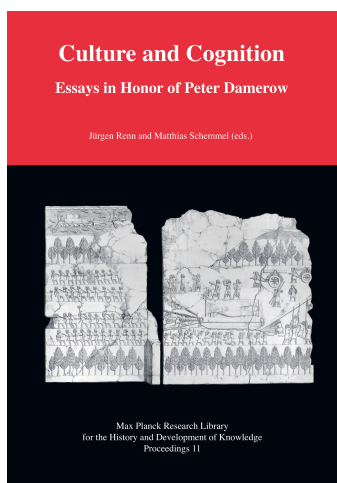Max Planck Research Library for the History and Development of Knowledge
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Markham J. Geller:

Pappus' Theory in Mesopotamian Science

Chapter 8
Pappus' Theory in Mesopotamian Science
Markham J. Geller

As Woody Allen once famously said, "Confidence is what you have before you understand the problem." This was exactly my own situation when I decided to explore whether Babylonians ever employed theoretical propositions or hypotheses. Like Mr. Allen, I was confident of the results, that Babylonians and Greeks were miles apart as far as theory is concerned, and that no real connections between Greek and Babylonian theoretical sciences ever existed.

Let us begin with a relatively simple example, namely pre-Socratic theory regarding the composition of all matter deriving from four basic elements, earth, air, fire, and water, with their associated characteristics of being cold, hot, wet, and dry. No corresponding comprehensive concise statement of cosmological theory has turned up in Mesopotamia, nor is it likely to turn up; for one thing, there is no Akkadian term for "air," nor can we find any Babylonian description of the origins of matter, beyond the usual mythopoeic clichés. This is the typical pattern frequently discussed in modern secondary literature, that Babylonians were good at assembling data but were unpracticed at formulating rules. But as we shall see, this may not be entirely correct.

My view began to change after considering the work of Pappus of Alexandria, which claims to reflect the thinking of Euclid and his contemporaries. Here is what Pappus says:

> Analysis is a method of taking that which is sought as though it were admitted and passing from it through its consequences […] for in analysis we suppose that which is sought to be already done, and we inquire what it is from which this comes about, and again what is the antecedent cause of the latter, and so on until, by retracing our steps, we light upon something already known or ranking as a first principle; and such a method we call analysis, as being a reverse solution. But in synthesis, proceeding in the opposite way, we suppose to be already done that which was last reached in the analysis and arranging in their natural order as consequents what were formerly antecedents and linking them with one another, we finally

> arrive at the construction of what was sought; and this we call syn-
> thesis. (Thomas 1957, 597)

Marshall Clagett, the noted American historian of science, explained this distinc-
tion between *analysis* and *synthesis* as "one of the most important of the general
methodological achievements of the early Greek mathematicians," and he ex-
plains that *analysis* "commences with the assumption of what is to be proved and
then proceeds backward by successive inferences," that is, to prove the hypothesis
correct. *Synthesis* works in the opposite direction, "starting with the previously
accepted or proved theorem and proceeding therefrom to the proof of the new the-
orem." This was all explained by Clagett and many others as an example of the
so-called "Greek miracle" of the fifth century BCE, during which time the Greeks
far surpassed their predecessors in defining new areas of scientific thinking.[1] But
could Pappus' important dictum apply to Babylonian science as well?

Mathematics

The first place to turn to is mathematics, always the best starting point for discus-
sions of scientific method. We now know that the famous Pythagorean theorem,
$a^2 + b^2 = c^2$, was known to Babylonian mathematicians a millennium before
Pythagoras, but without ever formulating the rule as such (Damerow 2001). In-
cidentally, Babylonians always fall short of expectations by not being able to
formulate simple theorems. But what we cannot judge is how Babylonian mathe-
maticians explained their texts, since it is possible that a typical discussion within
an ancient Babylonian academy may well have recognized $a^2 + b^2 = c^2$ as a
rule, but never wrote it down. But why write it down? Was anyone to know that
someone some 3700 years later might be interested in what was being taught in a
Babylonian classroom?

However, it does seem that Babylonian mathematicians indeed worked back-
wards from a hypothetical proposition, à la Pappus' category of *analysis*. A
typical math problem from Old Babylonian Uruk (c. 1700 BCE) computes how
many man-days are required for four different teams of workers to build a ramp
consisting of sections of unequal lengths. After a long and detailed calcula-
tion, the answer is 15 (as a position in the sexagesimal system, which is equal
to $15 \times 60 = 900$) (Friberg 2007, 291). The only reasonable conclusion is that
Babylonian mathematicians, long before Euclid, were employing the *analysis*-
method of working backwards from a given answer—in this case a nice round
number—in order to prove how one arrives at the hypothesis through mathemati-

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[1] Clagett (1966, 33) is nuanced in his approach and his comments on Egyptian and Babylonian science
are quite sober.

cal calculations. This method is standard for Babylonian mathematics and Pappus would have appreciated it.

Divination (Forecasting)

It would be useful to turn to other fields to see if Greek scientific methods have any Babylonian antecedents. We begin with celestial omens, to see if any of these patterns can be identified. Here is a typical example from the classic text *Enūma Anu Enlil*, from the sections dealing with movements of the planet Jupiter (Reiner and Pingree 2005, 40–41):

> If Jupiter (and) Venus stand against each other: the enemy will conquer the the land, as much as there is.

> If Jupiter (and) Venus 'eat' one another and stand against each other: end of the dynasty of the king of Amurru (i.e. the West).

> If Jupiter (and) Venus vie with one another and stand against each other: end of the dynasty of the king of Amurru.

> If Jupiter reaches Venus and they follow upon each other: the flood will come but will not irrigate the field of the commons.

> If Jupiter reaches Venus and passes her: flood in the land will be scarce.

> If Jupiter stands in the rear of Venus: there will be massacre in the land.

> If Jupiter enters into Venus: the prayer of the land will be in the heart of the gods.

Often these omens are repetitive (Reiner and Pingree 2005, 136–137):

> If Jupiter has a 'flare-up' (*ṣirhu*) in the evening watch toward the North: *rapādu*-disease will seize the head of Akkad.

> If Jupiter has a 'flare-up' (*ṣirhu*) in the middle watch toward the North: *rapādu*-disease will seize the middle of Akkad.

> If Jupiter has a 'flare-up' (*ṣirhu*) in the morning watch toward the North: *rapādu*-disease will seize the foundation of Akkad.

> If Jupiter has a 'flare-up' (*ṣirhu*) in the evening watch toward the
> South: *rapādu*-disease will seize the head of Elam. etc.

The typical pattern is that there are many more omens in the protases, in the "if-clause," than anticipated results in the apodoses clauses which follow. For instance, in a similar series of omens from the planet Venus, the results are that the king's son will be killed by his father, a city will be torn down, there will be disruption in the land, there will be a year of remission of debts or lamentation in the land, there will be revolt and famine, etc. (Reiner and Pingree 1998, 93). A similar sequence of lunar eclipse omens combined with winds from the four cardinal directions will result in the royal lands being destroyed, the land will suffer from calamity or the king will die (Rochberg-Halton 1988, 104). What we see is a finite number of such results on the right of the equation in contrast to a vast array of omens and signs on the left side of the equation.

Other examples of the imbalance between the variety of omens on the left side of the equation and the repetitive themes on the right hand column of omen results can also be found in other genres, such as in terrestrial Šumma Alû omens. Cf. the following (Freedman 1998, 296)[2]:

> If a flash of light (*birṣu*) appears in someone's house, scattering of
> the man's household.
>
> If a flash of light (*birṣu*) appears on the wall in someone's house,
> worry for the house.
>
> If a flash of light (*birṣu*) appears on the south wall in someone's
> house, the owner of the house will die (or) worry for the house.
>
> If a flash of light (*birṣu*) appears on the north wall in someone's
> house, the lady (or) owner of the house will die.
>
> If a flash of light (*birṣu*) appears in the bedroom of someone's house,
> a daughter of the house will die.
>
> If a flash of light (*birṣu*) appears on the exterior wall of someone's
> house, a house-slave will die.

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[2]See also Freedman (1998, 133), in which a sequence of omens all have the identical results, i.e., a house will be deserted; in another sequence, the city will be deserted (Freedman 1998, 41). In other instances, in each omen a king of various regions will die (i.e., the king of Guti, Subartu, Akkad, Lullubu, Hanu, or Amurru); see Freedman (1998, 41). In yet another sequence in which various images of a Bailiff-demonic (*rābiṣu*) are found in someone's house (e.g., white, black, red, or yellow-green images), the household will be scattered (Freedman 1998, 277).

If a flash of light (*birṣu*) appears on the wall of an upper room or drain pipe of someone's house, a daughter-in-law of this person's household will die.

If a flash of light (*birṣu*) appears on an exterior wall[3] of someone's house, husband and wife will be divorced and the household will be scattered.

If a flash of light (*birṣu*) like lightning appears in someone's house and has struck someone, that house will have a *mukīl rēši*-demon.

The same pattern occurs in many other genres as well, such as omens derived from the birth of a miscarried foetus, or so-called *Šumma Izbu* omens (Leichty 1970, 78):

If a ewe gives birth to a lion, and it has the face of an ass—there will be severe famine in the land.

If a ewe gives birth to a lion and it has the face of a dog—pestilence.

If a ewe gives birth to a lion and it has the face of a pig—the lady (of the house) will die.

The predicted results of famine, pestilence, and death are all standard. Of course, from a formal point of view, all these omens represent *post hoc ergo propter hoc* fallacies (Bottéro 1982, 426). Consider the following terrestrial omens from the earlier Old Babylonian period (George 2013, 95, 20'–22'):

If in a man's house, in the toilet, a green shoot is sprouting: [the man's household] will obtain food in future.

If in a man's house snakes kiss each other: the population will diminish(?).

If in a man's house mongooses kiss each other: he will achieve greatness.

It is not possible for us to know how such predictions were derived from an almost infinite range of omen topics, but this is where Pappus' observation on *analysis* vs. *synthesis* becomes relevant. In all of the above cases and many more, we can surmise that the first stage in this process was the identification of the result:

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[3]Lit. desert-wall.

the death of a crown prince, regime change, an enemy at the borders, the death of a wife, pestilence, crop failure and famine or even a good crop, and so forth. The obvious way for such a list to be composed is to begin with a hypothetical or actual event: a failed military campaign, a devastating flood, or a bad harvest. The obvious next step is to ask what unusual event happened previously which might have forecast that such a thing would take place; in other words, first comes the event, then working backwards to establish the predictive omens. An earthquake occurs and then one asks if anything unusual happened lately; whatever that was, becomes the omen. Essentially, what we are suggesting is the opposite of what has been proposed for the logic of Babylonian omens: the usual assumption is phrased as, "if P, (then) Q," meaning "on the condition that (or supposing) P, Q happens, or will happen" (Rochberg 2010, 377–378), while we are supposing a somewhat different formulation, at least in the first stages of a proposition: "if Q, then P." Once the pattern has been established and the omen has been identified, then one can revert to the usual pattern of our omen texts, "if P, (then) Q," as described by Rochberg (2010, 373–397).

There is a complication, as always. Not all omens are negative (like most of the ones already cited). Omens based on examining entrails of sheep or birds have specific rules which apply, consisting of complex calculations based upon whether the omen occurs on the right or left side of the particular organ being examined, or in later Latin terminology, the *pars familiaris* or *pars hostilis* (Maul 2013, 86). Here is a rudimentary example (Koch-Westenholz 2000, 190):

> If there are two Paths [on the sheep's liver] and the right one lies above the left one: the forces of the prince will prevail over the forces of the enemy.

> If there are two Paths and the left one lies above the right one: the forces of the enemy will prevail over the forces of the prince.

Omens of this kind depend upon technical laws of divination—not simply a binary "yes" or "no" answer to a question—within a system as complicated as astrology, although based on different assumptions.[4] But luckily, this does not change the overall picture as defined by Pappus of Alexandria, who further explains *analysis*: "by retracing our steps, we light upon something already known or ranking as a first principle" (Thomas 1957, 597). In other words, ancient divination worked

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[4]See Maul (2013, 64–109) on the complications of extispicy in first-millennium BCE omen texts. In fact, each defined area of the sheep liver is divided into upper, middle, and lower registers, each of which is subject to examination on the basis of right-left orientation of any deformities, thus applying binary opposition to numerous statistical variations. The final answer to the omen inquiry is derived from a calculation based upon numerous variables.

backwards from a general hypothesis, namely that *the answer to an oracle question can be found on the sheep's liver*, and one then works backwards step-by-step to test the proposition, examining each of the approximate 100 signs or indicators to see whether each is right or left, positive or negative. This is, in fact, like Pappus' "something already known" or "first principle," since "right" and "left" in all omen texts represent markers of positive and negative propositions, which become the basis for a statistical calculation.

Figure 8.1: Babylonian model of a liver (© Trustees of the British Museum).

Astronomy

But would *synthesis*, as defined by Pappus, have existed within this system? This would mean gathering signs or omens, working in a forward fashion to predict an event, without the benefit of hindsight. In fact, something new occurs in Babylonian science, beginning in the seventh century BCE, which does actually reflect Pappus' category of *synthesis*—the so-called Astronomical Diaries. These texts are not omens but records of celestial events, carefully recorded on a daily basis in Babylon, and the celestial data is correlated with market prices, weather, height

of the river, and occasional significant events, such as Alexander the Great enter-
ing Babylon. Here is a short extract from an Astronomical Diary, from 419 BCE
(Sachs and Hunger 1988, 64f):

> Night of the 29th, Mercury's [first appearance] in the west [in Aries].
> […], barley, 3 sut 3 sila; at the end of the month 3 sut 4 sila; dates
> at the beginning of the month and at the end of the month […]…
> mustard, 2 pan 3 sut; cress, 3 sut; sesame, 1 sut; wool, 50 shekels
> … Jupiter was in front of Mercury; Mercury was in Aries; Saturn
> was in the end of Pisces; Venus and Mars, which had set, [were not
> visible]. Month XII, around the 1st, Saturn's last appearance in the
> end of Pisces. The 6th, a ewe gave birth, and (the young) had no jaw.
> (–418 BCE)

Figure 8.2: Babylonian Astronomical Diary (© Trustees of the British Museum).

Similar diaries mention that there was rain or even hail, or thunder, or that the
river rose 20 fingers, and so forth. The interesting detail in the passage cited here
is the reference to a lamb being born without a jaw, which had obvious omen

significance, although no prediction was being made. Nonetheless, it would have been easy to look up this sign in a compendium of *Šumma Izbu* omens, as we saw earlier, to see what this omen might mean.

There is, however, a major difference between the astronomical diaries and classic divination. Astronomical diaries represent a major shift in Babylonian scholarship towards *synthesis* rather than *analysis*, in which the calculation no longer works backwards from a given hypothesis, but data is assembled in order to establish a new hypothesis. The purpose of the astronomical diaries is to record the data for astrological predictions, with the assumption that celestial movements influence terrestrial events, in particular agriculture, weather, and even politics. The way for ancient scholars to make the case for celestial influence was to gather all relevant facts on a given day, day after day, to establish the connections. This methodological innovation is supported by one other important bit of information from Babylonia.

Not long after the introduction of Astronomical Diaries, we see the beginnings of the zodiac in Babylonian astronomy and astrology, which is a major development for a variety of reasons. One characteristic of the zodiac is its simplicity: it replaced a Babylonian star and constellation list which consisted of some 300 lines; a meagre listing of 12 zodiac signs could be mathematically adapted to map the heavens in an unprecedentedly precise manner. What we lack from Babylonia, of course, is any theoretical treatise on the zodiac and how it was to be used, but the obvious simplicity of this mechanism is a statement in itself, that we are moving in the same direction as Thales and Heraclitus and others in attempting to simplify the way the data is presented and evaluated.

Medicine

Let us consider how this system would work in medicine. The Babylonian *Diagnostic Handbook* is a lengthy collection of symptoms corresponding to some parts of the Hippocratic Corpus. The *Handbook* is partially arranged from head to foot according to human anatomy, with other sections relating to epilepsy and related diseases, gynecology, and pediatrics; in all, this text consists of some 40 tablets or chapters listing several thousand different symptoms, all ending in either a prognosis or diagnosis. The point about the *Diagnostic Handbook* is that it is about disease and not patients; it does not record individual case histories. This means that numerous symptoms for a considerable number of diseases were divided up according to parts of the human body; that is, all the symptoms affecting the head, eyes, ears, nose, mouth, neck, and so forth, were listed separately, according to their associations with human anatomy, rather than listing all of the relevant symptoms for each disease (Geller 2005, 254–255):

(Foot Disease)

If his calf on the left *is short* and [throws up] dark-red blood from his mouth […].

If his foot on the right hurts him, it is the Hand of Ištar; if his left foot [hurts him, it is the Hand of …].

If (both) his feet hurt him, it is the Hand of Inanna; if his feet hurt him, it is the Hand of …, he will recover].

If he drags his foot on the right (and) his mouth twitches, [it is a stroke (caused by) the Snatcher(-demon), it will be prolonged and he will die].

If he drags his foot on the left, [he has been struck a] blow by the [Hand] of Baba, [he will die].

[If] his foot on the right keeps shrinking, it is the Hand of Ištar; it is seizure by a ghost, [he will die].

[If] his foot on the left keeps shrinking, it is the Hand of his God; if (both) his feet keep shrinking, [the Hand of a God; evil has seized him].

Why did they do this? One reason might be purely practical, in that a practitioner could look up which diseases might correspond to any single symptom, for example, yellow spots in the eyes or blood in the urine; we should think of the ancient *Diagnostic Handbook* as the equivalent of an index to a modern medical textbook. But one thing is clear, that it would be virtually impossible to diagnose diseases based on the several thousand symptoms scattered throughout this text, or even to recognize the diseases from this arrangement of symptoms. On the other hand, applying Pappus' methodological principle of working backwards goes a long way to explaining this puzzling text: the *Diagnostic Handbook* was assembled by working backwards from the diseases themselves. Once a disease was hypothetically recognized by a given set of symptoms, based on observation, the next step was relatively easy, to identify and organize the individual symptoms according to various parts of the human body.

If this is the case, then can we find evidence for *synthesis* in Babylonian medicine? This is not an easy question to answer, since the system of therapeutics is already well established relatively early in the second millennium BCE, and thus predates the type of distinction we have noted above between traditional astronomical divination (in *Enūma Anu Enlil*) and astronomical diaries. Nevertheless,

there may be some indications of *synthesis* in medical recipes, if we consider the following therapeutic recipe for rectal disease dating roughly from the eighth BCE (Geller 2005, 145):

> If (a man's) limbs are limp and his chest and back hurt him, his arms, shins and knees hurt him, his right or left testicle aches him, and he shows blood in his urethra, that man suffers from stricture of a diseased rectum. To cure him …

This, then, could qualify as *synthesis*: the relevant data is assembled via observation in order to establish an hypothetical diagnosis, which is especially noteworthy since none of the symptoms actually refers to the anus, but to other parts of the body. This is unlikely to be a case of the backward logic of *analysis*, since each of the symptoms would be more realistically associated with other typical medical conditions within Babylonian medicine, such as kidney-disease or being lame. The question is whether there is any development in diagnostic methods as compared to earlier periods. Among the relatively few examples of medical texts stemming from the second millennium BCE, a pattern appears which differs considerably from the above-cited recipe for diagnosing and treating rectal stricture, since descriptions of symptoms from earlier periods tend to be brief and self-explanatory, such as the following:

> If a man is behexed, you dry out …

> If a man is ill with jaundice, you soak …

> If a man's tooth is attacked by a worm, you grind up … etc. (Schwemer 2010, 37)[5]

indicating relatively simple diagnoses to be treated. Occasionally, descriptions of symptoms are more elaborate, such as the following from a mid- to late-second millennium medical tablet:

> If a man has pain in his kidney, his groin constantly hurts him, and his urine is white like donkey-urine, and later on his urine shows blood, that man suffers from 'discharge' (*muṣû*-disease). (Geller 2005: 35, 23'–24')

There is no mystery here, since symptoms are all associated with the penis and the logic is transparent. The theme of witchcraft as a medical problem is also attested in mid-second millenium BCE Akkadian sources from the Hittite capital Hattuša, and these popular texts were constantly recopied in later periods,

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[5]See the bibliography in Schwemer (2010, 38–39).

with somewhat more complex patterns of diagnosis than those just discussed. In one case, problems affecting the hips and toes are ascribed to the patient having walked in unclean water, while in another case his various symptoms (paralysis, fever, impotence) are explained as having been caused by witchcraft generated through a buried figurine of the patient (Schwemer 2010, 39). There is relatively little sophistication in the diagnosis, since witchcraft was standardly associated with certain physical and mental conditions in divination, magic, and medicine. There is little evidence of *synthesis* within these earlier texts and in fact the presence of *synthesis* in medical texts in general is open to question.

What we lack, in any case, is any simple statement of theory, or any rule which tells us how these symptoms are collected and sorted in order to produce the hypothetical diagnosis. In the *Diagnostic Handbook*, symptoms are often described as red, yellow, black, and white, or moist or dry, swollen or distended, similar in many respects to what is found in Greek medical writings, but without justification in Babylonia. But we can detect one step in the direction towards theory in Babylonia: simplification. One Late Babylonian tablet from the Achaemenid Babylonia, from roughly 500 BCE, was published by Irving Finkel as the *"Poor Man's" Diagnostic Handbook* (Finkel 1988, 153), in which on this single fragmentary tablet symptoms of the body are listed from head to foot; all forty chapters of the original *Diagnostic Handbook* are reduced to a text of some 25 lines. Here is a translation.

1 [If the patient's head(?) continually hurts him and he] constantly cries out, (it is) the Hand of Anu (var. another god).

2–7 [(If) his …] continually hurts him, (it is) the hand of [(a god)].

8 [(If) his … continually hurts him, (it is) the hand of Marduk.

9 [(If)] his [… continually hurts him], it is the hand of Anu.

10 (If) his *mouth* continually hurts him, (it is) the hand of Adad.

11 (If) his tongue and its *vessels* continually hurt him, (it is) the hand of Lisi.

12 (If) his chest continually hurts him, (it is) the hand of Ishtar.

13 (If) his shoulders continually hurts him, (it is) the hand of (gods) Shullat and Hanish.

14 (If) his right side continually hurts him, (it is) the hand of Ishtar.

15 (If) his left side continually hurts him, (it is) the hand of [(a god)].

16 (If) his insides are continually inflamed, (it is) the hand of [(a god)].

17 (If) his loins continually hurt him, (it is) the hand of [(a god)].

18 (If) his right foot continually hurts him, (it is) the hand of [(a god)].

19 (If) his left foot continually hurts him, (it is) the hand of [(a god)].

20 (If) his *brain* is struck, it is the hand of Zababa.

21 (If) his … continually hurts him, (it is) the hand of [(a god)].

22 (If) [his …] continually hurts [him, (it is) the hand of (a god)].[6]

There is another example of simplification in a unique late text from Uruk, from approximately the same period as Finkel's *Poor Man's Handbook*, in which a list of diseases within the body is associated with four internal organs. This text is more complicated than it looks, but it clearly reflects some kind of new theoretical thinking in Babylonia which has not appeared earlier, and this theory is expressed in a concise and simplified schematic form. Here is an extract (Geller 2014, 3):

ul-tu KA *kar-šú mu-ru-uṣ*	from the throat, head and
sag.du(*qaqqadi*) *u pi*-[*i*]	mouth disease
KI.MIN *pi-i šin-ni*	ditto, mouth, teeth their
⌜mur.dúr⌝.meš-*šú-nu*	'toothworms'
KI.MIN MIN ⌜*gir$_{11}$*⌝-[*gi*]-⌜*iš*⌝-*šum*	ditto, ditto, red skin lesions
KI.MIN MIN ᵈdìm.me	ditto, ditto, Lamaštu
KI.MIN MIN *pa-šit-t*[*u₄*] ᵐⁱ*mar-tu₄*	ditto, ditto, Pašittu-daughter
KI.MIN ⌜*ma-li*⌝ *me-e*	ditto, dropsy
KI.MIN *qāt etimmi* (šu.gedim.ma)	ditto, hand of ghost
KI.MIN *maš-ka-du*	ditto, joint disease

From about this same time, we also have a unique tablet, again from Babylon,[7] containing a table of domestic and wild animals associated with zodiac signs in

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[6]These attributions of symptoms to the hand of a god are likely to be technical rather than pious.

[7]Heeßel (2000, 112–130); see also the discussion in Geller (2014, 87–88). The text is also relevant to the Microzodiac, treated in the forthcoming dissertation of Marvin Schreiber.

numbered sequences, as well as material medica and dietary restrictions (not to eat leeks, pork, wheat, or drink milk) on certain days of the month, each associated with a zodiac sign. This late, unique, and exotic text, a type of zodiacal hemerology, once again attempts to simplify and record astrological and related data in a tabular form which could potentially be used to develop general rules as applications of astrology.

The Role of Motion and Concluding Remarks

There is one additional aspect of ancient Babylonian science which is worth considering. The matter is speculative, but in an article devoted to Peter Damerow, this kind of speculation is quite appropriate. It has long been noticed that traditional Babylonian divination, such as the liver omens described above, gave way to astrology and soon after the advent of the zodiac, other forms of predicting the future became increasingly obsolete. Although many reasons are given for this profound change in thinking and practice, one factor appears to have escaped notice. Most of Babylonian divination is static: a phenomenon is witnessed and recorded and an event is associated with the portent, for example, an unusual birth, an unusual node on a sheep's liver, or even the position of a star or planet in relation to fixed stars. The novelty of astrology and divination based on the zodiac, as well as astronomical diaries, is that predictions were based upon motion and movement of the stars, rather than on their static positions. The astronomical diaries, for instance, record the position of the moon at regular intervals during the month, noting its constantly changing position in relation to zodiac signs, and even remarking that the moon "passes a little to the east" (Sachs and Hunger 1988, 195, 33). The point of these observations is that the *movement* of the moon and planets was responsible for astral influences on terrestrial events, as mentioned above.

The reason why this change in perspective is significant is because the same interest in motion and movement became a basic tenet of early Greek science, especially the idea that movement generated power. We return again to Clagett (1966, 52):

> Constant attention to change and movement and speculation as to the causation involved stimulated the basic idea that when things change or move there are activating forces—no longer mythological but physical forces […]. The early emphasis on force, power, action is also reflected in the medical works contemporary with the philosophical activity. Thus Plato says that Hippocrates (b. at Cos in 460? BCE) holds that to find the fundamental nature (*physis*) of a

thing we must examine its "power," or *dynamis*—i.e., its capacity of acting or being acted upon.

Liba Taub observes something similar in the writings of Aristotle:

Aristotle acknowledged that the idea of the primacy of local motion had been around for a long time; he noted that many of his predecessors who had studied motion had treated local motion as the primary principle of change. (Taub 1993, 37)

What strikes us here is not only Aristotle's own attention to motion, but that earlier thinkers have been speculating about motion as well. It should not therefore surprise us that Babylonian astronomers charting the heavens also considered motion and movement of celestial bodies as worthy of careful notation. Greek philosophy naturally proceeded in a much more sophisticated way in identifying various types of motion within physics,[8] but this does not detract from the possibility that Babylonian scholars were charting celestial motion as theoretically relevant to predicting the future.

So what are the implications of this data for our view of ancient science before the Greek "miracle" suddenly appeared in Miletus and elsewhere? First of all, we still do not have evidence of Babylonian theory from academic treatises, but we can detect some movement in the right direction, that is, moving closer to the pre-Socratics. The tendency towards schematic presentations of data in tabular form is a feature of Late Babylonian scholarship, more-or-less contemporary with the beginning of Greek philosophy, and the similar tendency towards simplification of a large amount of complex data probably indicates greater interest in developing general rules. But where are these general rules from Babylonia? We lack them, but the example of the zodiac gives a pretty clear picture of how a very elaborate system of celestial divination with thousands of individual clauses could become boiled down to a bare minimum of characters—12 zodiac signs—that can be manipulated mathematically. But perhaps the most interesting implication of all is that Pappus of Alexandria describes a methodology for Greek mathematics, which applies to Babylonian science as well. It seems that Babylonian astronomical diaries, a new genre of scientific texts, represent clear examples of *synthesis*, that is, accumulating data in order to formulate a new hypothesis about celestial influences or astrology, while more traditional forms of Babylonian divination (including medical diagnostics) relied upon *analysis*, which worked backwards from a proposed hypothesis or proposition.

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[8]See Taub (1993) in relation to Ptolemy.

Acknowledgements

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