that the capacities are capacities of Jerusalem, then many problems would have been solved.

39 This passage shows how cautious we must be in the interpretation of the Mishnah when dealing with units of capacity. There are many references showing that the Mishnah uses, without clear distinction, the different types of units of capacity, sometimes even in the same Mishnah.

in this Mishnah are Jerusalem units of capacity. The *litra*, which is generally[40] used as a unit of weight, can also be used as a unit of capacity;[41] it represents the capacity of water weighing a *libra* or *pondo*. It is equal to half a Jerusalem *log*. We have already observed, in Roman metrology, that there is a relationship between the units of capacity and the units of weight, and that a *congius* of water weighs one *pondo*. Therefore, it makes sense that, in talmudic metrology, the units of capacity are also used as units of weight representing the weight of the water contained in this capacity. But this is contrary to the accepted notion that the *litra* is equal to 1/2 *log*[42] of Jerusalem or to 2.4 *revi'it* of Moses, and not to 1/2 *log* of the desert or two *revi'it* of Moses, as is generally accepted. Furthermore, this passage of Y. Terumot proves that the units of capacity are the large units and not the small units, the *log* being equal to the *sextarius*.

The exegesis of this Mishnah raises the problem of the correct interpretation of the type of unit of capacity mentioned in each Mishnah. In our Mishnah, according to the interpretation of the Jerusalem Talmud, we are dealing with the units of capacity of Jerusalem. It is often difficult to decide whether we are dealing with

40 Almost all the mentions of the *litra* in the Talmud and *midrashim* concern the unit of weight. See for example B. Bava Batra 89a and Sifrei 162 (on Deuteronomy 25:13).

41 The *litra* appears as a unit of capacity in our passage in Mishna Terumot X: 8. It is also probably a unit of capacity in the following quotations: B. Nedarim 59a, ליטרא בצלים; B. Eruvin 29a, עוכלא תבלין וליטרא ירק; B. Hulin 84a, ליטרא ירק, ליטרא בשר, and B. Sanhedrin 94 מ' סאה גוזלות בקינוז סעודה.....ליטרא ירק בסעודה. In all these cases, we are dealing with the measure of a quantity of stuff that can be measured in standard receptacles. This is unlike the case of inflexible items like bread or bread of figs, which cannot be measured this way and require weighing. It seems they tried to avoid the weighing whenever possible. In B. Eruvin 29a, Rashi writes explicitly that *litra* means a unit of capacity of vegetables, but in B. Hulin 84a, he writes: the weight of one *litra* vegetables. Maimonides, who writes that *litra* always means half of a *log*, nevertheless writes in Hilkhot Matanot Ani'im VI: 8 a *litra* of vegetables, i.e. the weight of 35 *dinars* (35 x 4.25 = 148.75 gr).

42 As already noted, the Rabbis did not believe that we are dealing in this Mishnah with the measures of Jerusalem. Maimonides writes in Hilkhot Eruvin I: 12 that the *litra* is always 1/2 *log*. Therefore, according to him, *ad locum*, 1 *mana* = 100 *denarius* and 1 *litra* weighs only 35 *denarius*, in contradiction to Y. Terumot X: 8.
Rashi writes in B. Eruvin 29a that the *litra*, as a unit of capacity, is worth one *log*. The position of Rashi, although in contradiction to Y. Terumot X: 8, is coherent. We know that Rashi had a good knowledge of the talmudic weights because he lived in the Roman Empire. He knew that the *litra* was about 340gr, and 0.96 of the *mana*, and he could equalize this volume of 340 cm^3 water only with a *log* because Rashi, like most of the *rishonim*, took only small units of capacity into account. Therefore, the correction by the *Gra* is not consistent with Rashi's commentary.

units of Moses or with others; there is even one instance where two different types of units of capacity appear in one Mishnah.[43]

12. About the *Modius*

The *modius* is a Roman measurement of the capacity of dry contents, which is cited several times in the Talmud. B. Eruvin 83a writes that Bonios sent Rabbi a *modius* of artichokes that came from Nausa.[44] Rashi and R. Hananel explain that the *modius* is a *seah*. The *modius* is actually equal to 16 *sextarius*, while the *seah* is equal to 24 *log*, or, now that we have demonstrated that the *log* is equal to the *sextarius*, to 24 *sextarius*. It is then, at first glance, strange to find the equating of the *modius* and the *seah*.[45] There is a talmudic principle that, in dry capacities, the matter heaped above the utensil used to measure capacity, גודש, represents half of the capacity of the utensil, i.e. a third of the total capacity.[46] If we apply this principle to the *modius*, we see that the utensil itself has a capacity of 16 *sextarius*, but the heap above the utensil is eight *sextarius* and the total is then 24 *sextarius*.[47] This

43 See Mishna Eduyot I: 2, where Shamai considers that a pastry of 1 *kav* (of Moses) is used for *hallah*, while Hillel considers that only a pastry of 2 *kav* (of Moses) is concerned. But the Sages fix the volume of the pastry used for *hallah* to 1.5 *kav* (of Jerusalem) or 1.8 *kav* of Moses. Similarly, in Mishna Yoma IV: 4, according to Rav Ashi, the Mishnah should be understood in the following way: בכל יום היה חותה בשל סאה (מדברית) ומעירה לתוך שלושת קבין (ירושלמיות).

44 According to Jastrow, the *modius* was copied from the standard measure of the temple of Nausa.

45 Josephus in *Jewish Antiquities*, Book IX, chap. 4, sect. 5, says that the *seah* is equal to 1.5 Italian *modius*.

46 See B. Eruvin 14b and B. Sabbath 35a: האי גודשא תילתא הוי.

47 If the heap above the utensil represents 50 percent of the actual capacity of the utensil, this utensil must be quite flat. Rashi explains that the utensils were cylindrical with a height equal to the radius. If H is the height of the cylinder, R its radius and h the height of the heap, then the volume of the cylinder is: π h R^2 and the volume of the heap is: 1/3 π h R^2. The condition is then: π HR^2 = 2 x 1/3 π h R^2.
According to Rashi, H = R, we then have the condition: h = 3/2 R. The slope of the heap is then α with tang α = 3/2 and α = 56.31º. Of course such a heap, with a slope of 56.3º, will be unstable and will slide; the assumption of Rashi about the shape of the utensil of dry capacity is not realistic. If we consider that the height H of the utensil is equal to R/2, then the capacity of the utensil is 1/2 π R^3. The condition is now the following: 1/2 R^3 = 2/3 π h R^2 and therefore h = 3/4 R; tang α = 3/4 and α = 36.87º. Even this slope of 35.87º is too great and at the limit of instability. The slope should be less than 30º. The only way to get a satisfactory solution is to consider a utensil in the shape of a portion of sphere.

gives us an acceptable justification of the use in the Talmud of the Roman *modius* for the *seah*,[48] and confirms our equating of the *log* with the *sextarius*.

48 This proves that the capacity of this *modius*, which Rabbi estimated to be 144 eggs, was not, as is generally accepted, the volume of liquid of the box. Rather, it represents the number of eggs that can be stored in it, multiplied by 1.5 to take the heap into account (see the section about the problem of the eggs in talmudic metrology). It is generally accepted that the *seah*, which is a unit both of dry and liquid capacities, always has the same volume. It seems that it is only because of the lack of a correspondent Roman unit that they used the *modius*, equal to 16 *sextarius*, as a correspondent unit of the *seah*, equal to 24 *sextarius*, even though the *seah* is 1.5 *modius*, on account of the principle האי גודשא תילתא הוי. There is nevertheless a strange passage in Y. Terumot V: 1, which mentions in the name of Rabbi Abbahu the following: כמה סעה עבדה, תשעין ושית בעין; the *seah* thus represents 96 eggs while in B. Eruvin 83a it is said that the *seah* of the desert represents 144 eggs (in B. Eruvin 83a also, we are dealing with a unit of dry capacity). If we consider the following passage: Y. Terumot V: 1 (R. Abbahu):
קבא כמה עבד? עשרין וארבע ביעין, כמה סאה עבדה? תשעין ושית ביעין, then 1 *seah* = 4 *kav* = 96 eggs. This passage contradicts Y. Terumot X: 8: כמה סאתא עבדא? עשרין וארבע לוגין, from which we can deduce the generally accepted equation: 1 *seah* = 6 *kav* = 24 *log*.
The only plausible explanation is that if, generally, the *modius* was considered synonymous with the *seah*, in this passage Rabbi Abbahu identified the *seah* with the *modius*. This quotation is probably the origin of the following passage of the Kalir in אז ראית וספרת belonging to the Yotzer of Parashat Shekalim יוצר לפרשת שקלים: וסאת יבש חסרה שליש בלח וסאת הלח אחד משלשה בבת. In any case, this citation of Rabbi Abbahu remains a very difficult passage. Sperber (1965), p. 270, basing himself on Epiphanius, has suggested the possible existence of another parallel standard: 1 *seah* = 4 *kav* = 16 *log* = 96 eggs instead of the accepted standard: 1 *seah* = 6 *kav* = 24 *log* = 144 eggs. It would be strange, however, that such a parallel standard would appear in only one case, as late as the end of the third century at the time of Rabbi Abbahu. There is other evidence in the Talmud that 1 *seah* = 6 *kav* = 24 *log* = 96 *revi'it*. In B. Pesahim 109b (also in many other places), it is written that a *miqveh* is three cubic cubits and, in the same way, it writes in B. Pesahim 109a that a *revi'it* is 2 x 2 x 2.7 = 10.8 e^3. From these two equivalent equations we can conclude that: 40 *seah* = 3 x $(24)^3$ = 41472 e^3. Therefore, 1 *seah* = 41472/10.8 x 40 = 96 *revi'it* and, necessarily, one *seah* is equal to six *kav*. There is other evidence in both the Talmudim that one *seah* is six *kav*. In B. Bava Batra 89b and 90a (and similarly in Tosefta Bava Batra V: 4, in B. Sotah 8b and in Y. Sotah I: 7) we find the following passage (according to the corrected text in the Steinzalts edition):
אבל עושה הוא סאה תרקב וחצי תרקב וקב וחצי קב ורובע ותומן וחצי תומן ועוכלא ובמדת הלח הוא עושה הין וחצי הין ושלישית ההין ורביעית ההין ולוג וחצי לוג ורביאית ושמינית ואחד משמונה בשמינית וזהו קורטוב.
See also a very similar enumeration in Rambam, *hibur*, Hilkhot Genivah VII: 7. In the first enumeration there is a transition from the submultiples of the *seah* to the *kav* because the *seah* is worth six *kav*, not four. Similarly, in the second enumeration, there is a transition from the submultiples of the *hin* to the *log* because the *hin* is worth 12 *log*. If the *seah* was worth four *kav*, then חצי תרקב would be equal to a *kav*.
In conclusion: 1 *kav* = 24 eggs (Y. Terumot V: 1); 1 *seah* = 6 *kav* (above); 1 *seah* = 24 *log* (Y. Terumot X: 8) and, finally, 1 *seah* = 144 eggs. This confirms that in B. Eruvin 83a the

13. The Load of 30 *Log* Oil Lifted up on a Ladder of Fifty Cubits by Young Priests

Mishna Sukkot V: 2 discusses the festivities on the evening following the first day of Sukkot. Four branched candlesticks were erected in the courtyard of the Temple, with a vessel at their top, at a height of 50 cubits.[49] Four ladders were placed in front of the candelabra, and four young priests each lifted a utensil of 30 *log* of oil onto the ladder and poured the oil into the vessel on top of the candlestick. The Talmud[50] says that these young men were more praised than the son of Martha, the daughter of Boethos, who was able to raise two flanks of an ox and place them on the altar. It was then considered a true achievement. Therefore, it seems that a *log* of 0.545 l is more likely than a *log* of 0.272 l because the lifting of a load of about eight kg does not seem to be an exceptional achievement. On the contrary, lifting a load of 16 kg on a ladder at a height of about 26 m is more impressive.

14. The Washing and Purification of the Hands with a *Revi'it* of Water

The beginning of the first Mishnah in Yadayim states: מי רביעית נותנין לידים לאחד, אף לשנים.

Two men can purify their hands, one after the other, with one *revi'it* of water. According to the plain explanation of the Mishnah, each of them must wash his hands a first time (מים ראשונים), and then a second time (מים שניים). In other words, both hands must be wetted twice on both sides, on all their surfaces, included the area between the fingers. This seems again to militate in favor of the larger measure, of one *revi'it* being equal to about 139 cm^3. This is all the more true because the Mishnah describes the washing of people's hands by servants,[51] and because of the ruling that if it appears that the first washing is incomplete,[52] the entire washing

modius of 144 eggs was equal to a *seah*. as Rashi writes that the *modius* is the designation of the *seah*. The passage in Sifrei 163 on Deuteronomy 25: 14, יכול לא יעשה קב תרקב וחצי תרקב ורביע תרקב is more problematic, because the two last denominations represent respectively 1.5 and 0.75 *kav*.

49 See B. Sukkot 52b.

50 Ibid.

51 נותנין לידים means that a servant washes your hand, נוטלין לידים means you wash your own hands (see Mishna I: 5 and Tosefta I: 7). Therefore, the correct reading in Mishna I: 5 must be והקוף נותן לידי.

52 Mishna Yadayim I: 1, if the surfaces of the hands are not correctly wetted, the hands must be dried and the washing must begin again. Therefore, the servants, although parsimonious in the use of the precious water, could not afford themselves such an affront.

cannot be completed.[53]

15. Conclusion

One of the big challenges raised by talmudic metrology is the determination of the talmudic units of capacity. We have succeeded in fixing definitively the talmudic

53 It must nevertheless be observed that there are many divergent opinions about this Mishnah.
1. Maimonides understands that Mishna Yadayim I: 1 deals with מים שנים, but normally a man needs a whole *revi'it* in order to wash his hands correctly, whether he washes for eating *hulin* (Hilkhot Berakhot VI: 4, he must pour water only one time on each hand), or whether he washes for eating *terumah* (Hilkhot Mikvaot XI: 3 and 8, he must pour water twice on each hand). All other commentators understand differently (see especially Rabad on Hilkhot Mikvaot XI: 8).
2. Maimonides does not clarify the meaning of the superior boundary of the hand עד הפרק (see Hilkhot Berakhot VI: 4 and Hilkhot Mikvaot XI: 4). It is generally accepted that he follows the opinion of the Rif (see *infra*) and believes the hands must be washed up to the wrist joint of the arm (see Kessef Mishneh on Hilkhot Berakhot VI: 4). It should be noted, in support of this opinion, that he writes in his commentary on Mishna Erakhim V: 1, אף על פי שהיד ודאי הוא עד פרק הזרוע.
3. There are also divergent opinions about the meaning of עד הפרק, the limit to which the hand must be washed.
   a. The Rif believes that one must wash the hands in all instances up to the joint of the arm. This is not clear according to our text of the Rif in Berakhot, but this was the reading of the Ran (Ran on the Rif in Berakhot 41b) and of R. Karo (Kessef Mishneh on Hilkhot Berakhot VI:4).
   b. R. Gershom, in B. Hulin 106b, understands: the first joint of the fingers for *hulin*, the second joint of the finger for *terumah*.
   c. Rashi, in B. Hulin 106b, understands: the second joint for *hulin*, the third joint for *terumah*.
   d. See also *Tosafot* in B. Hullin 106b, אמר רב.
   e. In B. Bekhorot 45a, discussing a completely different topic connected with physical disabilities of priests, Rashi writes: עד הפרק: האמצעי של האצבעות.
4. There is a serious objection against the opinion of Maimonides, that when washing for *hulin*, one needs to pour water on the hands only one time, from B. Sota 4b where the Talmud writes about washing for *hulin*: צריך שיגביה ידיו שמא יצאו המים חוץ לפרק ויחזרו ויטמאו את הידים. It appears clearly that, even washing for *hulin*, one needs מים ראשוני and מים שניים. Futhermore, Maimonides has, incomprehensively, written this law in Hilkhot Berakhot XI: 16 when this law, according to his opinion, applies only when washing for *terumah*. The justification of this law is found in Hilkhot Mikvaot XI: 4. This objection, to the best of my knowledge, has never been raised.

It appears that even Maimonides, who considers pouring water only one time on both hands for *hulin* to be adequate, in the case of *terumah* needs to completely wash both hands twice, until the joint of the hand on the arm with one *revi'it*. His *revi'it* of about 75 cm^3 seems barely enough for that purpose. Nevertheless, because of all these contradictory opinions, this point is probably not the most convincing evidence about the capacity of the *revi'it*.

units of capacity with regard to the Roman units of capacity.

1 *eifah* = 1 *bat* = 3 *seah* = 6 *hin* = 18 *kav* = 72 *log* = 144 *touman* = 288 *revi'it*.

1 *metretes* = 3 *urna* = 4.5 *modius* = 9 *semimodius* = 12 *congius* = 72 *sextarius* = 144 *hemina* = 288 *quartarius*.

eifah = metretes
seah = urna
1 *hin* = 2 *congius*
1.5 *kav* = 1 *congius*
log = sextarius
touman = hemina
revi'it = quartarius

III. FUNDAMENTAL RELATIONS OF THE TALMUDIC SYSTEM OF UNITS

1. Relations between the Talmudic Units of Capacity and of Weight

We have seen that the talmudic units of capacity are equal to the Roman units of capacity; similarly, the talmudic units of weight are equal to and have the same name as the Roman units of weight. We can depart from the fundamental relationships of the Roman system:
1 *congius* = 10 *pondo*; 1 *sextarius* = 10/6 *pondo* = 160 *denarii*.
We can then write: 1 *sextarius* = 160 *denarii*.

1 *miqveh* = 960 *sextarius* = 153,600 *denarii* = 1600 *pondo* = 523,920 cm^3.

2. Relationship between the Talmudic Units of Capacity and the Talmudic Units of Length

The talmudic units of capacity are equal to the Roman units of capacity, and the talmudic units of length are directly deduced from the Roman mile. We can depart from the fundamental relationship of the Roman system:
$(1 \text{ Roman foot})^3 = 1$ *amphora*.
$(f)^3 = 1$ *amphora* = 48 *sextarius*.
Now, 1 Roman mile = 5000 f = $2000\sqrt{2}$ c (f = Roman foot; c = talmudic cubit).
Thus f = $0.4\,c\sqrt{2}$ and, therefore, we get the relationship: $(0.4c\sqrt{2})^3$ = 48 *sextarius*, or: $3.62\,c^3$ = 960 *sextarius* = 1 *miqveh*.

Conclusion: we can deduce the fundamental relationship of the talmudic system from the fundamental relationship of the Roman system of measurement:

1 *miqveh* = 960 *log* = 3.62 c^3

This relationship has been established on the assumption that the quadrantal relationship is rigorously exact. If we consider that the cubit c is equal to 52.38 cm and the *log* is equal to the *sextarius*, which is equal to (327.45 x 10)/6 = 545.75 cm^3, then the relationship becomes:

1 *miqveh* = 960 *log* = 3.6456 c^3.

We can compare this relationship to that given in the Babylonian Talmud:

1 *miqveh* = 960 *log* = 3 c^3

We must then consider several possibilities:

a. The relationship given in the Talmud, that the dimension of the *miqveh* is three cubic cubits, which the Sages estimated to be forty *seah*, is a very rough estimation. Nevertheless, the Rabbis throughout history have considered this relationship to be precise. Therefore, we will rule out this possibility.
b. The estimation that the *miqveh* is three cubic cubits is ancient, but it was maintained, and it remained valid after the alignment of the talmudic system of units with the Roman system of units, because the units of Moses were very close to the Roman units. This alignment happened without notable change. Then, in order to reconcile the two contradictory formulas, we must assume that the relationship between the *seah* and the cubit is expressed in generous cubits. The relationship given by the Talmud was probably, at its origin, an exact relationship; it was preserved after the alignment with the Roman units, on condition that it would now be expressed in generous cubits.
c. The estimation that the *miqveh* is three cubic cubits is recent; it was made during the talmudic period, after the alignment of the talmudic system of measurement with the Roman system. We must also admit, in this case, that the relationship between the *seah* and the cubit is expressed in generous cubits.
   The ratio between generous and strict cubits will be the cubic root of (3.6456/3) = 1.067.
   This ratio is close to the ratio of 1.05 proposed by R. Jacob Emden.[54]
d. The estimation that the *miqveh* is three cubic cubits is ancient and is certainly anterior to the alignment of the talmudic system of units with the Roman system

54 See Weiss (1984), p. 213.

of units. The difference between the coefficient 3 of the original case in point and the coefficient 3.6456 of the new case in point accounts for this evolution: the cubit diminished slightly and the units of capacity increased slightly. For example, the cubit diminished by about 5 percent and, from an original value of 0.55 m, became a new value of 0.5238 m, whereas the units of volume increased by about 5 percent and the *log* was enlarged from 519.92 cm^3 to 545.75 cm^3. The volume of the *miqveh* equal to 960 *log* grew from 499,123.2 cm^3 to 523,920 cm^3, and the *miqveh*/cubic cubit ratio increased from 3 to 3.6456.

Based on this assumption, the original cubit was about 55 cm; it was multiplied by 0.95 and reduced to 52.38 during the alignment with the Roman system of units. This reduction was for the sake of security for the Sabbath limit (because the *thum* Sabbath would be undervalued). But in other cases, such as Sukkah or Kilaim, this was not the case. In these cases, therefore, we must use a generous cubit of 1.05 cubits in order to find the lengths prescribed by the Torah.

The original *log* was about 519.92 cm^3, it was multiplied by about 1.05 and fixed at 545.75 cm^3. This was generally to be on the safe side, especially for the obligation of *miqveh* (because the practical *miqveh* would then be greater than the minimum theoretical dimension). Nevertheless, in the case of the estimation of the *revi'it* to determine the quantity of wine that may be drunk by the Rabbi who learns or judges, we do not need to be so meticulous, and it is likely that in this case the difference was neglected. This seems also to be the case for the determination of the volume of the pastry from which *hallah* must be made. In this particular case, it is possible that Rabbi Yanai lowered the minimum capacity of the pastry used for *hallah* to ensure that no submitted pastry could escape its obligation. See *infra*.[55]

e. Conclusion

The different solutions described above rest on two divergent assumptions. The first assumption is that the units of capacity of Moses, or more precisely most of the units of capacity of Moses, were equal to the corresponding Roman units of capacity. This was indeed the position of Rabbi Samson ben Abraham of Sens in his commentary on Mishna Kelim XVII: 11. The relationship 1 *miqveh* = 960 *log* = 3 cubic cubits must then be understood with generous cubits of about 1.06 strict cubits. It would nevertheless be strange to have such a coincidence not only for the system of units of capacity but also for the units of length (the same mile) and for

55 See *infra*: Back to the Units of Tzipori.

the units of weight. In this last case, we are nevertheless speaking, according to the *geonim* and R. Samson of Sens,[56] about the weights of Moses, which were equal to the Roman weights of the first century, while the units of capacity and length were more stable and not subject to modifications because of the interest of the Prince. I therefore believe that the second assumption is more likely: the units of Moses and of Rome were completely independent from one another, but were actually only slightly different. It is the Sages around the time of the beginning of the Common Era, at the end of the Second Temple period, who decided, *nolens volens* (whether on their own initiative or despite their objections), to attach the talmudic units of measurement to the Roman system of measurement, and to adapt the former units by a few percent. It is certain, by the time of Rabban Gamliel of Yavneh, that the equality between the talmudic and the Roman units of measurement was an accepted fact.[57] The relationship of 40 *seah* = 3 cubic cubits was at the origin of a rigorous formula understood with strict cubits. After the adaptation it must be understood with generous cubits of about 1.05 strict cubits.

3. Back to the Units of Tzipori

Now that we have demonstrated that the *log* is equal to the Roman *sextarius* and to the Greek *xestes*, let us come back to the following passage in B. Pesahim 109a:

אמר רבי יצחק קסתא דמורייסא דהוות בציפורי היא הוות כמין לוגא דמקדשא

The *log* is actually equal to the *sextarius* or to a Greek *xestes*, and therefore the *kesta* used for measuring the muries in Tzipori in earlier times was indeed a *xestes*. Let us now consider the following passage in Y. Pesahim X: 1:

לוגא דאורייתא תומניתא עתיקתא דמורייסא דציפורין

It must be corrected: indeed we now know that the old measures of muries of Tzipori were aligned with the units of capacity of Moses, the *xestes* being equal to a *log*, and the eighth part of the *kav* used for the muries in Tzipori was necessarily equal to half a *log*. Therefore, the text should be corrected[58] to:

פלגא לוגא דאורייתא תומניתא עתיקתא דמורייסא דציפורין

or to לוגא דאורייתא קסתא עתיקתא דמורייסא דציפורין

56 See his commentary on Mishna Sheviit I: 2.

57 See the account of the journey of Rabban Gamliel to Kziv. See the following references: Tosefta Pesahim II: 9, Y. Avoda Zara VII: 2, Leviticus Rabbah 37: 3. See also a divergent reading in B. Eruvin 64b.

58 This is contrary to the explanation of Weiss (1984), p. 291; p. 377 note 5; p. 380.

which is parallel to the passage in B. Pesahim 109a, mentioned above.

4. Back to the Units of Tiberias

We have seen that the units of Tiberias were equal to the units of Moses until the third century, during the life of Rabbi Johanan, when they were devalued by 20 percent, so that the *revi'it shel Tora* was now 5/4 of the new *quartarius*. Y. Hallah II: 6[59] writes:

> ר׳ אמי בשם ר׳ ינאי: קב טבריני חייבת בחלה, חד חליטר שאל לרבי יוחנן אמר איזיל עבד ארבע ופליג, ויאמר ליה תלתא ופליג, אמר ר׳ זעירי קבייא באתריהון ריבעא אזדרון, ויאמר ליה חמישה פרא ציבחר, שלא יבוא לידי ספק חיוב חלה.
>
> Rabbi Ami said, in the name of Rabbi Yanai: a pastry of a *kav* of Tiberias must be used for *hallah*. A certain Halitar asked Rabbi Johanan which pastry he could prepare without it being used for *hallah*. He answered him 4.5 *log*. But he should have answered 3.5 *log* [in order to remain under a *kav*]. R. Zeiri said, in their place [in Tiberias], the *kav* was devalued by 20 percent [25 percent of the new value], and therefore the *kav* which is used for *hallah* is actually five new *log*. He should then have advised him to prepare a pastry of a little less than five new *log*! He wanted to give him a margin of security in order not to transgress the obligation of *hallah*.[60]

We are thus still dealing with the consequences of the devaluation of the units of capacity of Tiberias during the third century. The problem now is why Rabbi Yanai and his pupil Rabbi Johanan decided that a pastry of one *kav* has to be used for *hallah* according to Shamai, and not two *kav* according to Hillel or 1.8 *kav* according to the Sages (and the Halakhah)?[61]

I propose the following answer. According to our former assumption, when the Sages decided to attach the talmudic units of measurement to the Roman units of measurement by a slight adaptation of a few percent (the diminution of the units of length and the increase of the units of capacity by about 5 percent), some pastries that were between 1.7 and 1.8 modern *kav*[62] could escape the obligation of *hallah*. Instead of creating a new limit of 1.7 *kav*, which has no basis in the Mishnah, they probably decided to adopt the limit of one *kav*, as taught by Shamai, in order to

59 Y. Hallah II: 5 in the edition of Vilna.

60 This illuminating explanation was proposed by Borenstein (1886).

61 See Mishna Eduyot I: 2.

62 1.7 modern *kav* corresponds to 1.8 ancient *kav* or the original *kav* of Moses, and reducing *hallah* is required.

make sure that no submitted pastry could escape its obligation.[63] The reason behind this ruling was later forgotten and neglected. If our assumption is correct, we can pinpoint the epoch of the adaptation of the talmudic units of measurement to the Roman units of measurement. This epoch seems to be posterior to Hillel and Shamai. On the other hand, we already mentioned that by the time of Rabban Gamliel of Yavneh, the grandson of the grandson of Hillel, the equivalence between the talmudic units and the Roman units was an accepted fact. Apparently, scholars like Rabbi Yanai were still aware of the original slight difference, and therefore Rabbi Yanai ruled according to the opinion of Shamai.

5. The Relationship between the *Etzba* and the *Revi'it*

If we consider the relationship of 1 *miqveh* = 40 *seah* = 3 cubic cubits,[64] we can write:

1 *miqveh* = 960 *log* = 3840 *revi'it* = 3 $(24e)^3$ = 41,472 e^3 e = *etzba*

or 1 *revi'it* = 10.8 e^3

We find also in the Talmud a similar relationship:[65] the *revi'it* is 2e x 2e x 2.7e = 10.8 e^3.

In many instances, the Jerusalem Talmud mentions[66] a different relationship:[67]

1 *revi'it* = 2e x 2e x 1.833e = 7.333 e^3.

63 R. Weiss objects to the consecutive *brakha levatala*. I don't know if one can speak of *brakha levatala* when one follows another tannaitic opinion.

64 References: B. Pesahim 109a, B. Hagiga 11a, B. Yoma 31a, B. Eruvin 4b and 14b.
After the redaction of this paper, Asher Grossberg, the renowned researcher of the old *miqva'ot* of the Mishnah period, focused my attention on the *miqveh* of Massada, which had a working volume of about 420 l. We can assume that this working volume of 420 l probably corresponded to a theoretical volume of about 332 l, or even less. This volume is much less than the theoretical volume of 40 *seah* = 960 *log* = 960 *sextarius* = 960 x 545.75 cm^3 = 523,920 cm^3 = 524 l.
This *miqveh* was built shortly before the destruction of the Temple. It does not fit the talmudic standard of 1 *log* = 1 *sextarius* = 545.75 cm^3. This *miqveh* seems to have been devised according to the rules of the Mishna Miqva'ot and the Halakhah. However, its volume is not in agreement with the talmudic standard. As already mentioned, it is not impossible that there were already differences of opinion as to whether the *log* is equal to the *sextarius* or to its half, the *miqveh* of Massada belonging to the minority opinion. One must emphasize that the people of Massada behaved according to the highest standards of purity, they were: אוכלי חולין על טהרת הקודש, and were certainly following their traditions.

65 References: B. Pesahim 109a.

66 References: Y. Pesahim X: 1 (near the end) , Y. Shekalim III: 2, Y. Sabbath VIII: 1.

67 In the *yotzer* of Shabat Shekalim, the *Kalir* brings the same quantity in a slightly different form. The *Kalir* lived in Palestine and was probably unaware of the Babylonian Talmud. As

Tosafot[68] suggest that the ratio of the Jerusalem Talmud refers to the units of capacity of Tzipori. We know, indeed, that the units of capacity of Tzipori are 1.44 times the corresponding units of Moses. Therefore, 10.8 e_m^3 = 10.8/1.44 e_t^3 = 7.5 e_t^3.

we proposed in *Talmudic Metrology* I, the *etzba* and the cubit of the *Kalir* are the same as ours, and he probably accounted a small *revi'it*. Stranger is the fact that the *Shulhan Arukh* (Rome, eleventh century), who knew both Talmudim, chose the enunciation of the Jerusalem Talmud, see the entry רבע.

68 *Tosafot*, B. Pesahim 109a examines the two contradictory formulations, in the *Bavli*: אצבעיים ברום אצבע ומחצה ושליש and in the *Yerushalmi*: על אצבעיים ברום אצבעיים וחצי אצבע וחומש אצבע אצבע אצבעיים על אצבעיים. This *Tosafot* has puzzled all the Rabbis, especially those who had a good understanding of the subject. Rabbis like Hohmat Manoah (17th century) and the Rashash (R. Samuel Strashun, 19th century) did not find a satisfactory solution. Weiss (1984), p. 253, explains this *Tosafot* by the introduction of units of length of Tzipori equal to 1.44 of the same unit of the desert. Let us consider this interesting *Tosafot*, which indisputably contains a mistake. The first part of the passage tries to derive the *revi'it* of 2e x 2e x 2.7e from the *miqveh* of 1c x 1c x 3c. *Tosafot* tries to show this derivation geometrically. We know that 1 *miqveh* = 3840 *revi'it*. 1 *miqveh* = 3 x (24) e^3 = 41472 e^3, therefore 1 *revi'it* = 10.8 e^3.

Tosafot observes that the height of 3 cubit = 72 e. If we take 3/80 of it we get 2.7 e. If we take 1/12 of both sides of the square base of 1 cubit = 24 e, we get 2 e.

72e x 3/4 x 1/20 = 2.7e
24e x 1/12 = 2e
24e x 1/12 = 2e.

Therefore, the volume of 2e x 2e x 2.7e represents:
3/4 x 1/20 x 1/12 x 1/12 = 1/3840 of the *miqveh* or 1 *revi'it*. The second paragraph of this first part of the *Tosafot* seems to be redundant, describing a slightly different division.

72e x 1/24 x 9/10 = 2.7e
24e x 1/12 = 2e
24e x 1/12 = 2e

(40 *seah* x 1/24 x 9/10) x 1/12 x 1/12 = 1/3840 *miqveh* = 1 *revi'it*.
The third paragraph of the first part of *Tosafot* seems to be corrupted, and proposes a third method, practically the same, of division of the 40 *seah*.

72e x 1/4 x 3/4 x 1/5 = 2.7e
24e x 1/12 = 2e
24e x 1/12 = 2e.

In a second part beginning with ולפי תלמוד שלנו, *Tosafot* tries to justify the formulation of the Jerusalem Talmud by the introduction of fictive units of length of Tzipori equal to $(1.44)^{0.33}$, cubic root of 1.44, equal to 1.1292. The volume of 10.8 e^3 must be divided by 1.44 in order to be expressed in units of Tzipori; this gives 7.5 e_t^3 or $2e_t$ x $2e_t$ x1.875 e_t. Practically, we can express all three dimensions of volume in units of Tzipori and divide either one of the dimensions by 1.44 or each of the dimensions by 1.1292. The first solution gives $2e_t$ x $2e_t$ x 1.875 e_t, the second solution would give 1.77e_t x 1.77e_t x 2.39 e_t or, with a slight excess, 1.8 e_t x 1.8 e_t x 2.4 e_t. *Tosafot* uses the first method, but the division by 1.44 is performed by twice dividing by 1.2. The first division gives 13.5/6, the second division

7.333 is thus approaching the value of 7.5, which would have been the correct coefficient. In other words, the expression in units of Tzipori of the *revi'it*, corresponding to the definition of the Babylonian Talmud, should be 1 *revi'it* = $2e_t$ x $2e_t$ x 1.875 e_t, which corresponds to 7.5 e_t^3. On the other hand, the ratio of the Jerusalem Talmud is equivalent to 1 *miqveh* = 3,840 *revi'it* = 2.933 cubic cubits. As we know that the exact ratio is 1 *miqveh* = 3.6456 cubic cubits, we can conclude that the ratio of the Jerusalem Talmud is less accurate than that given in the Babylonian Talmud.

6. Units of Capacities used as Units of Weight

We have already seen in connection with the *litra* that the Talmud used the *litra*, a

gives 11.25/6 or 2 - 0.75/6. *Tosafot* observes that the result, 1.875, is larger than the value of the *Yerushalmi*, 2-1/6, by 0.25/6.
A third part, beginning with כן צריך למעט, must be suppressed; it is out of the context. We will however come back later to this passage, which was accidentally introduced into the *Tosafot* by an editor who did not clearly understand the problem.
A fourth passage begins with ועוד מפרש דבירושלמי. It proposes working in natural units, or units of Moses, and to consider the volume described in the Jerusalem Talmud as a cylinder of 1.833e height, with a circular basis circumscribed to a square of 2e sides. The basis has an area of 2π, and the volume is 1.8333 x 2π = 11.519 e^3 instead of 10.8 e^3. The theoretical height of the cylinder should be 1.7189e. *Tosafot* find 1.8e and say that the difference with 1.833 is slight.
Let us come back to the third part. It says that the circle inscribed in the square of sides equal to 2 e_t (*etzba* of Tzipori) is slightly greater than the square of sides equal to 2e (natural *etzba*).
The area of the circle is π x e_t^2 = π 1.1292 e x 1.1292 e = 4.0061 e^2.
The area of the square is 4 e^2. The difference is 0.0061. *Tosafot* gives a difference of 1/9 = 0.111.
In other words, *Tosafot* writes that π x $(1.44)^{2/3}$ = 4.111 instead of 4.0061. This result is impossible to find with π = 3. It would give 3 x 1.17 x 1.17 = 4.111, but $(1.17)^3$ = 1.60 instead of 1.44! I suppose that they used π = 22/7 and $(1.44)^{1/3}$ = 1.144. In any event, the result is remarkable – and proves that they were able to proceed by trial and error to find a good approximation of the square of a cubic root. When it was necessary, they could use a better value than 3 for π. Now this proves also that they were well aware that the *etzba* of Tzipori is equal to about 1.1292 e, and not, as has been suggested, to 1.44 e. But what was the original purpose of this interesting, but off-topic, passage? Perhaps this passage was part of a mathematical development of a Tosafist, proving that the *revi'it* can be considered a cylinder with a circular basis inscribed in a square with sides of two *etzba* and a height of 2.4 *etzba*. This last detail was probably lost to the editor, and this passage was introduced. It is perhaps the testimony of a greater ability in calculus, of the Tosafists, than was believed.

unit of weight, also as a unit of capacity, i.e. the volume of water weighing a *litra*.[69] Similarly, we find cases where units of capacity are used as units of weight, i.e. the weight of the water contained in this capacity.

a. The Load that the People of the Generation of the Exodus Could Carry

We are actually dealing with the generation following the generation of the Exodus, the generation that entered the Holy Land.

According to B. Sota 24b, they were able to raise stones weighing 40 *seah*. This represents a weight of about 960 x 0.546 = 524 kg.

b. The Load that an Average Man Can Carry

In B. Bava Metzia 80b, Rashi writes that a man, when he has been loaded, can carry a weight of 30 *kav*. This is based on the following reasoning: a donkey can carry 15 *seah* and one is responsible in case of an injury caused by an overloading of 3 *kav* or 1/30 of the load it may carry. According to a *baraita*,[70] in the case of a man, one is responsible as soon as the overloading is by one *kav*; therefore, we may assume that a man can carry 30 times more, or 30 *kav* = 5 *seah*. This load represents 5 x 24 x 0.546 = 65.52 kg.

c. The Load that an Average Man Can Raise

The load that a man can raise by himself from the ground is much less than the load he can carry when he is loaded.[71]

From B. Sota 24a, it seems that a man can carry three times the load that he can raise. On the other hand, it appears from Leviticus Rabbah XVI: 14 that it is only two times as much. This load would then be between 21.84 kg and 32.76 kg.

d. The Load that one is not Allowed to Carry when Praying

B. Bava Metzia 80b states that when a man carries on his shoulders a load of less than four *kav*, he may pray carrying the load. But, if it reaches four *kav*, he must unload it and lay it down on the ground – because it is assumed he will be unable to concentrate on prayer. The load of four *kav* of Moses is 4 x 4 x 0.546 = 8.73 kg.

69 In Y. Sota VII: 5 (32b in the edition of Vilna) the commentary *Korban ha Eda* writes clearly that 40 *seah* means the weight of 40 *seah* of water.

70 See B. Bava Metzia 80b and B. Shabat 52b.

71 In B. Sota 24a, *Tosafot* גמירי brings a quotation of the Y. Sota VII: 2, stating this fact.

e. The Sheaf of Corn in which there is Two *Seah*

Mishna Peah writes that a sheaf in which there is two *seah* is too important to be considered a forgotten sheaf; it still belongs to the owner and not to the poor.

In their commentary, R. Isaac ben Malkitzedek[72] and R. Samson ben Abraham of Sens explain that such a sheaf is too heavy to be raised at once. Both quote the Sifrei § 149 on Deuteronomy XXIV: 19:

> לא תשוב לקחתו: כולו כאחד וכמה יהיה בו? שערו חכמים בעושה פחות מסאתיים.
> מכאן אמרו העומר שיש בו סאתיים ושכחו, אין שכחה.

According to this Sifrei, the expression שיש בו סאתיים must be understood as עושה סאתיים, which refers to a sheaf that weighs two *seah*, because it represents the weight that a man can raise at once.[73] This can actually be indirectly deduced from Mishna Peah VI: 7. Two *seah* are 48 *log* and represent a weight of 48 x 0.546 = 26.20 kg.

This is also the explanation given by R. Sirilio,[74] as mentioned in his commentary on the Mishna Melekhet Shelomo. But he identifies these two *seah* with the two *seah* considered in Mishna Terumot X: 8. According to this understanding, we are then dealing with two *seah* of Jerusalem, weighing 1.2 x 26.20 = 31.44 kg.[75]

This seems to be the correct interpretation[76] of this Mishnah and the figures are

72 He was an Italian rabbi of southern Italy (about 1090–1160), from the town of Siponto in Apulia. He is the author of one of the first commentaries on the Mishnah. His commentary was known in France by R. Tam, Rash, and Rabad of Posquières.

73 R. Yom Tov Lipman Heller (*Tosefot Yom Tov*, ad loc.) believes that one cannot raise this sheaf of corn because of its important volume and not because of its weight. He rests his argument on the weight of 40 *seah* that the men were able to raise under Joshua. R. Moses Zacuto in *Hidushei ha Remez* retorts that the data connected with Joshua's generation is an exaggeration; the reason here is that it exceeds the weight that a man can raise at once.

74 R. Solomon Sirilio was a Spanish rabbi, expelled in 1492 from Spain. In about 1544 he succeeded R. Levi ben Haviv as Rabbi of Jerusalem. He is celebrated as a commentator on the Jerusalem Talmud.

75 We can write: 2 *seah* = 48 *log* = 96 *litra* = 96 x 96 *denarius* = 96 x 96 x .00341 = 31.42 kg. According to the approximation of the Jerusalem Talmud, Y. Terumot X: 8, the weight is 96 x 100 x .00341 = 32.74 kg.

76 R. Israel Lifshitz, in his commentary *Tiferet Israel*, has proposed another explanation. He understands literally: a sheaf of corn in which there are two *seah* of grains of wheat. If we consider two *seah* of Moses, their capacity is about 26.26 l. We know that one *seah* gives about 8 t of wheat grain (density about 0.78) and 5 t of straw (density about 0.15). Thus, two *seah* of grain weighs: 26.26 x 0.78 = 20.48 kg. The total weight of the sheaf of corn is 20.48 x (13/8) = 33.28 kg. This result is of the same scale of sizes as the first explanation.

perfectly likely. This would not be the case if we considered the small units of capacity, equating the *log* with the Roman *hemina*. A weight of 13.10 or 15.72 kg can surely not be considered the maximum weight that a man can raise.[77]

7. The Mouthful and the *Revi'it*

B. Yoma 80a writes about the Mishna Yoma VIII: 1: "or if he drank a mouthful, he is culpable (of *karet*)." Rav Judah[78] said in the name of Samuel: not really a mouthful; but so much that if he moves it to one side, it looks like a mouthful. But we learned "a mouthful," say as much as a mouthful. The Talmud objects then, with a *baraita* that says: how much must one drink to become culpable? Beit Shammai says: one *revi'it*; Beit Hillel says: one mouthful; Rabbi Judah in the name of Rabbi Eliezer says: as much as a mouthful; Rabbi Judah ben Bathyra says: as much as can be swallowed at a time. The Talmud pursues the issue: is the quantity required by Beit Hillel (in the *baraita*) greater than the quantity required by our Mishnah (which we explained as meaning that it looks like a mouthful)? It answers: here also we can

Nevertheless this explanation, at first glance closer to the text of the Mishnah, actually seems far-fetched, because we must value the sheaf of corn according to its supposed production of grain and not according to its own characteristics (i.e. its weight). It is possible that this explanation was inspired by the commentary of R. Moses Zacuto: *Kol ha Remez*, who takes into account the weight of the grain and the weight of the straw.

77 This is the reason why the Remez, R. Moses Zacuto, in his commentary on the Mishnah, follows the system of small units of Maimonides, and considers the weight of the grain and the weight of the straw. In order to understand his commentary, we must mention that in Venice, there were three pounds: 1) the small *pond* (*libra sottile*) for the chemists, of about 301.2 gr, and the corresponding ounce of 25.1 gr; 2) the *libra* or *pondo del marco* for gold and silver, of about 358 gr, and the corresponding ounce of 29.83 gr; and 3) the *libra grossa* of about 476.4 gr, and the corresponding ounce of 39.7 gr. See *Grande Dizionario Enciclopedico UTET*, entry: "*misura*," p. 759. See Weiss (1984), p. 33. The Remez writes that an Egyptian man, an expert in measures, told him that the *issaron* of meal weighs about 4 Venetian pounds and therefore 2 *seah* , 6.6667 times more – about 26 *libra grossa* (more exactly 26.667 pounds) – corresponding to 12.7 kg. This is actually a weight that is easy to raise. But if you add the weight of the straw, you will get three times more, or 3 x 26.667 = 80 pounds or 38.1 kg, which an average man cannot raise. Actually, two *seah* of Egyptian meal, according to Maimonides, weighs 74.375 x 4 x 48 x 0.667 = 9.52 kg, less than the 12.7 kg of the Remez. It is likely that the Egyptian man spoke of *libra del marco*, leading to a weight of 26.667 x 0.358 = 9.55 kg (a good estimation of an expert), but the Remez had taken the *libra grossa*, leading to a more advantageous value. This commentary of R. Moses Zacutto is also brought in *Shoshanim le David* on Tosefot Yom Tov Peah VI: 6. This passage shows the quasi-veneration of R. David Pardo for R. Moses Zacuto; see, with a play on words, the expression זכותו יגן עלנו, and the contempt expressed against R. David Corinaldi.

78 Rav Judah bar Ezekiel.

explain that it looks like a mouthful. But if so it is of the same opinion as that of Rabbi Eliezer. There is actually a difference: for Beit Hillel it is enough if it looks like a generous mouthful, but Rabbi Eliezer requires (and is therefore more lenient) that we have the appearance of an exact mouthful. Rav Hoshayah[79] objected to this: if so (that a mouthful means enough that if he moves it to one side it looks like a mouthful) then there would be another case in which Beit Shammai takes the more lenient view and Beit Hillel the more severe one (see Mishna Eduyot IV). He[80] replied to him: When this came up for discussion, it came up in connection with Og, king of Bashan. (Therefore, in the *baraita* that concluded this discussion, Beit Shammai takes the more severe view.)

Maimonides writes that one is culpable if one drinks a mouthful, which is less than a *revi'it*. It seems, therefore, that he accepts the point of view of Samuel, as he explained in Mishna Yoma VIII: 1 in his commentary. The *Sefer haHinuch*[81] writes that this quantity is the volume of an egg (about 50 cm^3). Rashi and *Tosafot* understand that the mouthful, in its strict meaning, is greater than a *revi'it*. It is only because it was reduced according to the understanding of Samuel that Beit Shammai takes the more lenient view. Obviously, Rashi and R. Tam considered a small *revi'it*[82] of about 75 cm^3 (actually the value of Maimonides). This paper demonstrates however that a *revi'it* is at least about 136.44 cm^3.

Furthermore, we can estimate that the volume a man swallows at one time is about 40 cm^3. The volume corresponding to כמלא לוגמיו is about 50 cm^3. The maximum volume it is possible to store in the mouth is about 70-75 cm^3, but it is

79 A contemporary of Rav Judah bar Ezekiel.

80 Rav Judah bar Ezekiel.

81 The *Sefer haHinuch* is an anonymous book, written in Barcelona in the 14th century, which gained much popularity.

82 This talmudic passage was already considered by R. Israel Meir Kagan in Biur Halakha Orah Haim 271: 13. He mentions that כמלא לוגמיו is the volume of an egg (about 50cm^3), and that מלא לוגמי is the volume of two eggs (100 cm^3). He concludes that a *revi'it* is still today comprised of between one and two eggs, contradicting the thesis of R. Ezekiel Landau of Prague. If the latter was right, the capacity of the mouth should be more than three eggs, if, as he states, eggs diminished by half. Of course, this argument also contradicts the theory of the *Hazon Ish*, who shares a similar opinion. The latter (*Kabalat ve hakhnasat Shabat* 15) objects that the maximum capacity of the mouth is indeed more than three eggs. Therefore, the talmudic passage understood according to the classical exegesis of Rashi and *Tosafot* does not contradict his theory of the large *revi'it*. We propose below to accept that a mouthful is less than a *revi'it* without contradicting the theory of the large *revi'it*. At the end of the redaction of this paper, Eng. Y. Loewinger referred me to the commentary of Tosafot Rid on B. Yoma 80a, giving a similar explanation. Although different to my proposition, it grants it legitimacy.

still possible to move it to one side. Therefore, מלא לוגמיו is either about 70-75 cm^3, the volume which can be practically stored in the mouth, which is about 105-115 cm^3,[83] or the theoretical volume of the mouth, both cheeks being extended to the maximum.

It seems likely, therefore, that מלא לוגמיו, a mouthful, is less than a *revi'it*, but this inequality is less evident than for כמלא לוגמיו. The objection of Rav Hoshayah should be understood in the following way: now that you say a mouthful means like a mouthful, it is certain that this quantity is less than a *revi'it* and therefore Beit Shammai takes the more lenient view. But in fact, although less evident, מלא לוגמיו is also less than a *revi'it*, and the objection of Rav Hoshaya can also be used against the contradictors of Samuel, who understand the Mishnah and the *baraita* following their plain meaning.

8. Conclusion

The formal deduction from the objection of Rav Hoshaya (see Rashi and *Tosafot* ad loc.) is that a mouthful is more than a *revi'it*. This is surely in agreement with the opinion of those who advocate a small *revi'it*. Nevertheless, we have established that the talmudic units of capacity correspond to the Roman units of capacity, the *log* corresponding to the *sextarius*; therefore, the *revi'it* corresponds to the *quartarius* and is at least 136.44 cm^3. It is possible to understand the objection of Rabbi Hoshaya in a slightly different way, so that the mouthful of average people is less than a *revi'it*. This exegesis is contrary to that of Rashi, R. Tam and probably Maimonides, because they considered a small *revi'it* of about 75 cm^3. Our exegesis is justified by the actual capacity of the *revi'it* of 136.44 cm^3. Our exegesis is very similar to that of Tosafot Rid:

> שם מתקיף לה רב הושעיא א״א הו״ל מקולי ב״ש ומחומרי ב״ה כו׳ פי׳ התינח אי אמרת דב״ה מלא לוגמיו דוקא קאמרי. יש לומר שמרכין ראשון על הכלי שלא יבלע וממלא לוגמיו ויכילו יותר מרביעית. אבל כדי שיסלקנו לעולם לא יתכן שיסלק רביעית לצד אחד וגם בשני לוגמו אם יתכן שיכילו יותר מרביעית דוקא שירכין ראשו ולא יבלע. אבל אם עומד ראשו זקוף אין אדם בעולם שיוכל לתפוש רביעית כמלא לוגמיו שלא ירדו המים בגרונו והדבר מנוסה ובדוק. והנכון בעיני דל״ג א״כ ועל הכל מקשה אפי׳ אם תאמר מלא לוגמיו דוקא אינו רביעית משקין. ואמרי׳ נמי המברך אם טעם מלא לוגמיו יצא ואם לאו לא יצא. וכל שיעור הנכנס היא רביעית א״כ מלא לוגמיו פחות הוא מרביעית:

83 Benish (1987), p. 271 note 72, indicates the value of 109 cm^3.

Tosafot Rid believes that a mouthful is less than a *revi'it*; he necessarily considered a large *revi'it*. The origin of their different exegesis is probably caused by the different capacity of their *revi'it*. Tosafot Rid proposes suppressing the words אם כן, justifying that a mouthful is less than a *revi'it* both by experience and also by the ruling of the Talmud that one must drink a mouthful of the cup of benediction that contains a *revi'it*. Tosafot Rid understands and rules differently than R. Tam[84] and Tosafot Yeshanim[85] regarding the quantity of the cup of wine that one must drink on the Seder or after Kiddush. We can conclude that although the classical exegesis of this talmudic passage seems to support the thesis of the small *revi'it*, it can be perfectly understood following the conclusions of this paper, which advocate the theory of the large *revi'it*, the *revi'it* being equal to the Roman *quartarius*. Furthermore, R. Isaiah ben Mali of Trani is probably the first *rishon*[86] to advocate the theory of the large *revi'it*.

IV. THE PROBLEM OF EGGS IN TALMUDIC METROLOGY

In the Talmud, the egg plays an important role as a basic measurement of volume in different ritual laws, similar to the olive, fig, and date. The way of determining its volume is described in Mishna Kelim, which explains that one determines the arithmetical mean between the volumes of a big and a little egg, determined by the volume of displaced water. Furthermore, the egg plays another fundamental role in rabbinic metrology; it is the reference unit for all greater units, because it is the only natural unit to which we can refer. Nevertheless, the use of the egg as a fundamental and practical unit for all the units of capacity does not seem usual in the Talmud. The relationship between the egg and the other units of capacity is known through one only reference[87] in B. Eruvin 83a, where it states that a *seah* corresponds to 144 eggs. This appears to be the only reference in the Talmud to the connection of the traditional units of capacity and the egg. This seems to be connected to the situation in talmudic times. The units of capacity were understood through the well-known Roman units of capacity; it was not necessary to use eggs

84 B. Yoma 80a, Tos. beginning with הכי נמי.
B. Pesahim 107a, Tos. beginning with אמ טעם.

85 B. Yoma 80b, אם כן הוה ליה.

86 Rabbis living before the 16th century.

87 There is also a parallel reference in the Jerusalem Talmud, Terumot V: 1: קבא כמה עבד עשרין וארבע ביעין – how much is a *kav*? 24 eggs. Furthermore we find in Y. Terumot X: 1: כמה סאתה עבדה: עשרין וארבע לוגין.

to understand different units of capacity. During the period of the *geonim*, knowledge of the Roman units, particularly those of capacity, was forgotten. The Rabbis had no solution other than the use of the eggs, a natural unit, to master the talmudic units of capacity. As the measure of volumes through the volume of eggs is not easy, the *geonim* tried, in order to make things easier, to establish the weight of the water displaced by an average-sized egg in order to determine its volume and the volume of the other units of capacity. The tradition of the weighing of R. Hilai Gaon has been conserved and viewed as authoritative for many centuries.

It was only in the 14th[88] century that Rabbi Simeon ben Tzemah Duran noted for the first time that the *miqveh* determined by the volume of three cubic cubits[89] leads to much bigger eggs than the normal average-sized eggs.[90] He supposed that eggs have different sizes in different areas. Nevertheless, we never see him disqualifying an existing *miqveh*.[91]

This contradiction was evident at various periods in different places.[92] The

88 Already nearly a century before, R. Solomon ben Menahem Meiri of Perpignan noted on two occasions that the determination of volumes, for example for the reduction of the *hallah*, is safer when estimated by inches than by eggs. See *Beit ha Behira Pesahim* 109a (ומכאן אתה למד) and Eruvin 83b (שיעור חלה הוא).

89 Determined from the breadth of thumb (*etzba*); another available measurement of natural data.

90 See *Tashbetz* (Tshuvot Shimon Bar Tzemah), III: 33.

91 It can be proved that until his time, and even much later, the entire Jewish world used the data of Maimonides. We have already seen that Rashi and *Tosafot*, like Maimonides, reckoned by small units of capacity. Furthermore, in a responsum sent by R. Isaac bar Sheshet of Valencia, the leading rabbi of Spain, to his friend R. Vidal Ephraim of Majorca, the martyr (he was killed during the riots of 1391 CE), also the revered and beloved master of R. Simeon bar Tzemah, in connection with *miqva'ot*, R. Isaac writes that the volume of an average man is 20 *seah* and not 10 *seah* as proposed by R. Vidal. He added, with some humor, that the difference resulted from the fact that each of them had made his estimation according to his own body. According to the value of Maimonides, of 1 *revi'it* = 74.375 cm^3, 10 *seah* = 960 x 0.074 = 71.4 l. Therefore we may assume that R. Vidal was an average-sized man of 71.4 kg (the density of men and animals is about 1 kg/l) while R. Isaac was more corpulent. It was probably a joke and an exaggeration when he said, of himself, that he had a volume of 20 *seah* and, therefore, weighed about 140 kg. What is certain is that he evaluated the *seah* according to Maimonides. Despite the doubt R. Simeon bar Tzemah expressed with regard to the volume of the Jewish capacities, we never heard that he made any objection or disqualified a *miqveh* in Spain or in Algiers. As he was not particularly charitable toward his older colleague in Algiers, R. Isaac bar Sheshet, he would not have kept silent.

92 Almost a century before R. Simeon bar Tzemah, R. Solomon ben Menahem Meiri notes (*Beit ha Behira*, Eruvin 83b and Pesahim 109a) that the measure of volumes by the *etzba*

first to raise the problem in Europe,[93] among the Ashkenazi Rabbis, was R. Ezekiel Landau from Prague.[94] He observed that the volume of pastry to be used for *hallah*, determined by the volume of 43.2 eggs, is half of that volume if it is measured by 43.2 x 7.2 = 311.04 e^3. He concluded that either the breadth of men's thumbs had increased, or that the size of eggs had diminished.[95] He preferred the second assumption, as he was persuaded that men are diminishing, not only morally but also physically. The problem remains open and unsolved until today.

The only way to solve this contradiction is to realize that B. Eruvin 83b does not state that a *seah* has the same volume as 144 eggs, as was always understood, but that it fits 144 eggs.[96] The meaning, probably, is that in a box of one *seah* it is possible to place 144 eggs.[97] If we assimilate an egg to a revolution ellipsoid, of

(Jewish inch) is safer than by the eggs. He doesn't mention any weight as Maimonides did.

93 The problem was already raised in different instances. See Benish (1987), pp. 63-68 and Weiss (1984), p. 372. See also the introduction to *Mikraot Gedolot* (Venice, 1648).

94 However, a century before, R. Yom Tov Lippman Heller noted already (see *Madanei Yom Tov*, Berakhot III: §30; 80) that the volumes of Y. Terumot X: 8 are three times the small volumes of Maimonides, or more precisely 100/35 = 2.8571. This was actually the same objection as that of the Noda bi Yehuda, asked differently. R. Heller did not have a precise estimation of the weight of the *dinar* of Maimonides, and therefore he used his own measure of the weight of barleycorns. He had measured that 384 barleycorns weigh a pound of Prague (*lot*) = 15.85 gr, 6.76 percent less than the 17 gr of Maimonides. We have already seen in note 38 that because of many approximations and the imprecision of the ratio 100/35 = 2.8571 was actually 1.834. Because of the impression of exaggeration it gave, this passage of the Jerusalem Talmud was not generally taken seriously; it was considered as an individual opinion, not followed by the Rabbis or by Maimonides (see *Shoshanim le David*, Peah VI: 6).

95 In his commentary on the Mishnah, *Beit David*, published in 1742, R. David Corinaldi thought that he had demonstrated that halakhic eggs cannot be the eggs of a hen. He articulates this in Y. Terumot X: 8: one *litra* weighs 100 *dinar*. Like *Tosefot Yom Tov*, he does not know the weight of the *dinar*, but he knows that one *dinar* is 96 barleycorns. He assimilates these barleycorns with Venetian grains, and can then write that one *litra* is 9,600 grains and one egg is 3,200 grains. In the Venetian system, 1 *uncia del marco* = 144 *carats* = 576 grains. Therefore 1 egg = 3200/576 = 5.555 *uncia del marco* = 5.555 x 29.83 = 165.7 gr. This egg is surely not the egg of a hen, he says. References: *Beit David*, Peah VI: 6; Terumot X: 8, Kelim XVII: 11and Bava Metzia VI: 5. It should however be added that, in so doing, R. David Corinaldi increased still more the "exaggerated" value of the Jerusalem Talmud by 17 percent, increasing the exaggeration from 156 percent (2.8571/1.834) to 182 percent. Indeed, the barleycorn of Maimonides weighs 17/384 = 0.00443 gr, while the Venetian grain weighs 29.83/4 x 144 = 0.0518 gr.

96 In fact, the box was a *modius* in which one can store 96 eggs. The 144 eggs must be the result of a multiplication by 1.5 in order to take the heap into account.

97 This solution has been suggested by Bornstein (1887). The glory of this discovery is to his credit.

which the half axes are a and b, then its volume is $4/3 \times \pi \, b \, a^2$. The overall dimension of the egg is $2a \times 2a \times 2b = 8 \, b \, a^2$. The ratio egg/overall dimension is $\pi/6$.

When we take this new data into consideration, as well as the fact that the exact relationship between the units of capacity and length is 1 *miqveh* = 3.65[98] cubic cubits or 1 *revi'it* = 12.44 e^3,[99] then all the problems are solved. The *log* is equal to the *sextarius* and is at least about[100] 545.75 cm^3, and contains six eggs. The overall dimension of an egg is at least $545.75/6 = 90.96$ cm^3, but the volume of an egg is at least $90.96 \times \pi/6 = 47.63$ cm^3. This is very close to the value of Rabbi Hilai Gaon and Maimonides. The origin of this paradox could then be that when the knowledge of the Roman units of capacity disappeared, the Rabbis used the volume of the average-sized egg to reconstruct the whole talmudic system.[101] But they considered, erroneously, that the *seah* has a volume of 144 eggs instead of $144 \times (6/\pi)$ eggs, or about 275 eggs. The Talmud B. Eruvin 83b actually gives the number of eggs that can be placed in a box that has a capacity of one *seah*. This was the reasoning behind the undervaluation of all the units of capacity. During the gaonic period until the 15th century, when the most important Rabbis lived in Arabic countries, the problem of a contradiction between the units of capacity and length was not raised, probably because the consecutive units of length were compatible with the Arab units of length. Rashi and *Tosafot* also accepted the small units of capacity and were apparently not bothered by this problem, which – when raised for the first time in the 15th century – undermined all the talmudic metrology and introduced an element of incertitude. According to the conclusions of this paper, the objections that were raised were legitimate and lead us today to propose a definitive solution to this internal contradiction.

V. THE METROLOGY OF MAIMONIDES

1. The Units of Capacity

The metrology of Maimonides is now known with precision thanks to Yakov Meshorer's research of the Palestinian coinage in the time of the Mishnah, and the research by R. Y.G. Weiss of the old coinage of the countries where the Jews lived

98 And not 3.

99 And not 10.8.

100 We have seen that there is a small margin of uncertainty, as the *sextarius* ranges between about 545 cm^3 and 566 cm^3.

101 R. Solomon Ben Menahem Meiri notes this fact very clearly in *Beit haBehira*, Eruvin 83b, last paragraph before the second Mishnah. He writes: "As we have no more the measures of Moses, of Jerusalem and of Tzipori, we must come back to the evaluation in eggs."

in the Middle Ages and at the beginning of modern times. When we compare the data provided by R. T.H. Eisenstadt (1950)[102] and that given in Weiss (1984), we can see how much our knowledge has increased. Weiss's book is difficult to find, but it is a mine of information.

The metrology of Maimonides is an elaborate construction that has required much attention. He returns to the subject in many passages in his commentary on the Mishnah and his *hibur*.

a. Commentary on the Mishnah

The elements of the metrology of Maimonides are scattered throughout his commentary on the Mishnah. The main elements related to the problems of the units of capacity and the units of weight can be found in his commentary to the following Mishnahs: Peah VIII: 5; Shevi'it I: 2; Hallah II: 6; Terumot X: 8; Eduyot I: 2; Menahot, introduction, 5th part; Menahot IX: 2; Bekhorot VIII: 8;[103] Kelim II: 2; Miqvaot III: 1.

The main features are the following: the *dinar* is 96 barleycorns and the Egyptian *dirham* is 61 barleycorns.[104] The *revi'it* of water weighs about 27 *dirham*, the *revi'it* of wine weighs about 26 *dirham*, the *revi'it* of corn weighs 21 *dirham*, the *revi'it* of meal weighs about 18 *dirham* and the *issaron* of Egyptian meal weighs

102 R. Tzvi Hirsh Eisenstadt (Warsaw 1901 – New York 1966) was an important talmudic scholar, devoting much time to studying the works of Nachmanides. He was the same age as my late father, R. Eliezer Ajdler (Warsaw 1901 – Brussels 1998), and they were friends from *heder*.

103 In Mishna Bekhorot VIII: 8, we find the following data:
1. 1 Egyptian *dirham* = 61 barleycorns.
2. 1 *sela* = 6.25 *dirham* + 0.25 *kirt*
3. 5 *sela* = 31.5 *dirham*
4. 30 *sela* = 188.875 *dirham*
5. 50 *sela* = 314.75 *dirham*.

All these data prove that the *dirham* indeed weighs 61 barleycorns. The second ratio, however, is problematic. Indeed, 1 *sela* = 384 barleycorns. In the second equation 6.25 *dirham* + 0.25 *kirt* = 6.25 x 61 + 1 = 382.25 barleycorns. The approximation is relatively important; the exact equation is: 1 *sela* = 6.25 *dirham* + 0.6875 *kirt*.
In *Kaftor Vaferah* (ha-Mahon le-Limudei ha-Aretz, Vol. 3 [1997], p. 217) the author mentions the contents of Maimonides' commentary. The first equation is mentioned, 1 Egyptian *dirham* = 61 barleycorns. The second equation is stated slightly differently: 1 *sela* = (6.25 + 1/16) *dirham*. This equation is also approximate, and should be 1 *sela* = (6.25 + 1/22) *dirham*.

104 Maimonide' commentary on Mishna Bekhorot VIII: 8.

520 *dirham*.[105] One *dinar* has the same weight as 1.573 *dirham*. If the dinar weighs 4.25 gr then the *dirham* weighs 2.70 gr.

b. *Hibur*[106]

רמב"ם הלכות עירובין פרק א

הלכה יב

ליטרא האמורה בכל מקום מלא שתי רביעיות, ועוכלא חצי רביעית, ומנה האמורה בכל מקום מאה דינר, והדינר שש מעין, והמעה משקל שש עשרה שעורות, והסלע ארבעה דינרין, והרביעית מחזקת מן המים או מן היין משקל שבעה עשר דינרין וחצי דינר בקירוב, נמצא הליטרא משקל חמשה ושלשים דינר, והעוכלא משקל תשעה דינרין פחות רביע.

הלכה יג

סאה האמורה בכל מקום ששת קבין, והקב ארבעה לוגין, והלוג ארבע רביעיות, וכבר בארנו מדת הרביעית ומשקלה, ואלו השיעורין שאדם צריך לזכור אותן תמיד.

רמב"ם הלכות ביכורים פרק ו

הלכה טו

כמה שיעור העיסה שחייבת בחלה מלא העומר קמח בין מאחד מה׳ מינים בין מחמשתן כולם מצטרפין לשיעור, וכמה הוא שיעור העומר שני קבין פחות חומש, והקב ארבעה לוגין, והלוג ד׳ רביעיות והרביעית אצבעיים על אצבעיים ברום אצבעיים וחצי אצבע וחומש אצבע, וכל האצבעות הם רוחב גודל אצבעות של יד, נמצאת למד שהמדה שיש בה י׳ אצבעות על י׳ אצבעות ברום שלש אצבעות ותשע אצבע בקירוב הוא העומר, וכן מדה שיש בה שבע אצבעות פחות שני תשיעי אצבע על ז׳ אצבעות פחות שני תשיעי אצבע ברום שבע אצבעות פחות שני תשיעי אצבע היא מדת העומר, ושתי המדות כאחד הם עולים, וכמה מכילה מדה זו כמו ארבעים ושלש ביצים בינוניות וחומש ביצה והם משקל ששה ושמונים סלעים ושני שלישי סלע מקמח החטים שבמצרים, שהם משקל חמש מאות ועשרים זוז מזוזי מצרים בזמן הזה, ומדה שמכילה כמשקל הזה מקמח החטים הזה בה מודדין לחלה בכל מקום.

רמב"ם הלכות מתנות עניים פרק ו

הלכה ח

כדי שבעו כמה אם מן החטים נותן לא יפחות מחצי קב, ואם מן השעורים לא יפחות

105 Maimonides' commentary on Mishna Eduyot I: 2.
106 The text is according to the Vilna-Warsaw edition.

מקב, ואם מן הכוסמין לא יפחות מקב[107], ומן הגרוגרות לא יפחות מקב, ואם מן הדבלה לא יפחות ממשקל חמש ועשרים סלע, ואם מן היין לא יפחות מחצי לוג, ואם מן השמן לא יפחות מרביעית, ואם מן האורז רובע הקב, נתן לו ירק נותן לו משקל ליטרא והוא משקל חמשה ושלשים דינר, מן החרובין שלשה קבין, מן האגוזים עשרה, מן האפרסקין חמשה, מן הרמונים שנים, אתרוג אחד, ואם נתן לו משאר הפירות לא יפחות מכדי שימכרם ויקח בדמיהן מזון שתי סעודות.

It appears that there are some slight differences between the commentary on the Mishnah and the *hibur*. We will show that the *dirham*, which weighs 61 barleycorns in the commentary of the Mishnah, weighs 64 barleycorns in the *hibur*. Maimonides writes in his *hibur*[108] that 1 *omer* of Egyptian meal weighs 86 2/3 *sela* or 520 Egyptian *zouz*. Thus, 1 *sela* = 6 Egyptian *zouz* or 1 *dinar* = 1.5 Egyptian *zouz* and 1 Egyptian *zouz* = 96 / 1.5 = 64 barleycorns. In the Mishnah and the Talmud the *zouz* is equivalent to the *dinar*,[109] but in the commentary of Maimonides on the Mishnah and here also in this passage of *Hilkhot Bikkurim*, the denomination of the *zouz* corresponds always to the *dirham*.[110] In the introduction to his commentary to Menakhot, Maimonides writes that 1 *omer* of Egyptian meal weighs 520 Egyptian *dirham*.

In his *hibur*,[111] Maimonides writes that 1 *omer* of Egyptian meal weighs 520 Egyptian *zouz*. Again, we acknowledge that the two denominations relate to the same coin.

Let us then examine these changes between the commentary on the Mishnah and the *hibur*. In Mishna Bekhorot VIII: 8, Maimonides writes that the Egyptian *dirham* weighs 61 barleycorns; but in his *hibur*, as explained above, he writes that the Egyptian *zouz* weighs 64 barleycorns. This Egyptian *zouz* is the same as the Egyptian *dirham*, and it now weighs 64 barleycorns. In *Kaftor Vaferah*, chap. 16, it mentions both the *dirham* of 61 barleycorns and later the *dirham* of 64 barleycorns

107 This was the reading of the edition of Radvaz; he was puzzled and considered the possibility that Maimonides had a different reading in the Mishnah. The correct reading is: מקב וחצי, as mentioned in the edition of Shabtai Fraenkel.

108 Hilkhot Bikkurim VI: 15.

109 Or, occasionally, to the provincial *dinar*.

110 This denomination of the *dirham* conforms to different coins or weights:
1. A *dirham* or a *zouz* of 16 barleycorns; see Mishna Bava Kama IX: 7 (*zouz*), Mishna Peah VIII: 7 (*zouz*), Mishna Kiddushin I: 1 (*dirham*), Mishna Bekhorot VIII: 8 (*dirham*). Thus, 1 *dirham* = 1 *zouz* = 16 barleycorns.
2. A *dirham* of 36 barleycorns, see Mishna Sheviit I: 4 (*dirham*).
3. A Egyptian *dirham* or Egyptian *zouz* weighing about 2.70 gr.

111 Hilkhot Bikkurim I: 15.

without any remark about this contradiction. Kessef Mishneh[112] writes that the Egyptian *zouz* is a *dirham* weighing 2/3 of a *dinar* or 64 barleycorns. This position is confirmed in *Shulhan Arukh*.[113] The weight of the *dinar*, the international and fixed denomination, remained thus unchanged, but the weight of the *dirham* increased by 5 percent (this is a quite rare event), and the ratio *dirham*/*dinar* consequently increased. In his commentary of the Mishnah, the weight of the *revi'it* of water was originally 27 x 61/96 = 17.16 *dinar* = 72.91 gr. The volume of the *revi'it* was then 72.91 cm^3.

In his *hibur*, the weight of the *revi'it* of water is 17.5 *dinar* = 26.25 *dirham* = 74.375 gr. The volume of the *revi'it* is now 74.375 cm^3. Thus the *dirham*/*dinar* ratio has been adapted. The *dirham*, which in the Mishnah weighed 4.25 x 61/96 = 2.7 gr, weighs in his *hibur* 4.25 x 64/96 = 2.833 gr. The weight of the *revi'it* of water has been diminished in relative value from 27 to 26.25 *dirham* and in absolute value it has increased from 17.16 to 17.5 *dinar*, or from 72.91 gr to 74.375 gr.

It is strange that the weight of the *revi'it* of water, expressed in *dinar*, changed. It should have remained 17.16 *dinar*, now equal to 25.73 *dirham*. Why did Maimonides change the weight of the *revi'it* expressed in *dinar* and increase it by 2 percent, from 17.16 to 17.5 *dinar*? We know that the weight of a *revi'it* of water of 17.5 *dinar* is exactly the value adopted by some *geonim* who gave, for the weight of the volume of water displaced by an average egg, 16.666 Babylonian *dirham* and for a *revi'it* of water 25 Babylonian *dirham* with the ratio 25 Babylonian *dirham* = 25 x 7/10 = 17.5 *dinar*. It is likely that Maimonides submitted himself to this tradition[115] and did not rest on his own appreciation of the *revi'it*, which he had measured on his own as the average breadth of a thumb.[116] But what becomes incomprehensible is why he did not adapt his figures to the new situation, preserving at least the densities he had carefully measured. In his first measures he had found a density of 18/27, and more precisely 18.06/27.[117] Therefore, the weight of one *issaron* of meal should now be, according to his new data, 28.8 x 26.25 x 18/27 =

112 Kessef Mishneh on Hilkhot Bikkurim VI: 15 and on Hilkhot Kelei ha-Mikdash III: 3.

113 *Shulhan Arukh* Yoreh Deah 294, 6: 1 *maah* weighs 16 barleycorns = 0.25 *dirham*, and *Shulhan Arukh* Yoreh Deah 305, 1: 5 *sela* = 120 *maah* = 30 *dirham*.

114 One Babylonian *dirham* = 0.7 *dinar*. See Rashi, B. Bekhorot 49b and 50a.

115 Maimonides adopted a similar position toward the counting of the sabbatical year. See Hilkhot Shemita ve Yovel X: 6.

116 Weiss (1984) makes a similar assumption, p. 201.

117 520/28.8 = 18.06 *dirham*/*revi'it*. The *issaron* is 7.2 *log* or 28.8 *revi'it*.

504 *dirham*,[118] or, more precisely: 28.8 x 26.25 x 18.06/27 = 505.68 *dirham*. Maimonides seems to have increased the volume of the *revi'it* in order to agree with the gaonic volume but he did not adapt the weight of the meal contained in this volume, expressed in *dirham*, and, in practical terms, has artificially increased the weight[119] and the density of the Egyptian meal.[120]

Apparently, we have three independent elements in this conundrum:

1. A change of the weight of the Egyptian *dirham*, which is probably an external event.
2. An increase, by Maimonides, of the volume of the *revi'it* by 2 percent, from 72.91 cm^3 to 74.375 cm^3, probably to agree with the gaonic value.
3. A lack of adaptation of the weight of the *issaron* of Egyptian meal to the new data: increase of the weight of the *dirham* and of the volume of the *revi'it*.

In any event, the problem remains a true conundrum: we are confronted with an undeniable and yet incomprehensible increase of the weight of the *dirham* between the commentary of the Mishnah and the *hibur*, but we cannot account for the treatment of the consequences or, more accurately, for the absence of an adequate taking into account of its consequences by Maimonides, i.e. the adaptation of the different figures to the new situation.

2. The Units of Length

Maimonides made many efforts to give a complete definition of the *etzba*[121] or breadth of a thumb, but despite these efforts and his precise wording, a doubt remains about the length of his *etzba*, and discussions on the subject still continue. The common method of calculating the *etzba* is to use the formula: 1 *revi'it* = 10.8 e^3. With 1 *revi'it* = 74.375 cm^3, we find e = 1.9025 cm. This gives a cubit of 45.66 cm and a mile of 913.2 m.[122]

118 This represents 336 *dinar* or 1428 gr. The weight of the *issaron* in the Mishnah was 520 x 61/96 = 330.417 *dinar* = 1404.27 gr.

119 The weight of the *issaron* of Egyptian meal has increased from 520 x 61/96 x 4.25 = 1404.27 gr to the weight of 520 x 64/96 x 4.25 = 1473.33 gr.

120 In the Mishnah, this density was 18/27 = 0.6667; now it is (4.25 x 520/1.5) / (28.8 x 74.375) = 0.688.
In the last formula, the numerator is the weight in grams of an *issaron* of Egyptian meal; the denominator is the volume of an *issaron* = 7.2 *log* = 28.8 *revi'it*.

121 See Hilkhot Sefer Torah IX: 9.

122 The mile is 2000 cubits; see Hilkhot Tefila IV: 2 and his commentary on Mishna Yoma VI: 4.

Prof. A.Y. Grienfeld (1986)[123] has proposed calculating the length of the cubit[124] by calculating the weight of the *kaporet*, and subtracting the weight of the other different golden objects from the total weight of gold used in the Tabernacle. This method does not refer to Maimonides, but claims to be general. In Talmudical Metrology I, we already took exception to this method.

1. This method relies on a talmudic *sela* of 17 gr and a biblical *shekel* of 14.1 gr. This value is the gaonic and halakhic weight, but the historical value of the talmudic *sela* according to the historical coins is 14.16 gr,[125] and this would correspond to a biblical *shekel* of 11.7 gr.
2. This method relies on different assumptions about the thickness of the various plates.
3. This method relies on the assumption that the *keruvim* were made of wood covered with gold according to Ibn Ezra, but against Rashi.
4. There is a discussion in the Talmud[126] whether the cubits considered in the measures of the Ark of Covenant are cubits of 5 handbreadths (Rabbi Judah) or of 6 handbreadths (Rabbi Meir).
5. The *kaporet* is assumed to be a homogeneous rectangular prism of one handbreadth height. This assumption relies on nothing: the *kaporet* could also be a nonhomogeneous rectangular prism of one handbreadth height with empty holes, or a plate of less than one handbreadth thickness, with a peripheric edging of one handbreadth total height.

In Weiss (1984), the author has tried to demonstrate that the cubit used by Maimonides has a length of about 59-60 cm. His first argument is the passage of *Hilkhot Kiddush ha- Hodesh*,[127] from which it is concluded that people could cover 3º of meridian in seven days, or 47.62 km per day. A second argument is that Maimonides writes that one can cover the distance between Jerusalem and Mitzrayim, which seems to be the town of Fostat, in 10 days.[128] This would also correspond to a similar distance per day.[129] If one compares this data with a maximum

123 A.Y. Grienfeld תחומין התאמת האגודל ליתר אמות המדה (Alon Shvut, 1986).
124 Or at least an upper limit of this length.
125 Rashi's opinion seems to agree with this value; see Rashi on Ex. 21: 12 and Ex. 25: 39. See also Rashi on B. Bekhorot 49b.
126 Mishna Kelim XVII: 10 and B. Bava Batra 14a.
127 Hilkhot Kiddush haHodesh XI: 17.
128 Hilkhot Kiddush haHodesh V: 10 and 11 in conjunction with Hilkhot Kiddush haHodesh 13.
129 See Weiss (1984), pp. 333-34.

distance covered, of 40 miles per day,[130] this will give 1,190 m for a mile and 59.56 m for a cubit. In order to solve this contradiction, Weiss proposed that the *miqveh* of 1 cubit x 1 cubit x 3 cubits, and the *revi'it* of 2 *etzba* x 2 *etzba* x 2.7 *etzba* considered in the Talmud, have the shape of half of a revolution ellipsoid, and a volume of 1/2 x 4/3 x π x 1 x 2.7 e^3 = 5.65 e^3 instead of 10.8 e^3. Therefore e = 2.36 cm and the cubit is c = 56.65 cm. Fixler (2001) affirms that the mile used by Maimonides in his introduction to the commentary of the Mishnah and in his commentary on the first Mishnah of Berakhot is the same as his legal mile of 2000 x 24 x 1.9 cm = 912 m, from which he concludes that Maimonides underestimated the dimension of the earth. This explanation would answer the first argument but surely not the second. Anyhow, such an argument is untenable, as we know that Greek astronomy[131] and later Arab astronomy[132] already had correct

130 *Hibur*, Hilkhot Evel VII: 4.

131 It is generally accepted that the Greeks had a good knowledge of the size of the earth. Eratosthenes (284-192 BCE) was noted for having determined the size of the earth. Cleomedes (first century BCE) gave an extensive description of the method used. In the town of Syene (Assuan), the bottom of a deep vertical pit was illuminated by the sun only on the longest day of the year, so that the sun then stood exactly at the zenith. In Alexandria, situated further north, at about the same longitude, the shadow cast on a hollow sundial on that day was 1/50 of the total circle (an angle of 7.2º). Thus, the distance between the two towns must be 1/50 of the circumference of the earth. Since the distance was estimated to be 5,000 *stadia*, the earth's circumference must be 250,000 *stadia*. In modern times, there has been much discussion on the length of the *stadia* used. If we take 157 m as the most probable value, Eratosthenes' result of 39,250 km comes very close to the true figure. Cleomedes also mentions Posidonius (first century BCE) as having applied a similar principle, and finding a circumference of 240,000 *stadia* or 37,680 km. A later measure of the earth's size is the measure of Ptolemy (c. 90 – c.168 CE). He found a circumference of 180,000 *stadia*, but these *stadia* were different than those used in the former measures. It is not impossible that this last measure was never performed, and was the measure of Posidonius adapted to a *stadia* of c. 210 m. For the ancients' knowledge of the size of the earth, see G. Bigourdan (1851-1932), *L'Astronomie*, (Paris: Flammarion, 1916) and A. Pannekoek (1873-1960), *A History of Astronomy* (New York: Dover, 1989).

132 Once the exact meaning of the Roman mile had been forgotten, there was much confusion in Arabic geodesy about the meaning of the mile. In their geodesic measures some considered 56.66 miles per degree of meridian (Arabic mile of 1972 m), others 66.66 miles per degree (Arabic mile of 1666,66 m), and yet others considered 75 miles per degree (Arabic mile of 148.5 m). Because of this confusion about the mile used, new measures of the dimension of the size of the earth were undertaken under Caliph al-Mamun (786-833 CE). His astronomers found that 1º of latitude equals 56 2/3 Arabic miles, each of 4,000 "black *ells*" of 0.493 m. Thus, 1º of latitude measures 56.66 x 1.972 = 111.746 km and the circumference of the earth must be 40,229 km.

knowledge about the size of the earth. Maimonides used the halakhic mile, but on rare occasions he used also the geographical mile of the Arabic geographers.[133]

I personally would have been content with a *revi'it* in the shape of a cylinder of two *etzba* diameter and 2.7 *etzba* height. Its volume is 8.48 e^3 which leads to e = 2.06 cm and a cubit c = 49.49 cm. This value is much more acceptable and almost coincides with the Arabic cubit of 49.38 cm, 1/3000 of the Roman mile.[134]

Let us now examine the ingenious solution proposed by Weiss (1984).[135] Among the numerous descriptions in Maimonides' commentary of the Mishnah of the volumes of halakhic capacities like the *revi'it* and *log*, expressed in cubic *etzba*, let us consider Mishna Peah VIII: 5; מדה שיש בחללה ארבע אצבעות על ארבע אצבעות ורומה שני אצבעות ושבע עשיריות מאצבע ויהיה זה האצבע ששיערו בו מאצבעות היד הגודל וזה המדע אשר יש בחללה זה השיעור שזכרנו אחר (אחד)[136] שיהיה מרובע או עגול או משולש או זולתם מן התבניות, הוא נקרא לוג.....

and the introduction to Mishna Menahot: המדה שיש בכללה ד׳ אצבעות באורך וד׳ אצבעות לרוחב ברום שתי אצבעות ושבעה עשיריות מאצבע..... .

These two passages seem to contradict Weiss's assumptions (1984).[137] The text of the second seems to describe a rectangular prism, not a cylindrical prism, because of the use of the terms length, breadth, and height. These terms are not appropriate for a cylindrical prism, and still less for a volume in the shape of a half ellipsoid.[138] Similarly, the first passage seems to describe a prism with a basis of 16 square cubits, not a circle of four cubits in diameter. Weiss's assumption that the volume of the *revi'it*, or here the volume of the *log*, is a revolution volume that, further, is not prismatic but ellipsoidal, as well as my own assumption that it is a cylindrical

133 Maimonides writes in the introduction to his commentary on the Mishnah that the circumference of the earth is 24,000 miles. Maimonides certainly refers to an Arabic mile of 1,666.66 m, 66 2/3 miles per degree.
This indication is parallel to the dictum of Rava in B. Pesahim 94a, according which the circumference of the earth is 6,000 *parsah* or 24,000 miles. If we consider that Rava still used Roman miles, this would correspond to a circumference of 35,556 km, i.e. an undervaluation of about 10 percent.

134 This is not without interest; the Roman mile is equal to 2,828.43 Jewish cubits and to 3,000 Arabic cubits.

135 P. 254.

136 In parentheses, my correction.

137 P. 254.

138 Weiss (1964), p. 245, brings examples where, for example, the expression: 2 *amot* x 2 *amot* represents a circle: B. Eruvin 56b or *Tosafot* in B. Pesahim 109a (*revi'it*). But here Maimonides writes explicitly: length, breadth, and height.

volume, do not seem to be the genuine interpretations.

What about the two arguments in connection with the length of the mile traversed by travelers, who cover 47.6 km per day?[139] It seems nearly impossible to walk and cover 47.6 km per day for seven or ten consecutive days. I had hoped to remove any doubt by using a passage of Maimonides according to which the distance between his house in Fostat and the palace of the governor of Egypt, situated in al-Qahira, is two Sabbath distances.[140] However, the localization of this last place presents difficulties. The problem of the direct determination of the cubit and the *etzba* of Maimonides remains difficult. The best and most accurate method of determination of the *etzba* remains the use of the weight of the *revi'it* of water, which Maimonides fixes in his commentary of the Mishnah at 17.16 *dinar* or 72.91 cm^3, giving an *etzba* of 1.89 cm. In his *hibur* he fixes it at 17.5 *dinar* or 74.375 cm^3, giving an *etzba* of 1.903 cm.

3. The Quantity of Food for the Meals of the Poor, the Wife and the *Eruv*[141]

Maimonides rules according to the opinion of Rabbi Johanan ben Beroka in Mishna Eruvin VIII: 2: the bread of the *eruv*, corresponding to two meals, is made with a volume of 1/4 *kav* wholemeal. Half of this bread, פרס, represents a meal of 1/8 *kav* wholemeal or three eggs.[142] According to Maimonides, this volume of six eggs represents the quantity of two meals, whatever the nature of the food. Therefore, Maimonides rules that two meals are also equivalent to 18 dried figs,[143] which have a volume of six eggs. Maimonides considers 18 dried figs as equivalent to

139 They must ride horses, rather than donkeys, to be able to cover such a distance per day. See the following reference relative to the annulment of the fixation made by Hanania, the nephew of Rabbi Joshua. The annulment was announced by messengers riding horses: קם, רכב סוסיא, הן דמטא מטא והן דלה מטא נהגין בקילקול. Y. Sanhedrin I: 2 (6a in the edition of Vilna) and Y. Nedarim VI: 8 (23a in the edition of Vilna). Even if the donkey was more common (see II Regum IV: 22 and 24), we see that they used horses for the announcement of the new moon.

140 This passage comes from a letter of Maimonides to R. Samuel ben Judah Ibn Tibbon, See *Igerot ha Rambam*, edition Isaac Shilat, p. 550. This passage can be found in English translation in *Encyclopaedia Judaica*, Vol. 11, p. 757.

141 This paragraph aims at explaining some talmudic passages, considered above, according to Maimonides. Indeed, we had considered them as justifying the large measures, and we feel obliged to reexamine them according to Maimonides.

142 H. Eruvin I: 9.

143 According to B. Eruvin 80b. The correct version is discussed: see Meiri, Rashba and Ritva, ad loc.

two meals,[144] a *mana* of *develia* and a *kav* of grogerot.[145] In order to explain the last equation, we must accept that a *kav* of *develia* means the dried and pressed figs obtained with a *kav* of fresh figs.[146]

BIBLIOGRAPHY

Arbuthnot, J. (1727). *Tables of Ancient Coins, Weights and Measures*. London.

Benish, Ch.P. (1987). מדות ושיעורי תורה. Bnei Berak.

Berriman, A.E. (1953). Historical Metrology: *A New Analysis of the Archaeological and the Historical Evidence Relating to Weights and Measures*. London.

Boeckl, A. (1838). *Metrologishe Untersuchungen*.

Chisholm, H.W. (1877). *On the Science of Weighing and Measuring and Standards of Measure and of Weight*. London.

Corinaldi, D. (1738). בית דוד, הרב דוד קורינלדי. Amsterdam.

Cumberland, R. (1686). *An Essay towards the Recovery of the Jewish Measures and Weights*. London.

Decourtemanche, J.A. (1908). *Traité Pratique des Poids et Mesures des Peuples Anciens et des Arabes*. Paris.

Dictionnaire des antiquités Grecques et Romaines, five volumes. Paris, 1877.

Dictionary of Greek and Roman Antiquities. Ed. John Murray, London, 1877.

Dizionario Enciclopedico Italiano. Roma, 1955.

Ebengreuth, V. (1904). *Die Algemeine Munzkunde und Geldgeschichte*.

Eisenschmidt, J.C. (1708). *De Ponderibus et Mensuris Veterum Romanorum, Graecorum Hebraecorum*.

Eisenstadt, T.H. (1950) מכתב הרמב"ן ז"ל מעכו בענין צורת שקל ישראל ומשקלו. Talpiot, NY.

Encyclopedia Universal Ilustrada Europeo-Americana. Madrid.

Epiphanius (392). *The Treatise on Weights and Measures*. Ed. James Elmer Dean, The University of Chicago Press, Chicago (1935).

Feldman, D. (1927). שיעורי המצוות. Second edition, 1971, Israel.

Friedman, D.A. (1870). יחש המדות והמשקלות, ר' דוב אריה פרידמן. Warsaw.

Fixler, D. (2001). "מידות ושיעורי תורה בפירוש המשנה לרמב"ם". *B.D.D*. 12, pp. 35-60.

Grande Dizionario Encyclopedico UTET.

Greaves, J. (1647). *Discourse on the Roman Foot and Denarius*. London.

144 H. Eruvin I: 9, one dried fig has the volume of 1/3 egg, and the 18 figs represent a volume of 6 eggs.

145 H. Eruvin I:10 according to Mishna Peah VIII: 5.

146 This explanation seems likely. Firstly, Maimonides rules that a *kav* of fresh dates also represents two meals. Secondly, if we refer to the Mishna Terumot IV: 10, בדורס ליטרא ליטרא משקל ידוע וקציעות התאנים היבשות ואומר כי מי שלקח ליטרא קביעות על הבד, קציעות על פי הבד תאנים מתרומה וכשתן ונתנן על פי כך..... Maimonides explains that *litra* refers to the weight of the fresh figs. I do not know why he feels obliged to consider a *litra* weight, contrary to his principle, expressed in H. Eruvin I: 12.

Greaves, J. (1737). *Miscellaneous Works of J. Greaves*. London.
Grienfeld, A.Y. (1986). תחומין התאמת האגודל ליתר אמות המדה. Alon Shvut.
Grienfeld, A.Y. (1998). תחומין ערכי המדות בזמן מתן תורה. Alon Shvut.
Grienfeld, A.Y. (1997). תחומין משקל השקל לפדיון הבן. Alon Shvut.
Hultsch, F. (1862). *Griechishe und Roemische Metrologie*. Berlin.
Kaniewski, I. (1966 and 1969). שיעורין של תורה. Bnei Berak.
Karelitz, A. (1947). קונטרס השיעורים, הרב אברהם ישעיהו קרליץ. Bnei Berak.
Kaufman, A.S. (1997). "Surface Measure in Ancient Israel," in *B.D.D*. 4, pp. 77-79.
Lettronne, J.A. (1817). Considérations Générales sur l'Evaluation des Monnaies et sur la Valeur de l'Or et l'Argent avant la Découverte de l'Amérique. Paris.
Lampronti, I. (1750-1840). *Pahad Itshak*. Venice–Livorno.
Lessico Universale Italiano. Roma.
Madden, W. (1864). *History of Jewish Coinage*. London.
Merzbach, Y. (1949). עלה יונה. Jerusalem.
Meshorer, Y. (1967). *Jewish Coins of the Second Temple Period*. Tel Aviv.
Mussaphia, B. (1755). *Mossaph ha Arukh*. Amsterdam.
Natan of Rome, R. (1517). *Arukh*. Soncino.
Natan of Rome, R. (1926). *Idem*, edition Kohut. Vienna.
Noeh, A. (1948). שיעורי תורה. Jerusalem.
Noeh, A. (1951). שיעורי מקווה. Jerusalem.
Pardo, D. (1742). שושנים לדוד, הרב דוד פרדו. Venice.
Ricci, R. (1742). אדרת אליהו (מי נדה), הרב רפאל עמנואל חי ריקי. Livorno.
Ricci, R. (1742). חושב מחשבות (מקוה טהרה), הרב רפאל עמנואל חי ריקי. Amsterdam.
Rogers, E. (1914). *A Handy Guide to Jewish Coins*. London.
Scheftel, J. (1906). ערך מילין, ר׳ חיים יעקב שעפטיל. Berditchev. Reedited Tel Aviv, 1967.
Schurer, E. (1973). *The History of the Jewish People around 175 B.C.E.-135 C.E*. (translated from German). Edinburgh.
Segre, A. (1928). *Metrologica e Circolazione Monetaria degli Antichi*. Bologna.
Sperber, D. (1965 and1966). *Costs of Living in Roman Palestine. The Journal of Economic and Social History of the Orient*: 8 (1965) and 9 (1966).
Sperber, D. (1966). "Palestinian Currency Systems during the Second Commonwealth." *J.Q.R*. 56 (1965-66). Philadelphia.
Sperber, D. (1968). "Gold and Silver Standards." *Numismatic Chronicle*, 8 (1968).
Sperber, D. (1974). *Roman Palestine, 200-400, Money and Prices*. Bar-Ilan University, Ramat Gan.
Sperber, D. (1978). *Roman Palestine, 200-400, The Land: Crisis and Change in Agrarian Society as Reflected in Rabbinic Sources*. Bar-Ilan University, Ramat Gan.
Whiston, W. (1737). *The New Complete Works of Josephus*. London. Re-edition Maier, Paul, L. Kregel, 1999.
Zacuto, M. (1714). קול הרמ״ז הרב משה זכות. Amsterdam.
Zuckermann, B. (1862). *Ueber Talmudishe Muenzen und Gewichte*.

APPENDIX

I. Tables of Ancient Units of Measure of Capacities and Weights

1. Talmudic Units of Measure of Volumes and Capacities

Dry	יבש			Liquid	לח
Large Volumes					
kor	כור	= 10 *bat*		*kor*	כור
eifa	איפה	= 3 *saah*	= 72 *log*	*bat*	בת
seah	סאה	= 2 *hin*	= 24 *log*		
tarkav	תרקב	= 3 *kav*	= 12 *log*	*hin*	הין
issaron	עשרון	= 0.1 *eifa*	= 7.2 *log*		
kav	קב		= 4 *log*		
				log	לוג
Small Volumes					
kav	קב		= 4 *log*		
rova	רובע	= 1/4 *kav*	= 1 *log*	*log*	לוג
touman	תומן	= 1/8 *kav*	= 1/2 *log*	*litra*	ליטרא
		= 1/16 *kav*	= 1/4 *log*	*revi'it*	רביעית
ukhla	עוכלא	= 1/20 *kav*	= 1/5 *log*		
beitza	ביצה	= 1/24 *kav*	= 1/6 *log*		
			= 1/36 *log*	*meshura*	משורה
			= 1/64 *log*	*kortov*	קורטוב

Remarks
The units of capacity of dry contents and of liquids are often interchangeable. The best example is the *miqveh* of 40 *seah*, which is a unit of dry contents.[147]
ukhla 1/5 *log*: B. Bava Batra 90a, Rashi B. Eruvin 29a.
or 1/8 *log*: Rambam, Hilkhot Eruvin I: 12.

2. Greek Units of Measure of Volumes[148] Attic System

Liquids	*Larousse* Liters
cyathos	= 0.045
tetraton	= 0.135
kotyle	= 0.27

147 See Genesis 18: 6.
148 Reference: the big *Encyclopedia Larousse*, 7 vol., undated, about 1905.

kestes	= 0.54
hemichure	= 1.62
chous	= 3.24
amphora	= 19.44
metretes	= 39.3

Dry	Liters
kyathos	= 0.136
kotyle	= 0.27
hemichoiikion	= 0.54
choenix	= 1.08
hemiekton	= 4.30
hekteys	= 8.60
medimnos	= 51.8

3. Roman Units of Measure of Volume

	Larousse	Italian encyclopedias
Liquids	Liters	Liters
cyathus	= 0.046	0.045
hemina	= 0.274	
libra	= 0.327	
sextarius	= 0.547	0.545
congius	= 3.283	3.27
urna	= 13.132	
amphora	= 26.2635	26.20
culleus	= 525.27	
Solids	Liters	
acetabulum	= 0.068	
quartarius	= 0.137	
hemina	= 0.274	
sextarius	= 0.547	0.545
semodius	= 4.377	4.37
modius	= 8.754	8.73

4. Greek Units of Weight

	Larousse	Italian Encyclopedias
	Gram weight	Gram weight
chalque	= 0.09	

hemiobole	= 0.36	
obole	= 0.72	
drachme	= 4.32	4.36
mine	= 432	436
talent	= 25.920 kg	26.160 kg

Roman Units of Weight

	Gram weight
chalcus	= 0.071
siliqua	= 0.189
obolus	= 0.568
scrupulum	= 1.137
drachma	= 3.411
sicilius	= 6.822
uncia	= 27.288
sextans	= 54.78
quadrans	= 81.86
triens	=109.56
semis	= 163.72
libra (*pondo*)	= 327.45

	Kg
dupondius	= 0.655
decussis	= 3.275
centussis	= 32.745

5. Talmudic Units of Weight[149]

drachma		= 3.411 gram weight	דרכמון, דינר
libra	= 96 *denarius*	= 327.45 gram weight	ליטרא
mina	= 100 *denarius*	= 341.1 gram weight	מנה

6. Remarks

The value of 0.547 l for the *sextarius* is taken from the *Encyclopedia Larousse*. The *Great Italian Encyclopedia*[150] writes, for the *sextarius*: 0.545 l and the *Great Spanish Encyclopedia*

149 The problem of the talmudic weights is a chapter in itself. For the moment, we submit some elements necessary to understand the present section.

150 *Grande Dizionario Encyclopedic Utet.*

gives 0.533 l. The dictionary of Bailly (p. 1342) writes that the *xestes* is 0.54 l. The dictionary of Stuart Jones and McKenzie (p. 1189) writes that the *xestes* is nearly a pint of 0.567 l. Weiss (1984), pp. 27-28, assigns the following data: J. Greaves or Grovius (1647), in his Latinized name, referred to the measure of the *congius* of Farnese of 3,405.888 ml and, consequently, the *sextarius* was 567.65 ml. Hultch (1862) writes of a measure of the same *congius* of 3,371 ml and, consequently, the *sextarius* measures 561.83 ml. In the *Encyclopedia Britannica* the *congius* is 3,387.75 ml and the *sextarius* is 564.63 ml.

The weight of the *denarius* is calculated according to a *libra* of 327.45 gr. On the basis of the weight of old coins, i.e. *shekalim* of about 14.16 gr and *uncia* of about 28.33 gr,[151] a weight of the *denarius* of 3.54 gr has been advocated. In the present paper, I have followed the universally accepted weight of the *libra* of 327.45 gr. There remains an incertitude of nearly 4 percent.

II. Analysis of the Roman System of Units of Measurement

1. Units of Capacity

Solids

1 *modius* = 2 *semodius*[152] = 16 *sextarius* = 32 *hemina* = 64 *quartarius* = 128 *acetabulum*

Liquids

1 *culleus* = 20 *amphora*
1 *amphora* = 8 *congius* = 48 *sextarius* = 80 *libra* = 96 *hemina* = 576 *cyathus*

2. Units of Weight

1 *centussis* = 10 *decussis* = 50 *dupondius* = 100 *libra*.
1 *libra* = 2 *semis* = 3 *triens* = 4 *quadran* = 6 *sextarius* = 12 *uncia* = 48 *sicilus* = 96 *drachma* = 288 *scrupulum* = 576 *obolus* = 1728 *siliqua* = 4608 *chalcus*.

We assumed in the present paper, devoted to the study of the talmudic units of capacity, that the units of weight used in the Talmud are the same as the Roman units of weight. This position is justified by the Mishna Sheviit I: 2, ככר דבילה של ששים מנה באיטלקי, from which

151 See Weiss (1984), p. 28.
152 In this paper, all the Latin units used will be used in the nominative singular form.
153 Those Rabbis who follow the theory of the *geonim* (a *shekel* of 17 gr instead of 14.16 gr) explain that the units of weight and coins of the generation of Moses were equal to the Roman units. See R. Samson ben Abraham of Sens in Mishna Sheviit I: 2. Maimonides, ibid., seems to refer to the equality between the units of the time of the Talmud to those of *Italia shel Yavan*, the Italy (Sicily) under Grecian influence, corresponding to the Greek units.

it appears that the talmudic *mana* was equal to the Roman *mina*.[153] We find the same expression: ששים מנה באיטלקי ככר דבילה של in Y. Sheviit I: 1 and II: 1.The system of the talmudic units of weight was coupled with the Roman system, and the talmudic *mana* was identical to the Roman *mina*,[154] and was equal to 100 *denarii*.

II. Fundamental Equations of the Roman System of Units of Measurement

1. Relation between the Units of Weight and the Units of Capacity

There is preserved by Festus,[155] the Silian plebiscitum of unknown origin, a method of regulating the weights and measures to the following effect: that the *quadrantal* (*amphora*) should contain 80 pounds (*libra*) of wine, and the *congius* 10; and that the *sextarius* should be 1/6 of the *congius* and 1/48 of the *quadrantal*. The *quadrantal* was subdivided into two *urna*, eight *congius*, 48 *sextarius*, 96 *hemina*, 192 *quartarius*, 384 *acetatbula*, 576 *cyathus* and 2,304 *lingula*. As compared with the dry Roman measures, the *quadrantal* was three times the *modius*. The only measure larger than the *quadrantal* was the *culeus* of 20 *amphorae*, which was used, as was the *amphora* itself, in estimating the produce of a vineyard.

2. Relationship between the Units of Capacity and the Units of Length

The *quadrantal* was connected with the measures of length by the law stating that it was the cube of the foot, hence its name *quadrantal*, or, as other writers call it, using the Greek *kubos* instead of the Latin *quadrantal*, *amphora cubus*.[156]

There are two questions of interest connected with the Roman *quadrantal*: 1) whether the equality to the cubic foot was originally exact or only approximate, and 2) whether there was any exact ratio between the Roman and the Grecian measures. The discussion of these questions would be inconsistent both with the limits and with the chief object of this paper. A general statement of this dispute can be found under “Mensura” in the *Dictionary of Greek and Roman Antiquities* (1888).

IV. About the Capacity of the *Congius* and the Weight of the *Pondo* or *Libra* (Pound)

There is a *congius* in existence, called the *congius* of Vespasian or the Farnese *congius*, bearing an inscription stating that it was made in the year 75 CE, according to the standard measure in the Capitol, and that it contained, by weight, ten pounds. This *congius* is one of the means by which attempts have been made to fix the weight of the Roman pound or *libra*. Greaves (1647) writes that its capacity is 3,405.88 cm^3, giving a *libra* of 340.59

154 Boeckl mentions the existence in the Roman system of measures of weight of the *mina* (of Greek origin) of 100 *denarii*, often confused with the Roman *libra* of 96 *denarii*.

155 *Lex Silia de ponderibus publicis* (244-04 BCE), Publica Pondera. Festus, L.

156 Priscanus Medicus: Carmen de ponderibus et mensuris.

grams and a *sextarius* of 567.65 cm^3. Boeckl (1838) considers its capacity to be 3,380 cm^3, giving a *libra* of 338 grams instead of the accepted value of 327.45 grams. He mentions also the *sextarius* of Dresden and the *congius* of Saint Genevieve, which give greater values. Now, the Roman theory of the *amphora* being the cubic foot makes it 26,013 cm^3, if we consider a foot of 29.63 cm, leading to a *congius* of 3,251.66 cm^3, a *libra* of 325.16 grams, and a *sextarius* of 541.94 cm^3, or decidedly less than the actual measure. The other theory, that the *amphora* contains 80 *libra* of water, would make it 26,196 cm^3, leading to a *congius* of 3,274.5 cm^3, giving a *libra* of 327.45 grams and a *sextarius* of 545.75 cm^3, again too low for the measurement.

In any event, it appears that, probably because of the surface tension, it is difficult to measure the capacity of the Farnese *congius*. Further, it appears that its caliber has not been determined with sufficient precision according to modern metrology. The results of the measure of its capacity have important ramifications for the Roman pound (*libra*) and for the capacity of the Greek *metretes*, which are known more exactly by other information. One can consider as sufficiently approximate the result given by Hultsch: the *amphora* is about 26.26 liters, the *congius* has a capacity of about 3,283 cm^3 and the *sextarius* is about 547.17 cm^3.

What about the *libra*? We know from Letronne's calculations, from the comparative weighing of 27 consular monies and from 27 *solidus* of Constantine, that the *libra* is about 327 gr. Finally, from the same calculations slightly modified, Boeckh has proposed the value of 327.45[157] gr, which has been universally adopted for the Roman pound.

157 A *pondo* of 327.45 gr gives an *uncia* of 27.29 gr and a *denarius* of 3.41 gr. This last value is a little weak with regard to the weight of the *selaim* of the two revolts. On the basis of these weights, a *denarius* of 3.54 gr would fit better. For this reason, Weiss (1984), pp. 25-29, prefers to adopt the *congius* of Greaves of 3,405.88 gr, a *sextarius* of 567.5 gr, a *libra* of 340.59 gr, a *mina* of 354.78 gr, and a *denarius* of 3.55 gr. I personally prefer to remain cautious, and do not stray from the universally accepted value of the *pondo* of 327.45 gr. It is actually possible that the *sela* or talmudic *shekel* weighed about 14.16 gr and the *dinar* 3.54 gr, according to the Tyrian standard. But after the period of the Tyrian mint's activity and the increasing importance of the Roman standard, the difference between the Roman *denarius* of 3.41 gr and the Tyrian *dinar* of 3.54 gr was neglected. This explains why, during the revolt, Roman coins of one or two *denarius* were restruck into Jewish coins. In other words, it is possible that the Roman *denarius* was actually 3.41 gr and the Tyrian *dinar* was 3.54 gr. Nevertheless, the difference was considered negligible and both were assimilated.