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The Introduction of Rhythm in Life Science and Medicine (4th - 3rd century BC) — Part 2

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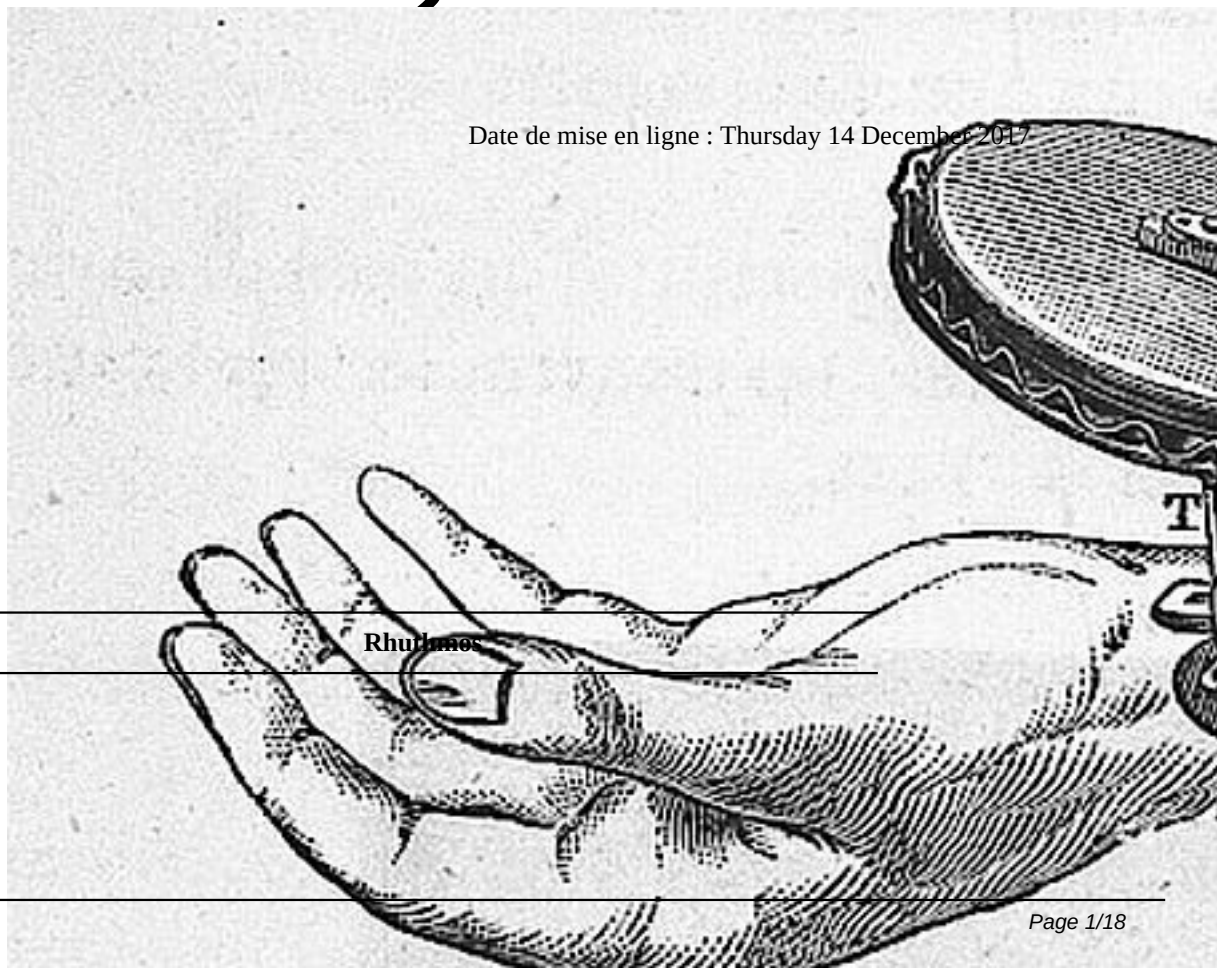

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Rhythm as Characteristic of Artery Pulse - Herophilus (ca. 325-255 BC)

Born in Chalcedon-Bithynia a few years after Aristole's death (322 BC), Herophilus moved at a fairly young age to Alexandria to begin his schooling. He was one of Praxagoras' pupils, yet we do not know where he received his teaching. He seems to have spent most of his life in Egypt. He wrote at least eight books, unfortunately none of them remains [1].

Through Praxagoras, he was familiar with Aristotle's anatomy and physiology; he also knew that pulsation only occurs in the arteries, not in the veins; that the pulse can be perceived in us from birth to death as an activity or function; and he was accustomed to pay attention to it for diagnosis. However, he surpassed both of his predecessors because he was one of the first scientists to perform systematic dissections of human cadavers.

Concerning the pulse, he opposed his master's opinion by clearly distinguishing between pulse and palpitation: "´¹¿Á¯¶¿½Ä± ÃÆÅ¼ò½ À±»¼¿æ -*diorìzonta sphugmòn palmoû*" (Galen, *De pulsuum differentiis*, 4.2, 8.716, see also 4.3, 8.723 and Rufius Ephesius, *Synopsis de pulsibus*, 2, in von Staden, 1989, p. 327) [2], "putting a definitive end, as Littré put it, to confusion in terms and things" (Littré, *Hippocrate*, 1842, chap. 9). Concurrently, he seems to have initiated the distinction between the two phases or parts of the pulse: the ´¹±ÃÄ¿»® - *diastolê* - dilation when the artery moves outward towards the physician's touch; and the *ÃÅÃÄ¿»®* - *sustolê* - contraction when it moves inward again, away from the touch [3].

He also opposed Praxagoras' view that the arteries pulsate by themselves and maintained that they pulse from two sources: from some connection to the heart and from a faculty flowing to them through their tunic (Galen, *De puls. diff.*, 4.2, 8.702-703). This was, according to him, "the reason why all of the arteries are observed to dilate at one and the same time and to contract [simultaneously], preserving for the heart the same fixed time for both motions." (Galen, *De puls. diff.*, 4.6, 8.733, trans. Heinrich von Staden). However, this simultaneity did not mean that the pulse was, in his view, related to the action of the heart as a pump and that it was provoked by the dilation of the arteries under the successive blood waves. The blood circulation and the central role of the heart in it were indeed discovered only in the 17th century by Harvey.

His general views on the human body and the role of pulse are excellently recapitulated by Heinrich von Staden.

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> Herophilos seems to have believed that the body is a material continuum that harbors no void, and that invisible, innate capacities or faculties control and regulate all bodily functions, often by attracting or pulling various forms of matter liquids, solids, air through ducts and other spaces in the body toward their appropriate destinations. These innate faculties are thoroughly secularized; no claim of divine design or divine force is made for them. Thus an invisible, innate faculty ("vital *dynamis*"?), extending simultaneous dilatation and contraction of the heart and of all arteries. This *dynamis* thereby pulls or "attracts" a mixture of blood and *pneuma* (the latter ultimately derived from respiration) from the heart through the entire body via the arterial system. Blood (without *pneuma*) apparently is similarly moved through the veins, while *pneuma* by means of which at least some sensory and voluntary motor activity is conducted is moved through the nerve ducts. (Von Staden, 1996, p. 87)

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Since none of his writings remains, we have no direct evidence that he ever used the term *rhuthmys* to refer to the pulse in his famous *µÁì ÃÆÅ¾ö½ - Perì sphugmôn - On pulses*. But, thanks to quite abundant later sources (Pliny, Marcellinus, Pseudo-Rufus, Galen, and others), we are able to assert with enough certainty that he did.

Since the end of the 19th century, there has been a swinging debate concerning the origin of Herophilus' definition of pulse rhythm. Wellmann (1895) long ago suggested that Herophilus adopted his terminology and theory of rhythm from Aristoxenus of Tarentum. This was also much later Jackie Pigeaud's view (1978, p. 262). But in his influential book on Herophilus, Heinrich von Staden strongly doubted that Aristoxenus influenced Herophilus. He noticed that "none of the numerous ancient sources which acknowledge Herophilus' debt to musical theory or metrics characterize it as a debt to Aristoxenus," and attributed implicitly his particular use of a limited number of metric patterns to his larger humanist knowledge and the rest of his rhythm theory to his own ingeniousness (1989, p. 278-279). Yet, in his 1996 article, he seemed to change his mind and considered Aristoxenus' influence "possible" (p. 89). Quite recently, Marquis Berrey returned to Wellmann's and Pigeaud's opinion and discussed again the main pieces of evidence that may prove Aristoxenus' influence on Herophilus (2011, p. 60 *sq*.). I will try to show that Wellmann, Pigeaud and Berrey are most probably correct and that this insight tells us a lot about one of the most important channels through which the Platonic-Aristotelian concept of *rhuthmós* began to spread over the Greek culture during the 3rd century BC.

Galen recalls that Herophilus borrowed concepts from "musicians" *(mousikoì)*: he compared the dilation *(diastolê)* with a musical up-beat *(ársis)*, the contraction *(sustolê)* with a down-beat *(thésis),* and the "defined sequences of time-units" they form (*hôrisménas khrónôn táxeis* - lit. definite or regular order of times) with what the musicians called "rhythm." In other words, a rhythm amounted to a sequence of dilations and contractions, i.e. of *ársis* and *thésis*, characterized by a specific "proportion" between the duration of the former and that of the latter. As we can see, this was a direct and faithful application of the *metric Platonic-Aristotelian paradigm*.

> For, just as musicians *[¿1 ¼¿ÅÃ¹º¿v - hoi mousikoì]* establish rhythms according to certain defined sequences or time-units *[aÁ¹Ã¼-½±Â ÇÁÌ½É½ Ä¬¾µ¹Â - hôrisménas khrónôn táxeis]*, comparing up-beat and down-beat with each other *[»»®»±¹Â ÁÃ¹½ º±v ¸sÃ¹½ - allêlais ársin kaì thésin]*, so too Herophilus supposes that the dilation *[´¹±ÃÄ¿»® - diastolê]* is analogous to the up-beat *[ÁÃµ¹ - ársei]*, while the contraction [of the artery] *[Ät½ ÃÅÃÄ¿»t½ ÄÆÂ ÁÄ·Á¯±Â - tên sustolên tês artêrías]*is analogous to the down-beat *[¸sÃµ¹ - thései]*. (Galen, *Synopsis librorum suorum de pulsibus*, 12, 9.464, trans. Heinrich von Staden, my mod.)

Let us first note a point that could seem marginal but that will not be without significance, as we shall see when we look into Galen's contribution. According to von Staden, Herophilus characterized the dilated state of the artery as its "natural condition" and the contracting movement as its "activity," but Galen attributed to him two divergent and inconsistent views on this question: sometimes Herophilus considered both the dilation and the contraction an activity or *energeia* of the artery, but at other times, most often as a matter of fact, only the contraction (von Staden, 1989, p. 272). But, more recently, Berrey has argued that, when he constructs a normative pulse rhythm for each age-group, as we shall see immediately, Herophilus actually makes each cycle start from the dilation of the artery (Berrey, 2011, p. 56). Given the conflicting evidence available to us, it is difficult to decide which option is correct but there is an argument that has not been used yet without though being decisive: Berrey's view could be more consistent with the choice of *ársis* and *thésis* for contraction and dilation noticed by Galen, since in dance and music they refer respectively to the raising and lowering of the feet or the hands and the former necessarily precedes the latter. As Bacchius noticed: "What do we mean by *ársis*? When our foot is in the air, when we are about to take a step. And by *thésis*? When it is on the ground." (Bacchius, *Isagoge* 98 in *Musici Scriptores Graeci*, quoted by Pearson, 1990, p. xxiv).

We should also note that Herophilus does not consider pauses or rests to be part of the pulse rhythm. The rhythm is, for him, an organized but continuous series of up-beats and down-beats, with no intervals.

> As most musical theory up to the time of Herophilus views up-beat and down-beat as contiguous in time, and hence recognizes no pause between them, so Herophilus unlike later writers on music and pulse-lore regards the contracting and dilating motions of the artery as immediately adjacent in time and hence finds no need to elaborate on the intervals of inactivity between contraction and dilation. (von Staden, 1989, p. 277)

Based on the evidence gathered so far, Herophilus' innovation could seem to consist in a mere displacement of concepts from music and poetry theory into medicine. But it is actually more than that. Herophilus further elaborates the common concept of rhythm to adapt it to his needs. This is what we see in a large fragment from his treatise *On pulses*, quoted in Galen's *On differentiating between Pulses*.

In this fragment, Herophilus proposes to characterize the pulse by four or five ways to differ *(´¹±Æ-Áµ¹½ - diaphérein)* i.e. differences, characteristics, or aspects.

> When he introduces the subject [Herophilus] says this for I will write down the entire passage [...] *"In general pulse seems to differ from pulse in amount [volume?], size, speed, vehemence [strength], and rhythm* [À»®¸µ¹, ¼µ³-¸µ¹, Ä¬Çµ¹, ÃÆ¿´ÁÌÄ·Ä¹, åÅ¸¼÷ - plêthei, megéthei, tákhei, sphodrótêti, rhuthmôi]*. From their differences in these respects pulse at times appears proper and [at times] not proper* [¿0ºµÖ¿Â º±v ¿Pº ¿0ºµÖ¿Â - oikeîos kaì ouk oikeîos - *lit. proper to a thing, fitting to their true nature, suitable and not]. One pulse seems to differ and be recognized generally as different from another, as was said, in rhythm, size, speed, vehemence* [åÅ¸¼÷, ¼µ³-¸µ¹, Ä¬Çµ¹, ÃÆ¿´ÁÌÄ·Ä¹ - rhuthmôi, megéthei, tákhei, sphodrótêti]*. [But if, in the same rhythm* [½ Ä÷ ±PÄ÷ åÅ¸¼÷ - en tôi autôi rhuthmôi]*, one pulse seems to differ from another, then [it is] in speed, size, and vehemence.]"* (Galen, *De dignoscendis pulsibus*, 4.3, 8.959-60, trans. Marquis Berrey, my mod.)

Two remarks: rhythm *(åÅ¸¼ÌÂ - rhuthmós)* is here contrasted first with four then three other concepts; furthermore, it comes either last or first in the list, as if it had a particular status in the series.

Three of these *differentiae* are clear enough. The "size - *¼-³µ¸¿Â - mégethos*" of the pulse means how much the artery moves outward to the physician; the "speed - *Ä¬Ç¿Â - tákhos*," how quickly; the "vehemence - *ÃÆ¿´ÁÌÄ·Â - sphodrótês*," with how much strength. Size, speed, and strength are clearly three quantitative criteria based on the observation of the dilation, whereas rhythm denotes the qualitative organization of a full cycle encompassing dilation and contraction. Let us notice that contrarily to its rhetoric or poetic counterparts, the pulse rhythm includes no aspect of strength. Rhythm does not perform any action, it is a pure sign, a *Ã·¼µÖ¿½ - sêmeîon*.

By contrast, there is a bit of obscurity in the relation of "rhythm" with the fifth *differentia*: "amount / volume [4] - *À»Æ¸¿Â - plêthos*." Von Staden wonders if, since no other text confirms that Herophilus used "volume" to describe or classify any pulse, it might be "a later interpolation" (von Staden, 1989, p. 274). If it is not, it is unclear whether the disappearance of this *differentia* in the second sentence of the definition given by Herophilus meant that, in his view, it was related in some way with one of the other *differentiae* and that it would have been therefore superfluous or redundant to mention it or, more simply, that it was of a lesser importance.

The problem did not escape Galen who concluded, since Herophilus mentioned *plêthos* only one time in his book, that the fifth *differentia* was actually for him secondary, even if he took it plainly into account in his practice.

> What more reliable witness to Herophilus' view do you wish to get than Herophilus? *"One pulse appears,"* he says, *"to differ from another, in rhythm, size, speed, vehemence, as was said."* If indeed the expression *"in [amount]" [À»®¸µ¹ - plêthei]* actually signifies some difference between pulses, why, then, did he omit it here [in the second enumeration] when he resumed his argument, not simply or lazily, but with the addition "as was said"? And why does he say that pulses *in the same rhythm [½ Ä±PÄ÷ åÅ¸¼÷ - en tautôi rhuthmôi]* differ in speed, size, and vehemence? [...] And what's more, while he appended these very words in just about every case, he nowhere added "in [amount]" *[Äx À»®¸µ¹ - tò plêthei]*. Rather, only in Book 1, not in all his works [did he add it], although he would not have omitted it if indeed it were a name of a difference between pulses. (Galen, *De dign. puls*., 4.2, 8.959-960, trans. Heinrich van Staden, my mod.)

Berrey suggests that *plêthos* may have had "some connection to frequency, which Herophilus measured with a water clock" that will be discussed below precisely through the flow of a variable "amount" or "volume" of water (Berrey, 2011, p. 56). An interesting clue in favor of this hypothesis is another passage where Galen comments the controversy among later physicians to account for Herophilus' use of a fifth *differentia* that was already unclear to the Ancients. According to him, *"À»®¸µ¹ - plêthei"* would not mean "fullness" as many thought it did, but "frequency - *ÀÅº½ÌÄ·Â - puknótês*." If it was not among the main differences that supported the pulse classification in four species, it was often mentioned by Herophilus and used in his clinical practice.

> I shall start from the passage they put forward, which is recorded in Book 1 of Herophilus' *On Pulses*. This is also the only passage they seem to have read. It runs as follows: *"In general, then, pulse is thought to differ from pulse in [amount]* [À»®¸µ¹ - plêthei]*, in size* [¼µ³-¸µ¹ - megéthei]*, in speed* [Ä¬Çµ¹ - táxei]*, in vehemence* [*ÃÆ¿´ÁÌÄ·Ä¹* - sphodrótêti]*, and in rhythm* [åÅ¸¼÷ - rhuthmôi].*"* This passage they put forward, asking what "[amount]" *[À»Æ¸¿Â - plêthos]* is, just as if we would not recognize what kind of thing he signifies with "[in amount]" *[À»®¸µ¹ - plêthei]* and as if "fullness" *[À»·ÁÌÄ·Ä¿Â - plêrótêtos]* were necessarily what it means. I then answer cleverly, I think: for I say the expression "[in amount]" *[À»®¸µ¹ - plêthei]* signifies "[in frequency]" *[ÀÅº½ÌÄ·Ä± - puknótêta]*. [...] So, since the difference in "fullness" neither reached the point of being discerned, as was shown, nor is mentioned elsewhere by Herophilus, whereas the difference in frequency *[ÀÅº½ÌÄ·Ä± - puknótêta]* is conceded by all, and Herophilus is found to record it ten thousands of times, it would be more reasonable to think that "frequency" was meant rather than "fullness." (Galen, *De dign. puls*., 4.2, 8.956-958, trans. Heinrich van Staden, my mod.)

We know through other sources that Galen is probably right. Marcellinus (late 1st - early 2nd c. AD) provides a precious insight in the clinical use of the pulse *frequency*, associated with strength and size, by Herophilus as means for measuring fever.

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Herophilus declared that a patient had fever whenever the pulse became more frequent *[ÀÅº½ÌÄµÁ¿Â - puknóteros]*, larger, and more vehement with much internal heat. If therefore [the pulse] should lessen its vehemence and size, the fever is in remission. He says that the frequency *[ÀÅº½ÌÄ·Ä± Äö½ ÃÆÅ³¼ö½ - puknótêta tôn sphugmôn]* of the pulse becomes primary when fevers begin and remains so until their final resolution. (Marcellinus, *De pulsibus*, 11, ed. Schöne p. 463, trans. Marquis Berrey)

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Moreover, as we will see below, he used frequency to differentiate between pulses of different ages. Nevertheless, it seems that Herophilus paid more attention to speed than to frequency. Von Staden notices that "speed was actively used" by Herophilus "and not 'frequency'" and that may explain why he did not mention it in his second list of differences.

> Whatever the exact relationship between "speed" and "frequency" in Herophilus' pulse-lore might be, it is clear from more than one ancient text that "speed" and not "frequency" was actively used by Herophilus to define certain kinds of pulse, i.e. that he did not merely develop "speed" as a hypothetical *differentia* which in practice was abandoned in favor of "frequency." (von Staden, 1989, p. 284)

Let us recapitulate. Since *plêthos* most probably meant "frequency," its disappearance in Herophilus' second list may well show that it was simply, in his view, another quantitative difference that could supplement the measure of the dilation but that had no direct connection with rhythm, that remained a larger concept encompassing the full cycle of the pulse. But it could also indicate that it was redundant with some other difference why not rhythm? So we will have to come back to this point below.

Rhythm as Characteristic of Life Stages - Herophilus

So far we have witnessed the emergence, supported by a common metrical knowledge, of the *metric Platonic paradigm* in a remote area of the medical knowledge. We will see now how, by using more sophisticated concepts borrowed from Aristoxenus, it became central, providing the support for a very long-lasting view of the living. Metric rhythm, which was considered at first only as one of the aspects of the pulse became an essential medical and scientific category laying the ground for ulterior equating of pulse, respiration and rhythm.

This transformation already shines through, despite its brevity and allusive aspect, in a passage of Pliny's *Natural History* (23-79 AD), where he reports that "the pulsation of the arteries" was compared by Herophilus to "certain measures and metrical laws, depending on the age of the patient."

> The pulsation of the arteries is more especially perceptible at the end of the limbs; and afford indications of nearly every disease, being either stationary, quickened, or retarded *[stabilis aut citatus aut tardus]*, conformably to certain measures and metrical laws, which depend on the age of the patient *[in modulos certos legesque metricas per aetates]*, and which have been described with remarkable skill by Herophilus, who has been looked upon as a prophet of medicine [with wondrous skill]. (Pliny, *Natural History*, 11.89.219, trans. John Bostock & H.T. Riley, my mod.)

This point becomes clearer in later more articulated sources which show that Herophilus relates specific pulses to different age-groups, using to that effect Aristoxenus' theory of rhythm, without yet replicating it slavishly.

We remember that the latter started from a primary time-length *(ÀÁöÄ¿Â ÇÁÌ½¿Â - prôtos khrÌnos)*, whose nature depended on the rhythmizable matter *(åÅ¸¼¹¶Ì¼µ½¿½ - rhuthmizÌmenon)* which was to be considered (poetry, dance, music), and then constructed the rhythm as an arithmetically organized set of primary time-lengths. He insisted though on the necessity to determine this primary time-length through perception (see chap. 3). Likewise,

even if he does not make use exactly of the same words, Herophilus defines the movements of heart and arteries as the "rhythmizable" peculiar to medicine; the "primary time-length" as the interval of time in which the artery of a newborn would dilate; and the pulse rhythm as a "set of primary time-lengths" endowed with variable arithmetic qualities.

Naturally, this does not mean sheer imitation. The *Synopsis de pulsibus - Synopsis on Pulse* by Pseudo-Rufus of Ephesus (2nd c. AD) [5] gives a fairly detailed account that shows what he owes to Aristoxenus and what he contributes on his own.

As Aristoxenus, Herophilus proceeds from the bottom up, from the elements to the whole. He starts by defining, based on the pulse of the newborn children, a "primary time-length," which he calls "*álogon* - irrational," or more clearly for us "*á-logon* - without definable ratios," i.e. literally without rhythm, just like a point in geometry is both elementary unit of space and without any extension. "It is similar in size, he says, to the prick of a needle."

Hence, whereas Aristoxenus insisted that the primary time-length be observable, it is qualified by Herophilus as "not distinct" in the newborns and seems thus to be determined only rationally.

> The pulse of newborn children, then, is completly short and not distinct in its contraction and dilation. Herophilus says that this pulse is constituted *"without definable ratios" [»¿³¿½ - álogon* - lit. irrational*]*. He calls the pulse which is without relation to some ratio *[ÀÁÌÂ Ä¹½± ½±»¿³¯±½ - prós tina analogían]* a pulse *"without definable ratios,"* for it has neither a double ratio, nor a ratio of one and a half to one, nor any other proportion *[ÄµÁÌ½ »Ì³¿½ - heterón logon]*, but rather is completely short, and we observe it to be similar in size to the prick of a needle. For this reason Herophilus first called it *"without definable ratios," [»¿³¿½ - álogon]* as one should. (Pseudo-Rufus, *Synopsis de pulsibus*, 4, ed. Daremberg p. 224-225, trans. Heinrich von Staden).

As a matter of fact, in a passage of *De dignoscendis pulsibus* Galen wonders, on an empiricist basis, how the latter could determine a primary "time-unit" that escapes perception.

> How therefore was Herophilus first to establish some time-unit in relation to sense perception [sc. for the rhythms of the pulse], by which he, in measuring the other [time-lengths], claimed that they consist either of two or three or more [of these units], or [that these units] are both perfect and *"not-subject-to-increase,"* as they themselves [other physicians] call them, or decreased a little or a great degree or the greatest degree? He seems to write these things as though, in all pulses, he were accurately discerning the time-units either of their motion only or also of the pauses that follow the time-units of motion. (Galen, *De dign. Puls.*, 3.3, 8.913, trans. Marquis Berrey, my mod.)

But Herophilus's view of the primary time-length is not either completely foreign to that of Aristoxenus, which had also a mathematical basis. The fact that he considers the *pyrrhic* as *alogos* is consistent with Aristoxenus' refusal to recognize it as a metrical unit. As von Staden notices, "the reason for both positions might be that there is no operation of real measurement against minima no *logos* in a sequence of two minima." (von Staden, 1989, p. 281)

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This conclusion seems to make irrelevant Berrey's view that "the *prôtos khrÌnos* of the infant is a normative time [a rhythmic norm] for the infantile age-groups, but a standardized time [an objective time-unit] for the adult age-group" (Berrey, 2011, p. 72; 2017, p. 199). Contrary to Berrey's opinion that the infant primary time-length was actually perceived and used in practice by Herophilus, it seems that it was only an abstract requisit, a necessary mathematical origin of a numerical series supporting the pulse specification for all other age-groups.

The holistic part of the theory seems to unfold at the same varying distance from Aristoxenus. On the one hand, it endorses his definition of rhythm as "that which arises whenever the distribution of [time-lengths] takes on some definite arrangement" and comes back to perception data. The progressive theoretical construction of the pulse rhythm as "arrangement of primary time-lengths" is supported by a thorough observation of the pulse itself and of its specificity in each age-group. It reflects the actual development of the body and is therefore considered as based on nature. But on the other hand, Pseudo-Rufus' account reveals that Herophilus restricts the proportions between the various time-lengths of the pulse to the four binary Greek meters, and therefore that he does not use Aristoxenus' theory, which described also larger meters, in its full extent.

> But when one's age progresses and one's body comes into its full growth, the pulse, too, increases with reference to ratio, getting a dilation which is proportionately more extended than the contraction. [It is possible, moreover, to establish their proportions using as means of demonstration the scansion that belongs to grammarians] *[º Ä¿æ À¿´¹Ã¼¿æ ÄÆÂ ³Á±¼¼±Ä¹ºÆÂ - ek toû podismoû tês grammatikês]*. You see, the first pulse found in newborn children will have the rhythm of a short-syllabled metrical foot, since it is short in both dilation and contraction, and it therefore is conceived of as consisting of two [short] time-units, whereas the pulse of children who are growing is analogous to the metrical foot [known] among them as *trochee*. This pulse consists of three time-units, holding its dilation for two time-units, but its contraction for one. And the pulse of those in the prime stage of their lives is equal in both, that is, in dilation and contraction, and is compared to the foot called *spondee*, which is the longest of the disyllabic feet. It is actually composed of four [short] time-units. This pulse Herophilus calls *"in equal quantity" [´¹p 4Ã¿Å - dià ísou]*. The pulse of those who are beyond their prime, and almost old, is itself also composed of three time-units, holding its contraction for twice as long as the dilation and longer. (Pseudo-Rufus, *Synopsis de pulsibus*, 4, ed. Daremberg p. 225, trans. Heinrich von Staden, my mod.).

Von Staden has proposed an excellent summary of this passage that gives all information we need, except maybe that it does not put enough emphasis on the novelty of the idea, compared to Aristoxenus, of the concurrently mathematical and biological development of a series of rhythms out of an originary point, with no ratio, i.e. out of a rhythm with no rhythm.

> The normal pulse rhythm in infancy is analogous to the metrical foot known as *pyrrhic* (u u). [...] In growing children and adolescents the natural pulse rhythm has become *trochaic* (- u). Each cycle of diastole and systole now consists of three primary units, the dilation lasting for two units, the contraction for one. By the prime of life, the normal pulse rhythm consists of four primary time units equally divided between contraction and dilation, hence this is the spondaic stage of life (- -). [...] Finally, those who are beyond their prime and, as Rufus (or Pseudo-Rufus) puts it, "almost old people," have entered an iambic (u -) stage of life. Their pulse consists of three primary time units, as in adolescence, but in an inverse ratio: the dilation lasts for the duration of one unit, the contraction twice as long (or even longer). (von Staden, 1989, p. 280-281)

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We can now better assess Herophilus' pulse rhythm theory from its bottom to its top. While most of the time taking observation into account, Herophilus uses both rational-mathematical reconstruction, Aristoxenus' theory of rhythm, and some elements of the most common metric model in his time. He also uses his own contribution to the theory of the living. This elaborate construction allows him to rebuild the concept of rhythm, which only appeared at first as one of the four aspects of artery pulse, into a central category opening upon a completely new medical conception of human life based on four stages, differentiated by their specific pulse rhythms.

This seems to shed light on the fact that rhythm appears either last or first in Herophilus' list of the pulse aspects. It also brings an answer to Galen's legitimate and revealing question: "Why does he say that pulses *in the same rhythm [½ Ä±PÄ÷ åÅ¸¼÷ - en tautôi rhuthmôi]* differ in speed, size, and vehemence?" (Galen, *De dign. puls*., 4.2, 8.959-960, trans. Heinrich van Staden) It really looks like rhythm has become for Herophilus a kind of overarching category.

As Berrey puts it, "the age-groups determine the normative *differentiae* of the pulse" (Berrey, 2011, p. 56). Since these age-groups are first determined by their characteristic rhythm, all others differences seem to be classified according to this primary difference.

> A newborn has a normative pulse described in terms of size, speed, vehemence, and rhythm; a teenager has a normative pulse described in separate terms of size, speed, vehemence, and rhythm; and so on for each group. (Berrey, 2011, p. 56)

Strikingly, Berrey notices that "rhythm seems to be the only *differentia* of the four laid out in the beginning of Herophilus' *On Pulses* (namely size, speed, vehemence, and rhythm) in which the extant evidence shows that Herophilus attempted to provide normative evaluations in the usual terminology of health and illness" (Berrey, 2011, p. 86). The calculation of the ratio of the dilation length to that of contraction, and its comparison with the rhythm (size, speed, and strength) considered as normal in a particular age-group allow to observe the extent of a pathological state. Health and illness thus depend on the deviation of the pulse rhythm from the norm per age-group.

This rhythmic pulse lore is the main reason that made Herophilus famous for centuries. His work *On pulses* set a model for the use of rhythm as arrangement of meters in medicine and biology that was to last at least until the 16th century.

Now we can come back to the still uncertain relation between rhythm and frequency. This relation was indeed to allow if well after another significant change in rhythm theory when, in the 18th and 19th centuries, the metric and rhetoric models were abandoned in life science in favor of mathematical models. Rhythm would not mean any more metric arrangement of time-lengths but sheer frequency or rate.

Let us consider Herophilus' unique construction of a portable water clock or *clepsydra*. This clock could be precisely calibrated to fit the age-group of each patient and seemed to have been commonly used to assess the state of the patients by measuring the frequency of their pulse.

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There is a story that Herophilus had such a confidence in the frequency of the pulse, using it as a reliable diagnostic sign, that he constructed a water-clock capable of holding a specified amount for the natural pulses of each age. And, upon entering to visit a patient, he would set up his water-clock and feel the pulse of the person suffering from a fever. By as much as the movements of the pulses exceeded the number that is natural for filling up the water-clock, by that much he declared the [patient's] pulse too frequent that is, that [the patient] had either more or less of a fever. (Marcellinus, *De pulsibus*, 11, ed. Schöne p. 463, trans. Heinrich von Staden)

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This device, whose configuration is carefully described by Berrey who compares it to the Egyptian devices of the same period (2011, p. 75-80), was used to measure the deviation of the frequency of the patient's pulse from normal frequency in each age-group and thus to measure, in particular, the patient's body temperature or fever, since Herophilos held pulse frequency to be a correlate of body temperature and age (Von Staden, 1996, p. 89).

Referring to this clock and more generally to Herophilus' pulse rhythm theory, Pigeaud emphasizes that Herophilus' work was one of the first and the most successful attempts "to apply measure to the diversity and fluidity of the body" and therefore "to introduce quantity into biological sciences" (Pigeaud, 1978, p. 261). Von Staden plainly agrees with this view. He particularly stresses Herophilus' tendency "to quantify and mathematicize aspects of both the exterior and the interior of the body, including its internal motions" (Von Staden, 1996, p. 88), even if he rejected exaggerated mathematicizing and following in this respect, some Hippocratics leaved ample room for individual variability.

This tendency was in tune with a trend in ancient Greek science that Geoffrey Lloyd and others have shown to be much more powerful than it was commonly admitted. While the Hippocratics used to quantify pharmacology, stages of the embryo, and periodicities that appear in physical disorders such as fevers, Herophilus extended "the process of measuring into small interior structures of the body and into individual internal physiological and pathological processes" (von Staden, 1996, p. 88).

> His attempts to measure bodily processes are perhaps also to be understood in the context of the renewed, more extensive preoccupation with scientific measurement in the third century BC. Eratosthenes' *On the Measurement of the Earth*, Aristarchos's *On the Sizes and Distances of the Sun and the Moon,* Archimedes' *On the Measurement of the Circle,* and Erasistratos's quantitative experiments are among the many manifestations of this interest. (von Staden, 1996, p. 88)

What does this context tell us about the relation between rhythm and frequency? Did this "preoccupation with scientific measurement," which was most common in the 3rd century, have an impact on the concept of rhythm by integrating in it, somehow, frequency?

Von Staden seems to consider them to be different but articulated: "Here [in Marcellinus' testimony], the pulse rhythms of different ages are not at issue [...] but the frequencies with which these rhythms occur" (von Staden, 1989, p. 283). The observation of frequency would *complement* that of rhythm "over a longer span of time."

> Herophilus' application of a theory of four stages of life to pulse-lore accordingly is based not only on those different rhythmic patterns within a *single* pulse-beat that were discussed above (trochee, spondee, etc.), but also on differences in the frequency with which these "rhythmic" beats occur over a longer span of time. (von Staden, 1989, p. 283)

Berrey proposes a slightly different view. He first insists on the difference between the measure of the pulse frequency and that of the pulse rhythm.

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Frequency, the *differentia* measured by Herophilus' water-clock is different from the *differentia* of rhythm measured by Aristoxenus' protos chronos. (Berrey, 2011, p. 74 - see also p. 75, n. 59)

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But in the end he suggests, since both imply the use of "normative time-units," that "Herophilus' water-clock's normative use of time parallels Herophilus' use of Aristoxenus' theory of musical rhythm" and, therefore, that there is "a conceptual continuity between these two attempts to measure the timing of the pulse" (Berrey, 2011, p. 81). In other words, rhythm and frequency may be both taken as "covering pulse timing" (p. 58).

As we know, the Aristoxenian concept of "primary time-length" was not an absolute time unit. Any "primary time-length" could be uttered, sung, played or danced in a variable "objective" time laps, depending on the choice of the performer. This meant that the tempo of a particular rhythm could change according to the occasion. But what was of no consequence in an artistic performance and could even be taken as a necessary requirement, was in medicine cause of inaccuracy and could hamper a correct diagnosis. It is therefore quite possible that Herophilus felt necessary to add to his measure of the pulse rhythm, mainly based on the ratio between systole and diastole, a measure of the pulse frequency, based on the number of diastoles during a fixed laps of time.

While there is no evidence that the introduction by Herophilus of frequency had a direct impact on the rhythm concept itself, his attention to frequency certainly prefigured its future development in medicine. Without joining in the "Whiggish historiography" which Berrey quite rightly rejects (2011, p. 58), it can be assumed that Herophilus may have possibly complemented the "ancient metrics" (based on poetry, dance and music and simple arithmetical proportions) by a "more modern" one (based directly on mathematics and on the continuous series of numbers) without confusing each other.

Rhythm as Theoretical Stake

To finish this chapter dedicated to the introduction of rhythm in medicine and life science, I would like to address the question of the intricate concept interchange that supported it. As was shown above, we have good reasons to believe that the first occurrences of the term *rhuthmós* that popped up in some texts produced by the Aristotelian milieu were probably not genuine and were borrowed from exterior contributions coming most probably from the Alexandrian medical school. Conversely, Herophilus' pulse lore would have probably not been possible without the Aristotelian school's contribution concerning rhythm. Von Staden, on the one hand, Wellmann, Pigeaud, and Berrey, on the other, have developed opposing views on Herophilus' debt towards Aristoxenus. But both views may actually be conflated since Herophilus clearly borrowed some important conceptual tools from Aristoxenus without yet reproducing his theory in all points, choosing only those he found useful and otherwise producing by himself those he could not find in his predecessor.

Berrey is certainly right when he underlines the sociological basis of these intricate conceptual interchanges. However, I would not argue, as he does, that

> the terms åÅ¸¼ìÂ, ÁÃ¹Â, and ¸-Ã¹Â are technical language because of the specificity of their usage within a certain sociolect, the domain of practicing musicians and musical theorists. The technical terms point both toward the sociolect, the technical language of the *techne*, and the social group employing them, the *technitae*. Therefore the terms åÅ¸¼ìÂ, ÁÃ¹Â, and ¸-Ã¹Â are part of the technical vocabulary of practicing musicians. (Berrey, 2011, p. 62)

This view seems too limited in various respects. Firstly, the milieu interested in rhythm was much larger than that of the musicians: the whole intellectual milieu under Aristotelian influence on both sides of the Eastern Mediterranean was sharing this common interest. Secondly, other philosophical schools were also interested in

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rhuthmós. As we saw above, Leucippus and Democritus used it in their theories, and it will be also extensively reused by Lucretius during the 1st century BC. Thirdly, the sociological view somehow freezes the circulation of concepts by reducing them to sheer technicalities, assigning them to a limited social group, and finally erasing the struggles to appropriate them. No critique of traditional science history can develop efficiently without recognizing the complex conceptual genealogies it is made of, i.e. the triumph and spread of certain conceptual paradigms, the defeat and momentary or definitive disappearance of others, and the constant and erratic shifts and intertwining of meanings.

In this regard, we should emphasize that when Herophilus borrowed concepts from the theory of music, and particularly from the theory of rhythm that had been elaborated by Aristoxenus just a few decades earlier (ca. 360 - ca. 300 BC), it also borrowed indirectly from Plato and the most Platonic parts of Aristotle's work. It therefore put aside all Aristotelian rhetoric and poetic elaborations of rhythm for instance as a holistic and performative meaning complex as well as all Democritean contributions, in favor of an already heavily Platonized music theory supported by a reductionist semiotics.

This metric and semiotic Platonic bias is particularly visible in two fragments of the Pseudo-Galen's *Medical Definitions* (2nd c. AD) which bear witness both of its origin and of its spreading in the 3rd and the 2nd centuries. The author tells us that Bacchius of Tanagra (275 - ca. 200 BC) and Zeno (end of 3rd c. - beg. of 2nd c. BC), who were both direct followers of Herophilus, defined artery rhythm respectively as follows:

> Rhythm is a motion which has an order in time *[º¯½·Ã¹Â ½ ÇÁÌ½¿¹Â Ä¬¾½ Ç¿ÅÃ± - kínêsis en khrynois táxin ékhousa]*.

> Rhythm is an order of time-lengths or an order in the duration in which occurs the diastole and systole of arteries. *[Ä¬¾¹Â Äö½ ÇÁÌ½É½ - táxis tôn khrynôn].* (Pseudo-Galen, *Medical Definitions,* K XIX, p. 408-409, quoted by Pigeaud, 1978, p. 263, my trans.)

The first definition is obviously borrowed from Plato's *Laws*: "the order of motion is called rhythm" *(ÄÇ ´! ÄÆÂ º11½®ÃµÉÂ Ä¬¾µ¹ åÅ¸¼ÌÂ D½¿¼± µ2½ - têi dê tês kinêseôs táxei rhuthmÌs Ìnoma eìn)* (Plato, *Laws*, 664a-665a, trans. R.G. Bury). And the second is a direct translation from Aristoxenus' definition of rhythm as "that which forms each time that time is divided into fractions" that was recalled above.

In other words, it should be emphasized that Herophilus' contribution consisted in accommodating in medicine and life science a concept of *rhuthmós*, which was at odds with its older materialist understanding as well as with its more recent Aristotelian poetic definition, and that by promoting the former it contributed to the vanishing of the latter. Even later physicians as Erasistratus (ca. 304 - ca. 250 BC), who considered atoms to be the essential body element, would not use the term *rhuthmós* in a Democritean sense any more but in the Platonic-Aristotelian sense that was transmitted to them by Herophilus.

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During the 3rd century BC, the *Platonic metric paradigm* began to spread out of the three domains from which it originated: dance, music and poetry the main "rhythmizable matters" according to Aristoxenus. It penetrated

rapidly and definitively into life science and medicine and began to bounce back into philosophy.

Herophilus seems to have been instrumental in this extraordinary mutation. He imaginatively brought together Platonic-Aristotelian conceptual features and empirical data resulting from his careful observation of the human body. He was the first to compare the pulsation of the arteries to musical and metric rhythm. Instead respiration probably seemed to him too irregular and possibly discontinuous to perfectly match the new paradigm, but it was soon to be "rhythmized" by some Aristotelian scientists.

By using the term *rhuthmós* to designate medical and physiological phenomena which were not hitherto considered as rhythmic on the sole ground, as Benveniste put it, that they constituted "continuous activities" that could be divided "by meter into alternate times," Herophilus' *On Pulses*, the Peripatetic School's *Problems*, and the Peripatetic Anonymus' *On Breath* definitively acclimated the concept of rhythm under its Platonic form to medicine and life science, but they also initiated a very long process of generalization that made it eventually fit to any reality, be it human or cosmic, cultural or natural, individual or collective.

> One can now talk about the "rhythm" of a dance, a walk, a song, a diction, a work, anything that requires a continuous activity divided by meter into alternate times. The notion of rhythm is now fixed. From *åÅ¸¼ÌÂ* as spatial configuration defined by the arrangement and proportion of distinctive elements, one reaches the "rhythm" as configuration of movements ordered in time *[la durée]* [...], "all rhythm is measured by definite movement." (Aristotle, *Problemata*, Book 5, 882b 2) (Benveniste, 1966, p. 335, my trans.)

From Herophilus' time on, the expansion never ceased, reaching little by little more uncharted territories. As we shall see when we look into Vitruvius' contribution, it was even to penetrate into some arts and practices devoid of any relation to time, as architecture. After a long period of relative stability during the Middle Ages, it resumed during the Renaissance leading to the emergence of a modern "pan-rhythmism" that reached its climax at the end of the 19th century.

Next chapter

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[1] For this section, I used von Staden's thorough study of Herophilus' works: von Staden, Heinrich. 1989. *Herophilus: The Art of Medicine in Early Alexandria,* Cambridge, Cambridge University Press and also Marquis Berrey's more recent research on Alexandrian science: Berrey, Marquis. 2011. *Science and Intertext: Methodological Change and Continuity in Hellenistic Science*, Phd Dissertation, The University of Texas at Austin; and Berrey, Marquis. 2017. *Hellenistic Science at Court*, Berlin/Boston, De Gruyter.

[2] Heinrich von Staden's (1989) collection collects 44 fragments of Herophilus related to pulse theory, drawn mostly from Galen. All references to Galen's work will be to title, book, chapter, then volume and page in Khün's edition (1821-1833).

[3] Contemporary medicine uses the terms of *diastole* and *systole* in reference to the movement of the arteries, but those of *dilation* and *contraction* in reference to the heart's pumping motion.

[4] Von Staden (1989) translates *plêthos* either as "mass," which is not very clear, or as "volume" [of water?], which is close to Berrey's "amount" (2011).

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[5] According to Scarano, Pseudo-Rufus was "a follower of the Herophilean sect flourishing in Rome at the time of Galen." Scarano, Giovanni Benito. 1990. "Sulla Sinopsi dei polsi attribuita a Galeno e a Rufo d'Efeso." *Med. nei Sec*. N.S. 2, p. 93-112.

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