Naming the phenomena : technical lexicon in descriptive and deductive sciences

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NAMING THE PHENOMENA

TECHNICAL LEXICON IN DESCRIPTIVE AND DEDUCTIVE SCIENCES

Abstract

This paper discusses the lexical strategies employed by several technical languages to express their content. While Greek sciences employ similar strategies and their vocabularies are quite transparent as they are Greek-based and use visual metaphors, there is a fundamental difference between descriptive sciences (especially medicine and biology) and deductive (i.e., mathematical) sciences in the way they 'visualize' their content. This difference also explains the divide between didactic poetry on descriptive sciences and mathematical poetry, which does not employ much technical lexicon and yet is not 'didactic' at all.

The technical languages of ancient Greece are diverse and each of them is characterized by a specific vocabulary, syntax, style, and other linguistic markers. Due to space constraints the present contribution will focus on the lexicon, which is the first and most obvious element of any technical language.[1] The main goal is to show how the vocabularies of two branches of science, the natural sciences (i.e., medicine, biology, zoology) and the mathematical sciences (i.e., mathematics and related disciplines), can be compared and what their differences and similarities tell

[1] This paper emanates from a larger project on Greek scientific language, in which syntactic and stylistic elements of Greek scientific prose (and poetry) are also considered. I would like to thank Fabio Acerbi, Tyler Mayo, and Monica Negri for comments and suggestions.

us. Because the former group of disciplines relies mostly on the observation, description, and classification of natural phenomena, we can also call them 'descriptive sciences', while mathematics and related disciplines, being mostly based on deductive reasoning, can be labeled as 'deductive sciences'.

While both the natural and the mathematical sciences began developing around the fifth century BCE, I will also look at the formative period of science in general, that is, the Presocratic philosophers, and I will end my survey with the Roman period. I will not, however, take a diachronic approach focused on the *development* of the technical lexicon in the respective fields. Rather, I will look at it from a strictly qualitative point of view, by first highlighting its principal linguistic characteristics and then introducing some general (and more speculative) considerations about the type of 'epistemological' underpinnings these technical vocabularies seem to suggest for the different disciplines and how they could be received by non-specialists.

1. Strategies for building a technical lexicon

The medical lexicon is the best example we have of a technical vocabulary, both because of the abundance of sources and because of the object of study itself, as many new terms were invented to name parts of the body, illnesses, and drugs. It is also the most studied.[2] Hence I will limit my survey to a few examples from medicine, before focusing on other sciences, especially the mathematical ones, which are far less studied.[3] In doing so, my first goal will be to analyze how these other fields

[2] Cf. LANZA (1979) 113-122 and (1983); LLOYD (1983); MALONEY (1987); SKODA (1988); DURLING (1993); LÓPEZ FÉREZ (2000); see also the comprehensive work by LANGSLOW (2000) on Latin medical language.

[3] On the Greek mathematical language, cf. MUGLER (1958-1959); FEDERSPIEL (1992), (1995), (2003), (2005), (2006); NETZ (1999) 89-126; ACERBI (2007) 213-218, 259-313, 532-534. On optics, see MUGLER (1964). I am not aware of any specific study of the lexicons of astronomy or mechanics.

operate and to show that their terminology in fact works in a way that is quite similar to the medical lexicon.

1.1. *Use of existing terms*

In the creation of any scientific vocabulary three main linguistic strategies are employed: the use of existing terms, the coinage of new terms, and the borrowing of terms from another semantic field for reuse as metaphors and metonyms.

The first strategy consists of adopting a term already used in standard language and giving it a more specific meaning within the discipline. Typical is the case of medicine, where terms already used by Homer are common: e.g., καρδίη "heart" or φλέβες "blood-vessels" (cf. e.g. Hippoc. *Epid.* 2, 4; *Art.* 45, 7; *Carn.* 5, 6-7, where φλέβες denotes "veins", as opposed to "arteries"). Among words for medical conditions, σπασμός for "convulsion" and φῦμα for "what grows", hence "tumor", are examples used by both Herodotus and Hippocrates.

But the same strategy is adopted elsewhere too. The Presocratics, eager to name their new concepts,[4] followed the same path. For example, speaking of both Leucippus and Democritus, Aristotle (*Metaph.* 985b15-17) says that they called the shape, i.e., configuration, of atoms "rhythm" (ῥυσμός) and their position in space "turning" (τροπή). These words are also used by poets, as when the plural τροπαὶ ἠελίοιο "turnings of the sun" (meaning the "west" or the "solstice") is found in Homer (*Od.* 15, 405) and Hesiod (*Op.* 479, 564, 663), and ῥυσμός/ῥυθμός occurs in Archilochus (fr. 128, 7) and Theognis (1, 964); among prose writers Herodotus has them both. While the terms were not new, then, their 'atomistic' meaning was (Philoponus, *In De an.* 68, 3, confirms that ῥυσμός is a λέξις Ἀβδηρική).[5]

[4] Cf. BARNES (1987) 18-22. On the 'scientific' language of the Presocratics, see also SNELL (1953) 227-245 and HAVELOCK (1983).

[5] But in HDT. 5, 58, 1 τὸν ῥυθμὸν τῶν γραμμάτων, referring to the "shape" of the letters, comes close to Democritus' use; cf. VON FRITZ (1938) 25-26.

In mathematics, too, many words are taken from everyday language: σημεῖον "(concrete) sign, limit", hence "point";[6] γωνία "corner", hence "angle"; κύκλος "ring, circular object", hence "circle"; λόγος "account, reckoning", hence "ratio"; στερεός "firm, solid", hence geometrical "solid" or "cubic" figure; σφαῖρα "ball", hence "sphere"; or verbs like δείκνυμι "to demonstrate", τέμνω "to cut", hence "to divide a line", or ἄγω "to lead", hence "to trace a line". These are all common Greek words, used in mathematics with a more specific meaning. Other items, such as γραμμή "line", τετράγωνος "square" (adj.), κύλινδρος "cylinder", seem more 'geometrically oriented' but they are still used in common Greek.

1.2. *Coinage of new terms*

The second strategy consists of the coinage of new terms, by means of either derivation or composition. The neologisms created in medicine to name all newly discovered organs and diseases are very well studied. Moreover, since many of these terms have passed into modern medical terminology, they are more familiar to us than, for example, the technical terminology of mechanics, astronomy, or other branches of ancient science. Yet examples in other fields will help us to better understand the scientific lexicon in general, while putting medical terminology into a broader context.

1.2.1. Derivation

Derivation by means of specific suffixes is used extensively in many technical languages. In medicine, the usual distinction between *nomina rei actae* in -μα and *nomina actionis* in -σις sometimes differentiates the result from the process (e.g., ἕλκωμα

[6] On the meaning of σημεῖον in mathematics and its origins, see FEDERSPIEL (1992); cf. also NETZ (1999) 113.

"ulcer" vs. ἕλκωσις "ulceration"; οἴδημα "tumor" vs. οἴδησις "swelling"). There are also specific suffixes used by medicine in nouns, adjectives, and verbs.[7] Common nominal ones include: -ίη/-ία for abstract nouns for diseases (e.g., αἱμορραγία "hemorrhage", ὀφθαλμία "ophthalmia", and a series of compounds whose second element is -αλγία "ache": e.g., καρδιαλγία "heartburn", κεφαλαλγία "headache"); -ῖτις, to indicate types of inflammation (e.g., ἀρθρῖτις "inflammation of the joints", ἡπατῖτις "inflammation of the liver"); -αινα for (foul) diseases (e.g., γάγγραινα "gangrene", ὄζαινα for a fetid polypus in the nose); -ότης for feminine abstract nouns, often to express a quality or durable attribute (e.g., ἐρυθρότης "redness", καμπυλότης "crookedness"); -(σ)μός for masculine nouns indicating a sick condition (e.g., μετεωρισμός "swelling", κνησμός "itching"); -δών for feminine deverbal nouns (e.g., σηπεδών "decay", from σήπω; σπαδών "convulsion, cramp", from σπάω). Common suffixes for adjectives are: -(ι)ώδης indicating similarity or quality (e.g, ἀλφώδης "leprous", ἰκτερ(ι)ώδης "jaundiced");[8] -ειδής indicating similarity (e.g., θρομβοειδής "lumpy", κιρσοειδής "varicose", from κιρσός "enlargement of a vein"); -ικός often meaning "suffering from…" (e.g., κεφαλαλγικός "suffering from headache", ὑστερικός "suffering in the womb", i.e., "hysterical"). In the verbal domain, to indicate "suffering from" something medical Greek often uses the typical denominative suffixes -(ι)άω (e.g., ποδαγρ(ι)άω "to have gout in the feet", λιθιάω "to suffer from calculi"[9]), -έω (e.g., αἱμορραγέω "to have a hemorrhage", κεφαλαλγέω "to suffer from headache"), -αίνω (e.g., ὑδεραίνω "to suffer from dropsy", πυρεταίνω, "to be feverish"[10]). The same formants can also convey a more causative/active meaning "to act upon (something/someone)" (e.g., πυριάω "to

[7] See López Férez (2000) 40-43; Maloney (1987) (inverse dictionary).
[8] See op de Hipt (1972) 1-250. On these compounds in Theophrastus, see op de Hipt (1972) 280-283 and Tribulato (2010) 489-490.
[9] This is a metaphor, as λίθος means "stone" in the bladder (= "calculus").
[10] Alongside this, the common Greek verb πυρέσσω is also used by doctors; both are based on the same metaphor, as fever is πυρετός, literally "burning heat".

put persons in a vapor-bath", τριχολογέω "to pluck hairs", προσγλισχραίνω "to make more viscid").

However, these suffixes are not limited to medicine. For example, -ῖτις not only indicates inflammation in the human body. It is also quite often used for plants: e.g., πυρῖτις, the "pellitory" (otherwise known as πύρεθρον), ἐρεχθῖτις, the "groundsel", ἡμιονῖτις, the "mule-fern". As a derivative, ἀμπελῖτις γῆ, "vine-land", is a type of earth used to get rid of worms in vines;[11] and the suffix is also used for stones: e.g., αἱματῖτις, the "blood-like" stone, or χαλκῖτις, the "calcite" or "alum".

In mathematics, the common suffix -σις for *nomina actionis* is used, for example, in ἔλλειψις "ellipse", whose exact meaning will be discussed below (§ 5.2). Another productive item is -ειδής to indicate similarity (εἶδος). Thus Archimedes can study τὸ κωνοειδὲς (σχῆμα), the "conoid", and τὸ σφαιροειδὲς (σχῆμα), the "spheroid". While σφαιροειδής is used before Archimedes to mean "spherical" (for example, by Aristotle), Archimedes uses it in a very technical sense. As for κωνοειδής, this seems to be a new coinage by Archimedes himself. Other new coinages with the same suffix are ἡ κογχοειδὴς (γραμμή), the "concoid" curve, discovered by Nicomedes (*c.* 280-210 BCE), and ἡ κισσοειδὴς (γραμμή), the "cissoid" curve, probably discovered by Diocles (*c.* 240-180 BCE).[12] On the verbal side, mathematics employs two other very common suffixes, -ίζω and -άζω, to express the idea of "acting on" mathematical objects, as in τετραγωνίζω "to square" (of lines and numbers), κυβίζω "to cube", and πολλαπλασιάζω "to multiply".

1.2.2. Composition

Medicine, again, is very active in producing compounds, for which I will give few examples, before proceeding to other

[11] Cf. GAL. *De simpl. med. fac.* 12, 186, 16-19 Kühn.
[12] The last two are also based on metaphors, which will be analyzed below.

disciplines. We find compounds with privative ἀ- (e.g., ἄσαρκος "without flesh"), with the positive prefix εὐ- (e.g., εὔσαρκος "fleshy", εὐεξανάλωτος "easy of digestion"), or with the negative prefix δυσ- (e.g., δυσέμβλητος "hard to set", of dislocations, δυσεντερία "dysentery"). Among preverbs, περι- intensifies (e.g., περιωδυνέω "to suffer great pain"), while ὑπο- diminishes (e.g., ὑπαλγέω "to have a slight pain", ὑπόλευκος "whitish"). The prefix ὑπο- can also have a local meaning of "below" or "under", as in ὑπογλωσσίς, referring to a swelling "under the tongue".[13]

Compounding as a way of creating new technical terms is also attested elsewhere. In the passage discussed above for ῥυσμός and τροπή, Aristotle (*Metaph.* 985b15-17) mentions a further term that is a new coinage of Democritus and/or Leucippus: διαθιγή "mutual contact" (from δια-θιγγάνω), to indicate the "arrangement" of atoms. Democritus also built compounds out of his own technical (yet common) terms. Thus, from ῥυσμός he created the *hapax* μεταρυσμεῖν referring to education, which "changes the shape" of human nature.[14]

Moving on to later times, mathematics is as productive as medicine in creating compounds. For instance, compounds derived from γωνία "angle" include: ὀκταγωνικός "octagonal", ὀρθογώνιος "rectangular", ἀμβλυγώνιος "obtuse-angled", ὀξυγώνιος "acute-angled", πεντάγωνον "figure with five angles", πεντεκαιδεκάγωνον "figure with fifteen angles", etc. The same goes for all the solid figures ending in -εδρον, which indicates the "surface", from ἕδρα "seat" (e.g., ὀκτά-εδρον, δωδεκά-εδρον, τεσσαρεσκαιδεκά-εδρον, for a solid with eight, twelve, and fourteen surfaces respectively). Other examples are παραλληλεπίπεδον, a figure delimited by parallel surfaces (from the

[13] Cf. LÓPEZ FÉREZ (2000) 43-45.

[14] DEMOCR. fr. 33B D.-K., καὶ γὰρ ἡ διδαχὴ μεταρυσμοῖ τὸν ἄνθρωπον, μεταρυσμοῦσα δὲ φυσιοποιεῖ "for education transforms the human being and by transforming him molds his nature"; cf. VON FRITZ (1938) 36-37.

adjective ἐπίπεδος "flat", and "plane" in geometry), πολλαπλάσιος "multiple",[15] and ὁμόκεντρος "concentric".[16]

In astronomy, too, compounds abound. One example concerns the phases of the moon (Geminus 9, 11): μηνοειδής "crescent-shaped", διχότομος "cut in half" (i.e., the half-moon), ἀμφίκυρτος "convex on each side" (i.e., the moon in its second or third quarter), πανσέληνος "full moon".[17]

Finally, the same compound can be used in different technical fields. One example is ὠκυτόκιος, which derives from ὠκύς and τίκτω and literally means "promoting a quick birth". In this sense it is applied to plants which have that effect (Diosc. 4, 14, 2; 5, 154; Theophr. *Hist. pl.* 9, 9, 3) and, in the neuter, also to any such medicine (Hippoc. *Mul.* 1, 77; Ar. *Thesm.* 504). But the word is also employed by Apollonius of Perga as a title for one of his works (Eutoc. *In Archim.* III 258, 16-17 Heiberg-Stamatis = IV 162, 12-13 Mugler Ἀπολλώνιος ὁ Περγαῖος ἐν τῷ Ὠκυτοκίῳ) – of course in a metaphorical sense.[18]

1.3. *Metaphors and metonyms*

The third strategy consists in using terms from other semantic fields metaphorically: words from daily language indicating a common object or phenomenon are recycled for a 'new', unknown scientific object somehow resembling the common one (usually in its appearance or, more rarely, in its function).

[15] Note that compounds like διπλάσιος or ἡμιόλιος can have a technical meaning ("double" and "in the ratio of one and a half to one [e.g., 3:2]", especially in musical notation), but also a more common one (generally "double" and "half as much", respectively).

[16] Similar productivity is shown by Theophrastus with compounds formed with ῥίζα; see TRIBULATO (2010) 491.

[17] Μηνοειδής and πανσέληνος are not neologisms, as they occur in HDT. 1, 75, 5 and EUR. *Ion* 1155, for example; by contrast, διχότομος and ἀμφίκυρτος are new technical terms.

[18] The same title is recorded for a work on rhetorical phrasing by Telephus, a grammarian of the second century CE (*Suda* τ 495; ω 61).

While metaphors are present everywhere in the Greek language, starting with Homer, we find the first 'technical' metaphors already among the Presocratics, who used very colorful images to describe their principles and philosophical ideas, as with Heraclitus' River and Empedocles' Love and Strife.[19] Metaphors remain popular in later philosophy. One of the most famous 'technical' words of Aristotle, who uses reasoning based on likeness in many of his biological-philosophical works,[20] is ὕλη, which literally means "wood", but in Aristotle becomes the substratum or "matter" of any physical object.

Turning to 'real' sciences, medicine is again the field most studied.[21] Here, two criteria can be recognized in the choice of imagery: similarity in aspect and similarity in function. In the first category, applied to bones are, e.g., περόνη "pin" (of a buckle), for a small bone of the leg (now called with a Latin term, *fibula*); κερκίς, the "weaver shuttle" or "pin beater", for the tibia or the radius;[22] πλάται "oars", for the shoulder-blades; or κοτύλη "cup", for a joint socket. Among bodily organs, ἶρις "rainbow" (from the goddess Iris) is the colored part of the eye, τὸ (ἔντερον) τυφλόν "the blind" is the part of the intestine without outlet, and μῦς "mouse" is the muscle.[23] In pathology, too, there are descriptive metaphors: e.g., ἄνθραξ "charcoal", for a disease of the skin; στρόφος "twisted cord", for a colic, which is a twisting of the bowels; ἧλος "stud", for a callus or wart (on both humans and plants) because of its shape and hardness; κριθή "grain of barley", for a stye on the eyelid (cf. It. *orzaiolo*). Metaphors from zoology still in use today are καρκίνος "crab", for cancer, and πολύπους "octopus", for a

[19] Cf. LLOYD (1966) 210-252 and (1987) 176-181.

[20] Cf. LLOYD (1966) 258-270 and (1987) 183-203, 209-214.

[21] On metaphorical language in medicine, cf. LANZA (1979) 118-119; SKODA (1988); LANGHOLF (1989) 12-16; LANGSLOW (2000) 178-201 (on Latin).

[22] On this double meaning, see below, § 4.

[23] Herophilus (*c.* 330/20-260/50 BCE) is particularly famous for using descriptive metaphors to name the organs and bones he discovered through human dissection (and perhaps vivisection); cf. VON STADEN (1989) 157-161.

polyp. On the other hand, similarity in function explains some metaphors that are used for bones: e.g., ζύγωμα "bolt", for the zygomatic arch or cheekbone, because it "connects" the cranial with the facial bones, or θώραξ "corselet", for the thorax, which "guards" the internal organs. Among organs, metaphors based on function are: πυλωρός for the pylorus, the "gate-keeper", which is the lower orifice of the stomach that "oversees" what gets out from this organ; πόρος "strait", indicating the pore, which is a "passage" through the skin; χιτών "tunic", which is used for many internal membranes that surround organs; πύλαι "gates", which refers to various orifices in the body. Finally, πέψις (and the verb [συμ]πέσσω), which indicates the idea of "softening, ripening" (hence a change of status because of heat), is also used to mean "to cook"; and from this the metaphorical meaning "digestion" derives.[24] Subsequently, following another metaphorical step, the same word may indicate a disease that is (or is not) "concocting" (Hippoc. *Acut.* 42 = 11, 51-52 Littré: οὐ πέσσεται ἡ νοῦσος). Finally, a name of a known, external anatomical part can also be metaphorically reused for an internal one on the basis of similarity: for example, bones or organs (femur, heart) have a κεφαλή "head"; the uterus has an αὐχήν "neck"; hands and feet have a στῆθος "breast" (i.e., the ball); and the heart has οὔατα or ὦτα "ears".

Yet metaphors are not confined to medicine. Botany uses medical terms referring to the human body: in Theophrastus, for example, κεφαλή "head" can indicate a part of a plant to which roots are attached (*Hist. pl.* 1, 6, 9), the "head" of the poppy (*Hist. pl.* 9, 8, 2), and an inflorescence (*Hist. pl.* 9, 11, 6).[25] The same author also applies the verb ψωριάω, whose primary meaning is "to have an itch" (in the human body), to the fig in the sense of "to be scabby" (*Caus. pl.* 5, 9, 10). Metaphorical adjectives can similarly be used to qualify a root: see ἰνώδης

[24] Whence, of course, the modern *Pepsi* – named after its digestive properties.
[25] On the language of botany, especially in Theophrastus, see TRIBULATO (2010), from whom this example is taken (p. 483).

"fibrous" (lit. "with tendons"), σαρκώδης "fleshy", or θυσανώδης "tassel-like" (*Hist. pl.* 1, 6, 4).

Machines were also described using terms from human (or animal) anatomy. Philo of Byzantium's torsion engine, for example, has "legs" (σκέλη), "arms" (ἀγκῶνες) with "heels" (πτέρναι), "eyebrows" (ὀφρῦς), a "tortoise-shell" (χελώνιον), a "hand" or "claw" (χεῖρ), and "little wings" (πτερύγια).[26]

Metaphors are equally used by the 'dry' and technical mathematicians, even if they are less frequent there than in the biological sciences. From anatomy, mathematics takes πλευρά "rib", for the side of a triangle or other figure, and ἰσοσκελής to indicate a triangle that has two identical σκέλη "legs", in the sense of "supports" (i.e., sides). Botany and zoology inspire the names of certain curves: so the κισσοειδής (γραμμή), the "cissoid", is "the curve similar to ivy", and the κογχοειδής (γραμμή), the "conchoid", is "the curve similar to a shell". Even more metaphorical from this point of view is κοχλίας "snail", for a three-dimensional spiral form that resembles the shell of a snail.[27] Another metaphor explains the term ἱπποπέδη, naming a figure-eight curve, the "hippopede", traced by a planet according to Eudoxus' model; the word literally means "horse-fetter" and is appropriate because horses were tied with figure-eight-shaped shackles. Similarly, μηνίσκος, literally "lunar crescent",

[26] Cf. e.g. (with E.W. Marsden's technical translation) PHILO *Bel.* 54, 9-10 τοῖς δὲ <u>σκέλεσιν</u> αὐτῆς πλάτος μὲν διδόναι διαμέτρου τέταρτον μέρος "give its <u>side-poles</u> a width of 1/4D"; 70, 18 ὁ δὲ <u>ἀγκὼν</u> τὴν <u>πτέρναν</u> εἶχεν ἐπηρεισμένην ἐπὶ τῶν λεπίδων "the <u>arm</u> had its <u>heel</u> pressing against the plates"; 57, 6 τὰς περιεχούσας <u>ὀφρῦς</u> "the surrounding <u>edges</u>"; 54, 12-13 τὰ <u>πτερύγια</u>, δι' ὧν τὸ <u>χελώνιον</u> ἄγεται "the <u>ridge-poles</u> through which the <u>block</u> is drawn"; and 74, 19-20 ἦν γὰρ ἡ <u>χεὶρ</u> ἐν τῇ διώστρᾳ καθηρμοσμένη, καθάπερ ἐπὶ τῶν ἄλλων καταπαλτῶν ἐν τοῖς <u>χελωνίοις</u> "the <u>claw</u> was fitted to the slider, just as to the <u>blocks</u> in other catapults". See also the images in MARSDEN (1971) 162, 180, 181, and the list of all these parts in MARSDEN (1971) 266-267, 268-269.

[27] In fact, the word for "snail" is also used in mechanics to indicate a "roller" (e.g., BITON 58, 9) or a "screw"; of the latter Oribasius lists two types used in surgical machines: the "square snails" and (with another metaphor!) the "lenticular snails" (ORIB. 49, 4, 54: τῶν δὲ κοχλιῶν οἱ μέν εἰσι τετράγωνοι, οἱ δὲ φακωτοί "among screws, some are square, some are lentil-shaped").

indicates the "lune", a concave-convex area bounded by two circular arcs as studied by, among others, Hippocrates of Chios (fifth century BCE). Finally, the ἄρβηλος is literally a semicircular knife used by shoemakers, but Archimedes adopted the term for a geometrical figure with that shape. Even leaving aside all these complicated curves and shapes with exotic names, several 'common' verbs adopted to discuss mathematical objects are metaphorical, or at least start from a concrete or visual image: τέμνω for "cutting" (i.e., "secating") a line, figure, etc., ἄγω for "leading" (hence "drawing") a line, πίπτω for a line that "falls" (i.e., "intersects" a square, segment, etc.).

Another interesting case is κέντρον, the "center" of a circle. Literally κέντρον is the "horse-goad", a pointed device used to spur on the animals. Because of its shape, the word came to denote many pointed objects, such as the point of a spear (Polyb. 6, 22, 4), the sting of wasps (Ar. *Vesp.* 225, 406), or the prickles of the sea-urchin (Ael. *NA* 12, 25); more technically, it was used to designate a spur to keep a "tortoise" (another metaphor, indicating a shed that protects besiegers) stable on the ground (Apollod. *Poliorc.* 144, 1), and the point of a pair of compasses (Vitr. 3, 1, 3). Since compasses draw circles and the point is also the "center" of the circle, κέντρον was then used by mathematicians in that particular sense. While κέντρον is thus used metaphorically in biology and mechanics, in mathematics it becomes a metonym.

Other metonyms that work in the same way (i.e., by transfer from the means onto the object) can be found in harmonics. Thus, the "foot" (πούς) in rhythm is so called because it is through our feet that we mark rhythm, as Aristoxenus says.[28] Another metonym in Aristoxenus is λιχανός. Literally this means "licking" (from λείχω), and so, metonymically, with or without δάκτυλος, it refers to the "forefinger". But in Aristoxenus,

[28] Aristox. *Rhythm.* 2, 16 Pearson: ᾧ δὲ σημαινόμεσθα τὸν ῥυθμὸν καὶ γνώριμον ποιοῦμεν τῇ αἰθήσει, πούς ἐστιν εἷς ἢ πλείους ἑνός "the means by which we mark rhythm and make it perceptible to the senses is a foot, one or more than one".

following a second metonymic step, ἡ λιχανός (sc. χορδή) then indicates both the string struck with the forefinger, and the note thereby produced.

2. The reason behind a name

After surveying the linguistic strategies informing the coinage of technical terminology, another important element to discuss, even though briefly, is the logic behind the choice of certain terms. In other words, how did physicians, mathematicians, etc. choose the names by which to call their objects of study?

2.1. *'Descriptive' terms*

A large part of the technical lexicon may be regarded as 'descriptive', since the technical terms themselves describe a perceptible phenomenon or its effects.

Most metaphors in medicine as well as in mathematics work by their descriptive quality. Among compounds, some anatomical terms are based on others, with further qualifications added in accordance with their relative position. Thus, μετακάρπιον indicates the bones in the palm of the hand, which are "after" the καρπός "wrist"; ἐπιγλωσσίς, the "epiglottis", is a valve which covers the larynx and is "above" the γλῶσσα "tongue". A very interesting example of naming what one sees comes from mathematics: see below, § 5.2, for a discussion of the hyperbola, parabola, and ellipse.

Names can also focus on a specific characteristic or effect of a natural phenomenon or concept. For example, drugs can be called after their effect, like the ἀριστολοχεία "birthwort", which means "excellent for childbirth".[29] Plants or stones can

[29] DIOSC. 3, 4, 1 ἀριστολοχεία· ὠνόμασται μὲν ἀπὸ τοῦ δοκεῖν ἄριστα βοηθεῖν ταῖς λοχοῖς "aristolochia: it is so called from the belief that it is extremely beneficial to women during childbirth".

be named after their characteristics: e.g., ἡλιοσκόπιος, the "sun spurge", which "looks to the sun", or σεληνίτης (λίθος), the "selenite" or "moon-stone", which was supposed to be found at night with the waxing moon (Diosc. 5, 141). The same criteria apply to names for diseases. These often indicate the affected body part (e.g., κεφαλαλγία, περιπνευμονία, ἡπατῖτις, νεφρῖτις, δυσεντερία) or their color (e.g., ἀλφοί "dull-white leprosy", ἐρυσίπελας "erysipelas", a disease characterized by red patches on the skin); or they suggest what the patient feels (e.g., καῦσος, a remittent fever with a "burning" sensation; κυνάγχη "canine quinsy", referring to a sore throat where patients feel as if "strangled like a dog") or describe the way the disease affects the body (e.g., λιπο-θυμία for a "swoon", which happens when the "vital force" "fails", παρα-φροσύνη for "delirium", which is when one is "out of one's mind" or, more literally, "beside" oneself).

All the compounds denoting geometrical figures are also descriptive: for example, the focus can be on the number of angles for plane figures (e.g., τετράγωνον "[figure with] four angles", i.e., "square", πεντάγωνον "[figure with] five angles", etc.) or on the "faces" for solid figures (e.g., τετράεδρον "[solid with] four faces", ὀκτάεδρον "[solid with] eight faces", πολύεδρον, "[solid with] many faces"); or else, the relevant terms describe the figures in some other way, as with παραλληλόγραμμον "[the figure] bounded by parallel lines".

2.2. *'Historically', 'geographically', or 'mythically' derived names*

Names in technical disciplines can also recall the 'history' or myth behind certain phenomena or objects. They are hardly technical terms, but rather tend to be words familiar to laypeople. The most famous case is, of course, astronomy, where constellations and stars are often named after a hero or heroine. However, something similar also occurs in medicine and botany. For example, a disease can be named after the person who first cured it, as with the Χειρώνειον ἕλκος "Chiron's sore", or after the person who first suffered from it, as with the Τηλέφειον ἕλκος "Telephus' sore". Equally, a medicine or "remedy" (πάνακες) may be given a 'historical' or mythical name, for example the root known as πάνακες Χειρών(ε)ιον "Chiron's all-heal" (which cures venom of snakes), or the remedies "of Asclepius" and "of Heracles" respectively (πάνακες Ἀσκληπίειον / Ἡράκλειον).

Similarly, plants can derive their names from those who first used them as drugs, like the black hellebore which some call Μελαμπόδιον because the goatherd Melampus used it to cure the daughters of Proteus of their madness (Diosc. 4, 162, 1). Plants may also be named after the places where they grow: e.g., the στοιχάς "French lavender", which derives its name from the Stoichades (the modern Îles d'Hyères) (Diosc. 3, 26), or the λιγυστικόν "lovage", from Liguria (Diosc. 3, 51, 1). Minerals too can have geographic names, like the μίλτος Σινωπική, the "Sinopic red earth", called after Sinope where it was sold (Diosc. 5, 96, 1), or the famous Μαγνῆτις λίθος, the "Magnesian stone", i.e., the "magnet".

3. The Greek scientific lexicon: making 'phenomena' visible

The above survey allows us to draw some preliminary conclusions about how the lexicon of the sciences works.

First, the three linguistic strategies outlined (use of existent terms, creation of neologisms, and recourse to metaphors) are employed by many disciplines other than medicine, although the latter is the most studied one; notably, the mathematical sciences avail themselves of similar strategies as well.

Second, the three strategies are not mutually exclusive. Thus, there can be 'metaphorical neologisms' like κισσοειδής (γραμμή) or ἐξάνθημα, indicating an "efflorescence" on the skin (i.e., a pustule), and λογχῖτις, a metaphor built by means of the suffix -ῖτις, to indicate a plant with spear-shaped seeds.

The third point worth stressing is that in general this lexicon is quite transparent. This is obvious where common words are reused, but neologisms and metaphors are also seldom obscure.

Technical neologisms are 'normal' Greek words as far as their suffixes or compositional elements are concerned. In fact, no suffix seems to be exclusively used in technical terminology. Leaving aside suffixes like -ικός, -ειδής, or, for verbs, -άω, -έω, -ίζω, -άζω, which are obviously not technical *per se*, we may consider the most 'medically' oriented words, like those in "-itis". These definitely sound technical *to us*, because in modern languages they are specifically connected with medical terminology (e.g., *arthritis*, *bursitis*, *tendinitis*, etc.). In Greek, however, the suffix -ῖτις also produces a great number of feminine adjectival forms that are unrelated to inflammations or plants.[30] For example, it can be used in geographic and more generally spatial denominations, such as Ζεφυρῖτις, an epithet of Aphrodite as worshipped in Cyprus, Πιτανῖτις, indicating a woman or the region "of Pitane", γυναικωνῖτις "women's apartments", or παρωκεανῖτις, "sea coast". Similarly, the suffix -αινα is found not only in terms for foul diseases, but also in feminine nouns denoting animals (e.g., κάπραινα "wild sow") or in the very common θεράπαινα "handmaid". I therefore suggest that not only were these neologisms quite transparent to a native Greek speaker because they were Greek-based, but they did not even look foreign or esoteric, as they made used of 'building blocks' that were common in the Greek language in general.

As for metaphors (and metonymies), these are among the most effective means to name new objects, concepts, and phenomena in disciplines where the description of a new reality is paramount. Accordingly, they are used not only in biology and medicine, which are mostly descriptive sciences, but also in mathematics to describe particular types of curves and in philosophy to illustrate abstract principles.

[30] As already noted by WILLI (2003) 67, n. 41.

Naming a new phenomenon or concept with a word that is taken from common language and denotes there similar but better-known phenomenon can be linked with 'analogy', a widespread epistemological procedure through which the human mind makes sense of the unknown by comparing it to something similar and known. Particularly in the sciences, new phenomena are often compared and illustrated by means of models or analogues taken from known reality. The Greeks used this process extensively to understand natural phenomena through reasoning by likeness, arguments by analogy, etc.[31] Technical language employs metaphors for the same reason. A metaphor taken from daily language and denoting a common object or phenomenon better 'visualizes' the new object or idea. The metaphorical lexicon can thus be seen as the application to language of analogical scientific reasoning. Therefore, the use of metaphors in mathematical and medical authors in the Hellenistic period cannot be understood, as Netz claims, as an example of the 'carnivalesque' and hybrid nature of scientific writing, where scientists "move towards the literary mode".[32] It is rather a most common epistemological strategy, which is in fact present from the very beginning of Greek scientific thought, as examples from the Presocratics, Aristotle, and the Hippocratic writers show.

If metaphors are visualized images by default, I would like to suggest that even neologisms, formed with common Greek suffixes and by composition, were in a way 'visual' – although based on a different type of visualization, which is connected more with language and etymology than with 'sensory' analogy. Since Greek scientific language is all Greek-based, it automatically sounded less unfamiliar to laypeople than modern scientific language does, even when rather common modern technical terms are concerned. For example, while laypeople generally

[31] On analogy in ancient scientific discourse, see REGENBOGEN (1930); LLOYD (1966); LANGHOLF (1989).

[32] NETZ (2009) 149-160 (the quotation is taken from p. 160).

know what an aneurism is, they might not know what the word really means – that ἀνεύρυσμα is derived from ἀνευρύνω "to dilate" and thus refers to the "bulging" of a blood-vessel. In this case, the meaning is clear but the etymological reasons *why* the aneurism is so called (in other words, the fact that *aneurism* is a 'speaking', i.e., etymologically transparent and suggestive, name) remain hidden to most people. Similarly, everyone knows what a pentagon is – but how many know *why* it has that name? None of this would happen to Greek native speakers, of course. They might not know the specific, nuanced meaning of a technical word, but they had no problem in grasping its etymological origin, and hence the general sense of the word.[33] The same is true of metaphors. Here again, in modern scientific language many of them are still present, but since their Greek origin is not known to most speakers we hardly perceive their 'educational' and visual force: for example, pores for us are just 'pores', and while the fact that the etymology is now opaque does not prevent us from understanding the meaning, we have still lost the descriptive sense that they are "passages". Similarly, we all know what the coccyx is, but we are hardly aware that this odd name is actually teaching us something about the shape of that bone, which is similar to the beak of a "cuckoo" (κόκκυξ). The same is true for mathematics: we all know what the 'center' of a figure is, and professional mathematicians will know what a 'cissoid' is; but how many of them visualize it as an ivy-like curve? And most of us do not know that the 'center' of a circle visualizes the drawing of the circle with a compass.

[33] Cf. also LLOYD (1987) 204, who rightly notes: "the general sense was given by the root, in each case, though by itself this was not necessarily very informative. What counted as *the* disease of the pleura, or kidneys, [...] was often a matter of dispute and depended on the writer's views on both the symptoms and the causes at work". Lloyd is certainly correct; here, however, I am focusing on the etymological transparency of technical terms and how they may have sounded more familiar to a Greek native speaker than modern medical terminology does to us (the latter being etymologically opaque, since it is based on 'foreign' roots).

Even the mythical names for stars will have been much more suggestive to a Greek than to the modern stargazer: any Greek would have been familiar with Andromeda's story and figure, for example. For many of us, by contrast, *Andromeda* is simply an odd name for a constellation. If anything, such a name must therefore have made it easier for a Greek to remember the constellation, whereas for us it tends to be just another new term to remember.

To conclude, a large part of the Greek technical lexicon consists of 'speaking' names, whose ability to 'speak' comes either from the fact that they are based on easily recognizable (and common) Greek roots, or that they use images taken from common language or from mythology; in either case, they draw on the common cultural reservoir of all Greek speakers. I would thus suggest that, thanks to the different strategies adopted (namely, 'etymological' visualization in the case of compounds or new coinages by means of suffixation, 'analogical' visualization in the case of metaphors, 'cultural' visualization in the case of mythical and historical names), Greek technical language is much more transparent[34] and in a way more 'democratic' than the corresponding scientific terminology used nowadays (and indeed since the end of antiquity).

4. Is Greek scientific terminology 'scientific'?

The fact that the Greek technical lexicon is clearer and more visual than our technical terminology does not *per se* speak to whether it is 'scientific'. As a working definition of what constitutes technical/scientific terminology I will adapt the analysis of Andreas Willi[35] and propose the following:

[34] WILLI (2003) 95 already reached similar conclusions for fifth-century Athens. I am now expanding his suggestion to cover later periods as well as additional sciences, notably mathematics.

[35] WILLI (2003) 66 and 69; see also LANGSLOW (2000) 6-28 and FÖGEN (2003).

1. Technical/scientific terminology is recognized by native speakers as belonging to a specific technical field, and specialists in particular are self-conscious in employing a vocabulary which is 'theirs'.
2. It is not in common currency, even if it may be understood by non-specialists.
3. It tends to be standardized, economic, and concise (i.e., polysemy and synonymy are generally avoided in favor of monosemy).
4. It tends to be systematic (i.e., it covers all aspects of a semantic field).
5. It is expressively neutral (i.e., the lexemes belonging to it do not convey any judgment: cf. e.g. *gonorrhea* vs. the slang term *the clap*).

I will now briefly review each of these points to see if the Greek technical lexicon complies with these characteristics.

In order to obtain evidence on how a layperson would have perceived the terms that are deemed technical according to (1), one must look at phenomena such as comic parody, as Willi has done for Aristophanes.[36] In later periods it is more difficult to find parody, but there is didactic poetry, which we will look at below (§ 6). For now, however, I will concentrate on the self-consciousness of the technical practitioners.

In this respect, both medical and mathematical languages seem to conform to our expectation. The stock expression ὁ/ἡ/τὸ [...] καλούμενος/η/ον is often used by the Hippocratic (and later) physicians to mark a technical term (e.g., Hippoc. *Morb.* 2, 65, 1; *Aff. int.* 47, 1; Gal. *Nat. fac.* 2, 24, 12-13 Kühn).[37]

[36] WILLI (2003) 51-95, 96-117.

[37] But there are exceptions: cf. LLOYD (1983) 154-155. A similar self-consciousness is displayed by Theophrastus, who stresses his use of terms 'borrowed' from other fields, for example when he notes that he employs ἶνες "tendons" and φλέβες "veins" in speaking about plants both because there are no terms for these parts in plants and because they resemble analogous parts in animals (*Hist. pl.* 1, 2, 3: ἶνες δὲ καὶ φλέβες καθ' αὑτὰ μὲν ἀνώνυμα τῇ δὲ ὁμοιότητι μεταλαμβάνουσι τῶν ἐν τοῦς ζῴοις μορίων "'fibers' and 'veins' [in plants] do not have a specific

The main evidence that medical terminology was perceived already in antiquity as 'technical' is offered by the development of Hippocratic lexicography in Alexandria in the third century BCE, the only parallel to which is the lexicography on Homer. In both cases, there was a need of some sort of exegesis to 'translate' Homer and Hippocrates into Koine Greek.[38] In mathematics, meanwhile, "definitions" (ὅροι) are set out at the beginning of many mathematical treatises. This search for definitions goes beyond Euclid, Archimedes, or Apollonius and reaches into astronomy (for example, Geminus' *Introduction to the Phenomena*). In the mathematical sciences in particular, defining a technical lexicon becomes paramount because, whereas medicine prefers neologisms, mathematicians use many common words, which must therefore be precisely defined for the discipline. Yet no lexicography on mathematics ever developed. This can be interpreted in different ways: that there was less of a need for it (because it was a more specialized field), that there was a smaller lexicon, or that there was less confusion. I believe it was a combination of all three reasons, as I will explain below (§ 5.1). Interest in definitions is attested earlier for other technical fields too, as may be gathered from the examples of Aristotle's *Metaphysics* Δ and Aristoxenus' *Harmonica* and *Rhythmica*. In fact, Aristoxenus even discusses the reason why certain notes are given specific, technical names (e.g., λιχανός in *Harm.* 2, 47-49). Thus, if one of the staple ingredients of scientific and technical language is to be 'self-conscious' in establishing the specific (i.e., technical) meaning of its concepts by defining the terms used, then the Greek technical lexicon does qualify, and from early on.[39]

Turning to (2), a technical lexicon, as a consequence of being recognized as belonging to a specialized field, should not be actively used (even when understood) by non-specialists.

name but borrow it from the [corresponding] parts in animals due to their similarity"); cf. TRIBULATO (2010) 486-487.

[38] On ancient medical lexicography, see VON STADEN (1992).

[39] See also THEOPHR. *Hist. pl.* 1, 1, 9.

Here we must distinguish between 'common' words that acquire a more specific meaning and neologisms or metaphors, which are likelier to be opaque to non-specialists. However, as we have seen, in the Greek scientific lexicon even neologisms and metaphors were more transparent to laypeople than modern technical terminology is. Thus, while the technical nuances of specific terms may have been known mainly to experts, I think that there was not such a divide between experts and laypeople, at least as far as a basic grasp of the terms' etymological meaning is concerned.[40] Even so, there were cases of double terminology, one for insiders and one for outsiders; for example, Galen (*Meth. med.* 10, 423, 17-424, 2 Kühn) mentions the case of the term κάταγμα "fracture", which was the word that everyone could understand, whereas the technical term ἄπαγμα was unknown to laypeople. Yet this seems to be mostly a question of use rather than understanding, since to a native speaker of Greek ἄπαγμα was as etymologically clear as κάταγμα (both being derived from ἄγνυμι "to break", with the addition of κατά and ἀπό respectively).

By contrast, a lack of standardization, polysemy, and synonymy (3) are often observed in the technical lexicon of many fields of Greek science, even if there are some differences between medical and mathematical sciences. In medical terminology, polysemy and synonymy are often present.[41] One term can thus be used for different organs (polysemy): for instance, κερκίς indicates the tibia in Herophilus (Ruf. *Onom.* 123 = Heroph. fr. 129 von Staden), but starting with Galen it is later also used to mean "radius" (e.g., Gal. *Anat. adm.* 1, 5 = 2, 245, 2 Kühn; *Oss.* Ia, 4 Garofalo = 2, 733, 11 Kühn;

[40] In fact, the necessity of being understood by laypeople is already apparent to the author of the *Ancient Medicine* 2, 3: μάλιστα δέ μοι δοκέει περὶ ταύτης δεῖν λέγοντα τῆς τέχνης γνωστὰ λέγειν τοῖσι δημότῃσιν "But to me it seems most important that in speaking about this art [i.e., medicine] one must say things that are understandable to laypeople".

[41] On this problem, see LANZA (1979) 116-117; LLOYD (1983) 160-167; SKODA (1988) 316-317.

Orib. 47, 6, 1);[42] and κεφαλή, αὐχήν, and πύλη are used to indicate many different internal parts of the body. There is also synonymy, as for example with the bronchi, which, as Rufus of Ephesus (*c.* 100 CE) explains, could be called βρογχίαι, σήραγγες, or ἀορταί.[43] Botany, like medicine, shows both polysemy (e.g., Theophr. *Hist. pl.* 9, 16, 1-3, explaining that there are two plants called δίκταμνον "dittany", beside one called ψευδοδίκταμνον "false dittany") and synonymy (e.g., Theophr. *Hist. pl.* 9, 8, 2: the "spurge" is called both τιθύμαλλος and μηκώνιον). In mathematics, the cases are more nuanced. A "point" can be called σημεῖον, but also πέρας "extremity" (of a segment), κέντρον "center" (of a circle or a sphere), μέσον "middle" (of a segment), κορυφή "top" (of a triangle or a cone). Similarly, a line segment can be named πλευρά "side" (of a polygon) or ἡ τοῦ κέντρου "the (line) from the center" (for a radius in a circle), but also βάσις "base" (of a triangle) or ἄξων "axis".[44] However, the synonymy here is only apparent, because the object indicated by the different names is clearly different within the context. By the same token, the "radius" of a circle is ἡ ἐκ τοῦ κέντρου (γραμμή); yet when the construction of circles is described we always read κέντρῳ μὲν τῷ Α διαστήματι δὲ τῷ ΑΒ κύκλος γεγράφθω ὁ ΒΓΔ "let a circle, BCD, be drawn with a center, A, and a radius, AB" (Eucl. *El.* 1 *Dem.* 1). What has been translated with "radius" is διάστημα, meaning "interval". The word indicates the radius *only* in this specific context, where reference is made to a circle, so that the two names (ἡ ἐκ τοῦ κέντρου and διάστημα) are contextual variants.[45] The only true synonyms in mathematics do not concern 'real' technical names but rather common (and hardly technical) words: for example, σχῆμα and εἶδος for "figure", ἄγειν and

[42] Cf. Skoda (1988) 33-34, 43-44, who also notes (p. 45) that in Hippoc. *Oss.* 17 κερκίς indicates the fibula (usually called περόνη).

[43] Ruf. *Onom.* 159: αἱ δὲ εἰς τὸν πλεύμονα ἀποφύσεις, βρογχίαι, καὶ σήραγγες, καὶ ἀορταί.

[44] Cf. Federspiel (1992) 398; also Netz (1999) 108-113.

[45] Cf. Federspiel (2005).

ἀνάγειν for "to trace" (a line), and διαιρεῖν, τέμνειν, and διατέμνειν for "to cut" (a figure or a line). These uses generate no ambiguity.

With regard to the question of 'systematicity' (4), things are often difficult to determine because in many disciplines the evidence is limited, consisting only of fragments. However, in those texts which we do possess either in full or in a continuous – though perhaps not complete – form, we see at least an *effort* at being systematic. The case of Euclid is obvious, but the same is valid for Aristotle's *Metaphysics* Δ, for Aristoxenus' *Harmonics*, and for Geminus' *Introduction to the Phenomena*, all of which seem to systematically 'name' all the objects or ideas they discuss.

Deciding whether this lexicon is expressively neutral (5) is not straightforward. One example that immediately comes to mind is the term ἱερὴ νοῦσος "sacred disease", which was substituted by the Hippocratic physicians with the 'neutral' name ἐπίληψις or ἐπιληψίη (although the title of the pertinent treatise remained Περὶ τῆς ἱερῆς νούσου).[46] But the more important question is how we evaluate metaphors, as these can be judgmental. As we have seen, metaphors in medical and mathematical terminology range from items of daily life to comparison with other natural/biological objects. I have not carried out a complete survey of metaphorical usages in the Greek technical languages, but the main driver behind the examples I have collected seems to be 'visualization' – as is generally true for Greek metaphors starting with Homer. Do these uses reveal a 'judgment'? To me, they suggest an attitude of looking at nature as a domain where everything is connected, and where similarities are therefore readily found – which in turn can be seen as one of the characteristics of science.

[46] Theophrastus, too, speaks of ἱερὰ νόσος when talking about herbs that are useful against epilepsy (*Hist. pl.* 9, 11, 3).

5. The difference of mathematics

So far I have sought to emphasize the similarities between the medical and the mathematical sciences in terms of the strategies used to create their terminology and the reasons behind it. In the previous section I have also stressed that the scientific lexicons of medicine and mathematics have similar flaws, like the presence of synonymy, and that the specialists concerned display a similar self-conscious attitude. But there are also differences, and it is on these that I will now concentrate. I will do so focusing on mathematics, because in this field there are linguistic phenomena that significantly change the way in which the technical texts can be received by laymen.

5.1. *The 'economy' of the mathematical lexicon*

As we have seen, descriptive sciences like medicine, botany, zoology, and mechanics used common words, 'transparent' neologisms, and 'speaking' metaphors, which were rather easy to understand. Although their lexicon sounded technical, many of these texts could be read and understood by neophytes once they had familiarized themselves with the specific vocabulary. On the other hand, since these descriptive sciences build up a nomenclature in order to 'name' all the phenomena, items, etc. that pertain to a given discipline, their vocabulary is vast and in principle always expanding. In addition, the principle behind a classificatory nomenclature is that each term is used for a specific phenomenon/item and that there is little room for terminological predictability. In other words, even when knowing that an inflammation of the eyes is called ὀφθαλμία, I cannot reliably predict the term for an "inflammation" of the mouth (*στοματία? *στοματ-ῖτις? in reality, it is στομαλγία, at least according to Pollux 2, 101).

By contrast, mathematics works in a completely different way. Since it is a deductive science, the idea here is that once the basic geometrical concepts are defined (ὅροι "definitions") and some general "truths" are established (κοιναὶ ἔννοιαι "common notions"), the rest can be rationally derived. This is exactly what we see in the mathematical texts, starting with Euclid, and it affects the lexicon as well. For example, once we have a τρίγωνον, it is pretty obvious what a τετράγωνον and a πεντάγωνον are, and we can even coin a new word like *ἑπτακαιδεκάγωνον for a figure with seventeen angles. Thus, while there are many terms in geometry, in fact they all derive from a small terminological basis, so that understanding and expanding the lexicon is relatively easy.

Most metaphorical names in mathematics were coined to name new curves or odd shapes, just as physicians would name a new organ. However, curves and odd shapes are to a certain extent unique and limited; for plane and solid figures, as we have just seen, the terminology is generated through compounds that are easy to understand (involving numbers, basic words, etc.). The lexicon of mathematics, therefore, is not different, but smaller than the lexicon of other descriptive sciences: it works by logical expansion from a rather limited number of key terms, whereas in the natural sciences each object has its own name and, in principle, no relationship to other objects.

To conclude, mathematical language is different from the language of the descriptive sciences not because it relies on different strategies or has a more specialized vocabulary; rather, it too uses common words, 'transparent' neologisms, and 'speaking' metaphors – while in fact having a less diversified lexicon. Yet there is something else that makes mathematics difficult, even though the latter relies on a vocabulary that is quite close to standard Greek. I will discuss this 'something' in the next two sections.

5.2. *From analogy to abstract visualization*

The main problem that affects mathematical texts, I suggest, is that while descriptive disciplines like medicine and botany seem to stop at new coinages and metaphors to visualize their content, in the mathematical sciences we witness a further step into this analogical/visual terminology, which I call the transition from analogy to 'abstract visualization'. The naming of the ellipse will show what I mean.

For the Greeks, the ellipse was the section of a cone or cylinder cut by a plane that is not parallel to the base:

> ἐὰν γὰρ κῶνος ἢ κύλινδρος ἐπιπέδῳ τμηθῇ μὴ παρὰ τὴν βάσιν, ἡ τομὴ γίγνεται ὀξυγωνίου κώνου τομή, ἥτις ἐστὶν ὁμοία θυρεῷ. (Eucl. *Phaen.*, *praef.*, p. 6, 5-8 Menge)
>
> "For if a cone or a cylinder is cut by a plane that is not parallel to the base, the section is that of an acute-angled cone, which is similar to a shield."[47]

Here Euclid does not call the curve "ellipse" but says that it is similar to a shield, θυρεός. Since this latter word originally means "door-like", it already involves a figurative reference to the term θύρα "door": a θυρεός is an *oblong* shield, hence different from a round ἀσπίς. The analogy undoubtedly gives an idea of what an ellipse looks like.

The name "ellipse", however, is due to Apollonius of Perga (third/second century BCE), who systematized the theory of conics in his *Conics* (of which books 1-4 survive in Greek, books 5-7 in Arabic, and book 8 is lost). Without reporting his long demonstration of what an ellipse is, nor explaining the difficult mathematical reasoning behind it, which is beyond the scope of this paper, I will refer to a diagram (Fig. 1) to show the origin of the name "ellipse". In fact, to understand why the ellipse is called "ellipse", one must start from the "parabola" (*Con.* 1, 11), another 'new' name given by Apollonius (alongside "hyperbola").

Apollonius' method is based on comparing the areas of the figures built on the coordinates of an arbitrary point on the

[47] For a discussion on the authenticity of the introduction of this treatise, see BERGGREN / THOMAS (1996) 8-13. Whether this passage is indeed by Euclid or not does not impact my argument; for the sake of clarity, however, I will still call its author 'Euclid'.

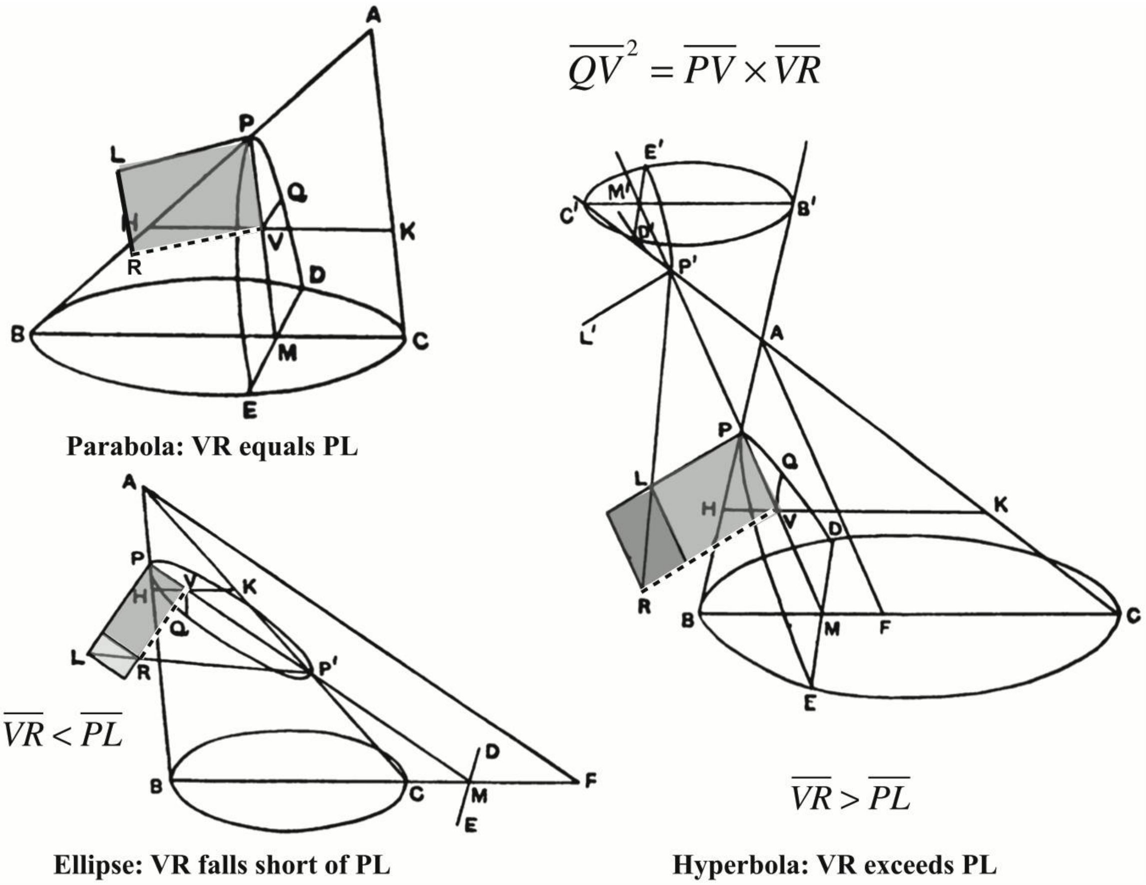

Fig. 1. Parabola, Ellipse, Hyperbola
(Apollon. Perg. *Con.* 1, 11-13)

curve (the "conic") obtained by intersecting a cone with a plane. He compares the square described on the segment QV, which we would call the "abscissa" of the point on the conic, with the rectangle contained by what we would call the "ordinate" of the same point on the conic (the segment PV), and another segment PL, which he builds from the figures. In the case of the parabola (*Con.* 1, 11), one gets $QV^2 = PV \times PL$, which means that the square of QV, if "applied" (παραβάλλειν) to the segment PL (namely, if transformed in a rectangle with one side being PL), gives PV as the other side (the gray area in Fig. 1); from this comes the name παραβολή "application". In the case of the ellipse (*Con.* 1, 13), Apollonius makes a similar argument, but this time the square QV^2 if "applied" to the segment PL, needs a line segment VR shorter than PL in order to maintain PV as the other side and obtain $QV^2 = PV \times VR$, with $VR < PL$. Thus, the rectangle PV x VR (the gray area in Fig. 1) is smaller than ("falls short" of) the rectangle PV × PL (the gray area + the light gray area) – whence the name ἔλλειψις "defect". A similar argument is made for the remaining curve (*Con.* 1, 12), except that in this case VR is longer than PL, so that the rectangle PV × VR (the gray area + the dark gray area) exceeds PV × PL (the gray area) in size – whence the name ὑπερβολή "excess".[48]

While Euclid's description was rather easy to understand even for a neophyte, what about the Apollonian definitions? Here, the ellipse is no longer a 'shield' but the explanation of what one sees on the diagram. "Ellipse", "parabola", and "hyperbola" are still 'speaking' names, hence unproblematic to process from a linguistic point of view: their etymological meanings may be lost to us – also because conics are now defined utilizing different arguments –, but for a Greek it would have been obvious that ἔλλειψις meant "defect", παραβολή "application", and ὑπερβολή "excess". Moreover, none of these terms was a neologism. They were all well-known and easily-understood Greek words. But are they easy to understand *mathematically*? I think it is obvious that they are not, even if they are all based on 'visualizations' of these objects, just like Euclid's 'shield'.

The point I would like to make is therefore that even if the term might have been clear from an etymological point of view, this would not necessarily translate into an understanding of *why* the name was given, as this required extensive mathematical training. This is where the mathematical lexicon, although based on the same principles and still aiming

[48] On the names of the parabola, ellipse, and hyperbola, see HEATH (1921) II 138; cf. also NETZ (1999) 100-101.

at visualization, becomes more technical and difficult – not because it is linguistically more technical, but because the very words imply some mathematical reasoning that may not be obvious.

5.3. *Visualizing mathematical objects: anaphoric articles, letters, and diagrams*

With conics we have seen how diagrams and demonstrations are integral parts of the naming of a geometrical object. In fact, this is a wider phenomenon typical of mathematical language.

The 'technical' names of geometric objects (e.g., σημεῖον, γραμμή, γωνία, κύκλος, τετράγωνον) are used by mathematicians in the so-called definitions, but in the demonstrations (theorems and problems), which form the real core of mathematical deductive reasoning,[49] another way of naming geometrical objects is often observed, and this works mainly at the level of syntax. For example, rather than simply being referred to as τὸ σημεῖον, a point is here named τὸ σημεῖον τὸ A or τὸ A σημεῖον or, in the most abbreviated form, τὸ A, where A is the letter that is given as the name of that point.[50] Similarly, we can have ἡ AB for "the (line passing through the points) A and B", ἡ ὑπὸ τῶν AB, BΓ "the (angle formed by the lines) AB and BC", ὁ ABΓ "the (circle passing through the points) ABC", τὸ ABΓΔE "the (polygon whose vertexes are the points) ABCDE", τὸ ὑπὸ τῶν AB, BΓ "the (rectangle contained) by (the segments) AB and BC". The complete linguistic phrase that lies behind an expression like τὸ A is in fact τὸ σημεῖον τὸ ἐφ' οὗ A "the point upon which the letter A is written"; and in the same way, τὸ ὑπὸ τῶν AB, BΓ is to be understood as τὸ ὑπὸ τῶν τμημάτων τῶν AB καὶ BΓ περιεχόμενον ὀρθογώνιον "the

[49] Cf. HEATH (²1926) I 117-142; ACERBI (2007) 218-219.

[50] A is thus always in attributive position, and *τὸ σημεῖον A would be wrong; cf. ACERBI (2007) 269.

rectangle contained by the segments AB and BC".[51] Even if this is brachylogic phrasing, for a Greek speaker the combination of article + preposition + letters would have been much more natural than for us, given the widespread use of the article to substantivize any prepositional phrase – so this form of expression would not have been unusual from a purely linguistic point of view.[52] But this is not the end of the story.

The main 'characters' in these phrases are: definite articles, letters, and prepositions, and they all have an essential function. The article that is preposed to denotative letters has an anaphoric function of 'pointing' to the diagram where the letters are reported. So a sentence like ἔστω τρίγωνον ἰσοσκελὲς τὸ ΑΒΓ... (Eucl. *El.* 1 *Dem.* 5) means "let there be an isosceles triangle, ABC", where τρίγωνον ἰσοσκελές is the subject conveying the indefinite 'general' idea of the geometric object, while the apposition τὸ ΑΒΓ points to the 'real' geometrical object, i.e., the triangle depicted in the diagram.[53] The letters indicate the most important points of that line, plane, or solid figure, thus 'visually' identifying these objects in the diagram. With a similar function, prepositions situate in space all (definite) points, lines, angles, etc. and help to define their relative position (e.g., ἡ πρὸς τῷ Β "the [angle originating] at the [point] B").

[51] On the ellipsis of the noun and the difference of usage between the 'short' form (without the noun) and the 'long' form (with the noun) in this type of phrases, see FEDERSPIEL (1995) 281-285. Cf. also NETZ (1999) 133-136.

[52] Logical relationships in mathematics are often expressed by syntactic means and specific formulae. I cannot treat these here, but it will suffice to say that both syntax and formulae, though strictly regulated, are not complex, as they are entirely made up of plain Greek words and constructions. However, there are sometimes problems with syntactic abbreviations: see FEDERSPIEL (2003), who takes into consideration the 'abbreviated syntagms' (those briefly discussed here) as well as the 'abbreviated clauses' (more complex and long forms of abbreviated phrasing, here omitted). On mathematical formulae, cf. AUJAC (1984); NETZ (1999) 127-167.

[53] The point is fully discussed and further exemplified in FEDERSPIEL (1995), who underscores the 'general law' that in mathematical texts the first occurrence of a geometric object is indefinite (i.e., general), hence the term indicating it is not accompanied by the article. Thus, in the example reported above the subject is τρίγωνον ἰσοσκελές and not τὸ ΑΒΓ; cf. also ACERBI (2007) 293-295.

As is clear, this way of naming geometrical objects is strictly linked to the diagrams where the letters can be seen. While the diagrams in our manuscripts may not be original, the denotative letters prove that diagrams were an integral part of mathematical writing[54] and worked as visual aids for the reader to follow the demonstration. Denotative letters thus connect the general enunciation with the diagram, which represents only a particular case for didactic purposes, even if the demonstration has a general validity beyond the figure in the diagram. The use of denotative letters is therefore in a way parallel to that of metaphors. Both letters and metaphors help readers to 'visualize' the scientific phenomenon studied.

However, in these examples, and even more so in cases like the ones concerning conics discussed above, there is a fundamental difference in the way this 'visualization' is carried out. While metaphors point to something outside the discipline and known to the reader/audience, denotative letters are *self-referential*, as they point to a diagram that is still part of the same mathematical realm. This language is thus more difficult and technical because it is enclosed *within the same field* and does not go beyond it – although its 'visual' strategies are very similar to those of medicine. The fact that mathematics needs to be visual *within itself* is a consequence of it being an abstract and deductive discipline. Even so, the Greek mathematicians found a way to make it visual, though one requiring a prior understanding of mathematical concepts.

6. Reaching beyond the experts?

We may now wonder whether this distinction between descriptive and deductive sciences and their respective lexicons can explain what we find when we look at texts that aim at a wider audience. As is well known, technical didactic poetry

[54] On lettered diagrams in Greek mathematics, see NETZ (1999) 12-67 and 68-88.

such as that of Aratus and Nicander was very popular in the Hellenistic period. These poems were 'best-sellers', notably that of Aratus; and yet they are full of technical words, a fact which seems to have bothered the ancient public less than it would bother modern readers if they were faced with poetry on quantum mechanics or biology.[55] It looks as if people did not face insurmountable problems when reading poems full of technical terminology. I have tried to explain this phenomenon by stressing how relatively easy and 'user-friendly' Greek technical terminology was in every discipline. In addition, given the nature of Hellenistic poetry and its obsession with glosses and erudite details, reading Aratus or Nicander would not have been so different from reading, say, a passage from the *Aitia* or (worse!) Lycophron's *Alexandra*.

Interestingly, however, all the instances of 'popular' poetry on technical subjects involve descriptive sciences. Even Aratus uses the technical terminology of astronomy, but only as far as mythical names are concerned. He does not deal with mathematical reasoning, nor does he use 'real' mathematical language.[56] For example, in order to describe the constellation of the Triangle (Δελτωτόν, another metaphor!) as an isosceles triangle he says that two of its sides are clearly equal to each other (*Phaen.* 235-236: ἰσαιομένῃσιν ἐοικὸς / ἀμφοτέραις [i.e., πλευρῇσιν]) – hardly a technical expression after Euclid's *Elements*. Of course there is no trace of mathematical astronomy with denotative letters and diagrams here. Aratus' poem thus deals with the 'descriptive' part of astronomy only, making it similar to medicine or botany.

And yet, there are some examples of mathematical poetry: e.g., several epigrams in book 14 of the *Palatine Anthology* (nos. 1-4, 6-7, 11-13, 48-51, 116-147) as well as the famous *Cattle Problem* attributed to Archimedes. However, these seem to be wholly different from the poems of Aratus and Nicander.

[55] Cf. FÖGEN (2003) 35-36, who however focuses on Latin authors.
[56] On the language of Aratus in general, cf. KIDD (1997) 23-32.

First of all, they are not didactic poems but 'riddles', which are left to the reader to solve. Second, they do not use any technical lexicon. The epigrams deal mostly with counting apples, nuts, talents, time (years, days, hours), weight (minae), and distances (stades),[57] and they are written in standard poetic Greek. Similarly, the *Cattle Problem* is about counting the cows of Helios.[58] While the epigrams are more about logistics in the ancient sense (i.e., calculation), the *Cattle Problem* is a real (and difficult) mathematical problem which was not solved until modern times.[59] Yet the language of the poem (just like that of the epigrams) is hardly technical but rather Homeric. So why was the mathematical technical lexicon not used in these compositions? The problem, I think, was that the real mathematical idiolect was not considered a proper medium for poetry because it moreover required external diagrams. What we have here are very difficult or even impossible problems, which are however expressed in plain language. I would even suggest that if they were composed by real mathematicians (and this is debated), they might have served to underscore the gap between 'insiders' and 'outsiders': first, these poems propound riddles while offering no solution; second, they look like games, as if they were the pastime of serious practitioners, who 'gave up' their own language (i.e., reverted to standard Greek) and yet wrote something incomprehensible to outsiders – which, in effect, is another way of saying that mathematics was for the select few, with or without its own technical language.

The only exception to this state of affairs (at least to my knowledge) is the debated letter of Eratosthenes to King Ptolemy, transmitted by Eutocius in his commentary on Archimedes' *On the Sphere and Cylinder* (III 88, 3-96, 27 Heiberg-Stamatis = IV 64, 5-69, 11 Mugler). This is a mixed text, in the form of a letter addressed to King Ptolemy III and aimed at presenting

[57] Cf. Taub (2017) 39-49 and 135-143.
[58] Cf. Taub (2017) 35-39.
[59] Cf. Knorr (1986) 294-295.

Eratosthenes' own solution of the famous problem of the doubling of the cube. The letter switches between genres. After the salutation, we find a quotation of an unknown tragedy telling of Minos, who had to build a tomb for his son Glaucus and wanted to 'double' it (hence the problem); a survey of past attempts to solve the problem by Hippocrates of Chios, Archytas, Eudoxus, Menaechmus; Eratosthenes' geometrical proof, followed by another mechanical proof (with a description of the instrument that is to be built); a note that these proofs had been inscribed on a monument built to memorialize the accomplishment; and finally Eratosthenes' own epigram to celebrate his feat, which was also inscribed on the monument. This is a very odd potpourri and has raised serious doubts about the text's authenticity. [60] The geometric part is purely technical and reads like any other text by Euclid or Apollonius. If it is authentic, it is a very odd piece indeed. Regardless, it is definitely not a text for 'outsiders' but rather addressed to one person only; Eratosthenes was not trying to 'reach out', but to brag about his own merits with his boss. The fact that the king might not have understood the proofs may have made Eratosthenes look even smarter.[61] So although eccentric and doubtful, this letter too suggests that mathematical writing (whether for insiders or outsiders) aimed at being obscure, drawing a dividing line between those who understand and those who do not. Most interesting is the epigram (which is the only part generally considered authentic) (Eratosth. fr. 35 Powell, from Eutoc. *In Archim.* III 96, 10-27 Heiberg-Stamatis = IV 68, 17-69, 11 Mugler):

> Εἰ <u>κύβον</u> ἐξ ὀλίγου διπλήσιον, ὠγαθέ, τεύχειν
> φράζεαι, ἢ <u>στερεὴν</u> πᾶσαν ἐς ἄλλο φύσιν

[60] Starting with Wilamowitz: see KNORR (1986) 17-24, who however advances some good arguments in favor of authenticity; cf. KNORR (1986) 210-218 for a mathematical analysis. For further discussion of the text, see also TAUB (2008) and (2017) 55-71, as well as NETZ (2009) 160-163.

[61] The same may be the case with Archimedes' *Sand-Reckoner*, dedicated to Gelon of Syracuse.

εὖ μεταμορφῶσαι, τόδε τοι πάρα, κἂν σύ γε μάνδρην
  ἢ σιρὸν ἢ κοίλου φρείατος εὐρὺ κύτος
τῇδ’ ἀναμετρήσαιο, μέσας ὅτε τέρμασιν ἄκροις
  συνδρομάδας δισσῶν ἐντὸς ἕλῃς κανόνων.
Μηδὲ σύ γ’ Ἀρχύτεω δυσμήχανα ἔργα κυλίνδρων
  μηδὲ Μεναιχμείους κωνοτομεῖν τριάδας
δίζηαι· μηδ’ εἴ τι θεουδέος Εὐδόξοιο
  καμπύλον ἐν γραμμαῖς εἶδος ἀναγράφεται.
Τοῖσδε γὰρ ἐν πινάκεσσι μεσόγραφα μυρία τεύχοις
  ῥεῖά κεν, ἐκ παύρου πυθμένος ἀρχόμενος.
Εὐαίων, Πτολεμαῖε, πατὴρ ὅτι παιδὶ συνηβῶν
  πάνθ’ ὅσα καὶ Μούσαις καὶ βασιλεῦσι φίλα
αὐτὸς ἐδωρήσω· τὸ δ’ ἐς ὕστερον, οὐράνιε Ζεῦ,
  καὶ σκήπτρων ἐκ σῆς ἀντιάσειε χερός·
καὶ τὰ μὲν ὣς τελέοιτο, λέγοι δέ τις ἄνθεμα λεύσσων·
  Τοῦ Κυρηναίου τοῦτ’ Ἐρατοσθένεος.

“If, friend, you care to find from a small [cube] a cube double its size, or nicely to change any solid figure into another, this is in your power; you could measure a fold, a pit, the wide basin of a hollow well in this way, when you catch between two rulers [two] means converging with their extreme ends. Do not try the difficult business of Archytas’ cylinders or to produce by means of conic sections the triads of Menaechmus; not even if some curved form of lines is described by god-fearing Eudoxus. For in these tablets you could easily find a myriad of means, starting from a small base. Fortunate are you, Ptolemy, because, as a father equal to his son in vigor, you gave him all that is dear to the Muses and to kings. May this last in the future, heavenly Zeus, and may he also receive the scepter from your hands. Thus may this be and let anyone who sees this offering say: ‘this is of Eratosthenes of Cyrene’.”

While not using denotative letters, this passage does contain some technical lexicon (κύβος, στερεός, κύλινδρος, κωνοτομεῖν, γραμμή, μεσόγραφον, underlined in the Greek). But again, it does not explain the proof. Rather, it describes the past history of the problem and then celebrates Eratosthenes and praises the king. In a sense, this is the closest example to a ‘descriptive’ poem about mathematics. Equally, it is not a riddle, and yet from it one cannot learn much other than that there has been a series of failed attempts at solving the problem in the past.

Mathematics, it thus seems, cannot be learned without diagrams, denotative letters, and prose – and in order to get those, one has to dive in into the 'real' stuff. Only after learning the principles, with all their logical intricacies (including the prose), one also enjoy the poetic riddles, because at that point one may actually be able to solve them. But when mathematics tries to be descriptive and uses the technical lexicon without abstract visualization, it can only be a 'history' of mathematics – this being the only aspect of mathematics that non-specialists can understand.

7. Conclusions

The preceding analysis has shown that the use of common terms, new coinages (involving derivation and composition), and metaphors is not limited to medicine but shared by the other sciences (biology, mathematics, harmonics, and astronomy). It has also suggested that the lexicon produced through new coinages or metaphors/metonyms is in fact quite easy to understand from an etymological/visual point of view for any speaker of Greek.

Yet mathematics also employs what I have called 'abstract visualization', which tightly connects the text and the words in it to the diagram and the geometric demonstration. Because of this abstract and self-referential visualization, mathematical language becomes more technical – not in linguistic terms, but conceptually speaking.

This is one of the most important differences between the descriptive and the deductive sciences when we compare how they were received outside their respective circles of experts. While the relative transparency of much of the technical lexicon may explain the popularity of didactic poetry in the domain of the descriptive sciences (e.g., Nicander and the astronomy of Aratus), this difference may also explain the odd nature of mathematical poetry, which is very obscure without using any technical terms. In a way, the impression one gets is that while didactic texts dealing with the descriptive sciences are 'accessible' despite their length and technical vocabulary, those engaging with the deductive sciences require an audience of people who have already learned the discipline 'from the inside': all that is left to the outsider is the history of the discipline.

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DISCUSSION

A. Willi: I find the distinction you draw between the creation of terminology in descriptive and deductive sciences extremely helpful and convincing; but at the same time I ask myself to what extent this is a distinction between two 'opposites' and not rather a sliding scale. When I think of ancient grammar and linguistics, it seems to me that this field partly aligns with your descriptive and partly with your deductive sciences. For one thing, one might perhaps compare expressions like τὰ εἰς νυμι for "the verbs in -νυμι" with something like geometrical ἡ ὑπὸ τῶν AB – of course what is at stake is not a diagram here, but it is at least some sort of an imaginary paradigm table. More importantly though, and to give just one example, when we have terms like μετοχή for "participle", this is by no means transparent to someone who does not already know what the 'participation' implied by the term refers to: in order to understand it, one first needs to be aware of the fundamental distinction between nouns and verbs.

F. Schironi: Yes, you are right. Indeed there are 'in-between cases'. Aside from grammar (which is a very good example I did not think of, although I have worked so much on the topic) I can think of astronomy and mechanics. In fact, the example of Aratus I gave was meant to illustrate exactly this. Astronomy can lean toward the deductive sciences when it is mathematical astronomy, but it can also be a 'descriptive science' when it is simply an illustration of constellations, their shapes, and their relative positions. Aratus treats astronomy only in the latter sense; indeed, the lack of mathematical analysis is one of the criticisms that Hipparchus will level against him, together with the fact that Aratus did not bother to carry out his own empirical observations (Hipparch. *In Aratum* 1, 1, 8: οὐ κατ' ἰδίαν παρατηρήσας ἢ μαθηματικὴν κρίσιν ἐπαγγελλόμενος ἐν τοῖς οὐρανίοις προφέρεσθαι).

L. Prauscello: I would consider the example of ἄπαγμα not as a case of polysemy but simply as a case of hyponymy, with ἄπαγμα representing a 'specialised subset' of κάταγμα. The testimony of Oribasius seems to support this interpretation: *Coll. Med.* 46, 6: οὐχ ἕτερόν τι γένος πάθους ἐστὶ τὸ ἄπαγμα τοῦ κατάγματος, ἀλλ' ἔστι τὸ ἄπαγμα.

F. Schironi: I listed it as a case not of polysemy but of double terminology, one for insiders and one for outsiders. As Galen and Oribasius testify, the term used by the outsiders (κάταγμα) was known by the insiders; yet, I am not sure that it is the same as saying that κάταγμα is more generic than the technical term ἄπαγμα, which would be the hyponym.

O. Tribulato: My question concerns the language of mathematics. Do you have evidence that technical compounds may have been alternating with 'phrasal terms', i.e., fixed phrases made of a noun and a specifying genitive, which have the same syntactic organization as the compound? I have briefly dealt with this phenomenon, a kind of 'compression', in my works on compounding and Langslow too identifies this feature as one of the markers of Greek medical language. I refer to forms such as ὀποβάλσαμον alternating with the phrase ὁ ὀπὸς τοῦ βαλσάμου: theoretically, the latter is the starting point whereas the former is the univocal technical term derived from it. The thing that I always found interesting is trying to understand whether there is a rationale behind the alternating use of both naming strategies.

F. Schironi: I have not found anything like that so far. One reason may be that most mathematical compounds are either nominal, but without a modifying element that has the role of a specifying genitive next to the head (e.g., παραλληλεπίπεδον, πεντάγωνον, δωδεκάεδρον, διάμετρος, περιφέρεια), or adjectival, so that the syntactic situation you describe is also excluded (e.g. ὀρθογώνιος, ἀμβλυγώνιος, ὁμόκεντρος, πολλαπλάσιος, ἰσοσκελής, ἑτερομήκης); cases like ἱπποπέδη where an alternation like the one mentioned by you might in theory be possible are rare, and they are so much terminologized that there is little scope for variation: a mathematical ἱπποπέδη is simply not the same as a 'horse's fetter', and πέδη alone is not a mathematical term either.

Of course you can have enunciations in which the compound is explicitly clarified by another phrase, as in Eucl. *El.* 6 *Dem.* 5: Ἐὰν δύο τρίγωνα τὰς πλευρὰς ἀνάλογον ἔχῃ, <u>ἰσογώνια</u> ἔσται τὰ τρίγωνα καὶ <u>ἴσας ἕξει τὰς γωνίας</u>, ὑφ' ἃς αἱ ὁμόλογοι πλευραὶ ὑποτείνουσιν "If two triangles have their sides proportional, the triangles will be <u>equiangular</u> and <u>will have those angles equal</u> which the corresponding sides subtend". Similarly, Diophantus clarifies his compound κυβόκυβος "sixth power" as follows (*Arithm.* 1, *praef.* p. 4, 26 Tannery): ὁ δὲ ἐκ κύβου ἑαυτὸν πολυπλασιάσαντος 'κυβόκυβος' "the result of the cube multiplied by its own is the 'sixth power'".

But I think that in mathematics the closest parallel to the phenomenon of 'compression' that you are interested in is the alternation of 'full' phrases with specific terms indicating geometrical objects vs. brachylogic phrases where only denotative letters, articles, and prepositions are present, without the 'head noun'. For example, Euclid starts *El.* 1 *Dem.* 1 with the full phrase: Ἔστω ἡ δοθεῖσα εὐθεῖα πεπερασμένη ἡ AB "Let a given finite straight line, AB, be given", but then refers to the same "finite straight line" only with ἡ AB (ἴση ἐστὶν ἡ AΓ τῇ AB). The linguistic process is of course different but the idea of 'compression' behind it is similar.

A. Vatri: What are the earliest examples of denotative letters? Do we need to surmise that texts that contained them were accompanied by diagrams (e.g., Aristotle's *De memoria et reminiscentia*)?

F. Schironi: The general consensus is that when there are denotative letters in a text, the latter was also accompanied by diagrams. So, in the case of Aristotle, we assume that there were diagrams in his texts, even if they are not preserved in the manuscripts. In Aristotle we also find the first secure attestation of denotative letters; however, we must distinguish two cases. Sometimes he uses denotative letters in a real mathematical/ geometric context (e.g., *An. pr.* 41b15-22; *Cael.* 287b7-14; *Mete.* 363a34-364a4) – in this case we can assume that a diagram accompanied the text (or the oral lecture). However, Aristotle also uses denotative letters in logical treatises when he simply wants to indicate an undetermined entity or a quality (e.g., *An. pr.* 39a14-41a20 *passim*; *An. post.* 79a33-81a34 *passim*). In this case, obviously, the letters did not refer to a diagram. As for *De memoria et reminiscentia*, which you mention, I tend to consider the first case (452a17-26) a non-mathematical use (so no diagram accompanied the text), but the second one (452b15-22) a more geometric use, since Aristotle speaks of 'proportional' segments and of construction. These distinctions are of course partly subjective; for example, Einarson ("On Certain Mathematical Terms in Aristotle's Logic", *AJPh* 57 [1936] 33-54 and 151-172, at 156-159) understood cases like *An. post.* 84b3-14 as more 'geometrically' oriented than is usually assumed.

Before Aristotle, the only possible case of denotative letters being used in connection with diagrams is the fragment of Hippocrates of Chios reported by Simplicius (*In Phys.* 1, 2, pp. 60, 22-69, 49 Diels). But this is difficult to assess because Simplicius is quoting from Eudemus, and so we do not know whether the letters were original or added later by Eudemus, who was a pupil of Aristotle. I would however lean toward their originality because otherwise it would be impossible to follow the demonstration, which seems to be reported as Hippocrates of Chios wrote it.

L. Prauscello: I have a broader question about the intended readership of technical literature, in particular mathematical texts. To what kind of readers did they reach out or gesture? Often mathematical texts have extended and quite sophisticated prefaces (see, e.g., the example of Eratosthenes you quote) to powerful addressees (kings etc.): rhetorically, there seems to be a double bind technique, so to speak: the mathematical authors somehow present their texts on the assumption that the contents will be understood, but at the same time they proudly proclaim the autonomy/difficulty of their disciplines.

F. Schironi: Yes, I agree. There is a tension in many mathematical texts between the prefaces, which are very personal and often present the text as 'easy' to non-specialists (e.g., Archimedes to Gelon in the *Sand-Reckoner*, Eratosthenes in his epigram to Ptolemy III on the doubling of the cube, or the proem of Hipparchus' *Commentary* to Aratus), and the treatise itself, which is highly technical and written in a very impersonal style, typical of mathematical prose. I think this might be part of the 'game' I hinted at: it is a way to impress the reader, who (as in the case of Ptolemy and Gelon) is or might also be the patron. A different case is when the preface is addressed to another mathematician, as with the many prefaces of Archimedes to Eratosthenes or Dositheus, or of Apollonius to Eudemus. In this case, the personal touch and the claim that the addressees will be able to follow are justified, because the text circulated among connoisseurs.

F. Dell'Oro: Par rapport aux termes techniques que tu appelles 'métaphoriques' et qui renvoient à l'aspect de l'objet à décrire, je me demande si on ne pourrait pas parler de 'mécanisme iconique', vu que, comme tu l'as justement dit, la métaphore dans ces cas ne renvoie pas à la fonction (d'une partie du corps, comme, par exemple, les omoplates appelées πλάται "rames"), mais seulement à leur aspect extérieur. Même dans le cas des maladies (κάρκινος "crabe" et "cancer") la signification ne se fonde sur rien d'autre que sur une image.

F. Schironi: Yes, in the cases you mention the metaphor is iconic because it insists on similarity of aspect. However, when we have metaphors or figurative terms that focus on the function of the organ/bone (e.g., πυλωρός, πόρος) it is not the 'aspect' which is the focus but the 'function' that the body part has – so the question is really to decide what we mean by 'iconic' metaphors: are they only those metaphors which focus on the external similarities (i.e., the aspect) or do they include metaphors which 'visualize' other elements like, for example, the function of organs or bones?

A. Cassio: Your decision not to take a diachronical approach to the vocabulary used by the Greeks for each scientific field is understandable, given the enormous amount of materials and problems involved. Yet, as far as medicine is concerned, one should not forget that one of the main aims of the impressive bulk of Hippocratic lexicography was to elucidate an incredible amount of vocabulary that had been rendered obsolete by the passage of time. All I want to do now is to draw attention to some of the remarkable complications posed by the old and respected Hippocratic terminology, since the physicians of Hellenistic and Roman times had to struggle with many words found in the *Corpus* whose meaning was far from obvious. This is clear from, e.g., various entries in Erotianus' *Vocum Hippocraticarum collectio* and numerous passages in Galen. To give only two or three examples, in the Hippocratic writings some perfectly obvious words could be used with a special meaning, very different from the usual one, like e.g. κάτοπτρον "mirror" for "probe" (Erotianus p. 56, 5 Nachmanson κάτοπτρον· ἡ μηλωτίς). At times the same medicinal/poisonous plant was called by different names in different dialects and areas, as with "hemlock" being called κραμβίον in Sicily (Erot. p. 55, 2 Nachm. κραμβίον· Σικελοὶ τὸ κώνειον οὕτω καλοῦσι) and κάμμορον or κάμαρον in Magna Graecia (Erot. p. 51, 16-18 Nachm. Ζήνων ὁ Ἡροφίλειος κάμμορον ἢ κάμαρόν φησι καλεῖν τὸ κώνειον τοὺς ἐν Ἰταλίᾳ Δωριέας). These local terms had found their way into the old medical writings, and after centuries it was necessary to explain what they meant. Problems were occasionally also posed not by medical terminology but by non-technical words that had become obsolete, like the adjective θαμινός "frequent" (Erot. p. 44, 10 Nachm. θαμινά· πυκνά). Interestingly enough, some obsolete Ionic terms could be familiar to physicians from the Homeric text (e.g., δέρτρον "peritoneum", Hom. *Od.* 11, 579, Hippoc. *Epid.* 5, 1, 26), but often things were not as simple as that: Galen felt obliged to explain that μελεδών in Hippocrates meant "attention, concern", while it meant "anxiety, distress" in Homer (*Dictionum exolet. Hippocr. explicatio* 19, 121 Kühn: μελεδὼν ἡ ἐπιμέλεια, οὐχ ὡς παρ' Ὁμήρῳ ἡ λύπη).

Hundreds of special cases show that in Imperial times the Hippocratic corpus was still authoritative, but far from easy to understand correctly, not so much because the terms were technical, but because both technical and non-technical ones had fallen into disuse.

F. Schironi: Thank you, Albio, for this addition. You are of course correct in claiming that with Hippocrates it is not only a question of technical lexicography but also one of old-fashioned terms which are no longer understood in later times, exactly as happens with the Homeric *glossai*. This is definitely the case with non-technical words like μελεδών or θαμινός, but also with κάτοπτρον, since Galen, for example, uses μηλωτίς, which is the gloss used by Erotianus for κάτοπτρον, or with the dialectal varaints of κώνειον. Not having adopted a diachronic approach to the question in this article, I did not look at this aspect, but of course this is something I will work on for my broader project on scientific language.

However, now that you bring up the question of Hippocratic lexicography, I also wonder whether its development might not also be due to the fact that, unlike with Euclid, in the Hippocratic corpus there are very few definitions, or they are scattered in the corpus, so that the need was felt to collect all these odd names and give them definitions.

L. Huitink: Although I agree with your thesis that 'technical' mathematical language is less transparent than that of other realms of knowledge, such as medicine, I wonder just how 'transparent' the latter really is. Take your example περόνη. I absolutely agree that the origin of this term, which is used for a small bone in the leg, is to be found in the (vague) physical resemblance between a thin bone and a "pin". However, how much does that help me when I am not a schooled student of medicine? For, within medicine, περόνη is the term for a specific bone, which allows me to distinguish it from, for example, the κερκίς and other bones. In other words, within the semantic field of "bones", περόνη fulfills a highly specific function. Would you agree that this is in fact what makes περόνη a properly *technical* term, the origin of which in a very different semantic field is no longer that important?

F. Schironi: I see your point and agree that when the term was used by doctors and among doctors it clearly became technical and most likely lost any 'metaphorical' underpinning. However, my point was mostly about how such a lexicon would have been perceived by 'outsiders'. To them, ignorant of skeletal anatomy, περόνη may have sounded 'more familiar' (because it was a common name of a rather common object) than to a modern layperson *fibula* does, which is simply a bone – and the name itself does not remind the layperson of anything else, unless this person knows some Latin. Of course, this is speculative because we cannot interview any Greek speaker of the Classical or Hellenistic periods, but the number of 'common' words reused to name anatomical parts and organs is so overwhelming that in my view we can indeed conclude that this lexicon sounded less esoteric and more visually 'suggestive' to Greek laypeople than the modern medical lexicon sounds to us. This of course does not mean that a layperson would have known what the bone called περόνη looked like 'in reality' – yet the word was more suggestive to him/her than *fibula* is to us.

A. Willi: Perhaps one could construct an additional argument in favour of the overall transparency of at least medical terminology from the fact that in the scene with the fake doctor in Menander's *Aspis* the figure is not characterised by the use of 'complicated' words, as might be the case in a modern comedy with a 'doctor' in it, but by the use of a particular dialect (Doric) – so the implication seems to be that in order to be taken seriously as a doctor, it would help to adopt the language of the medical schools in Cos or Cnidus, whereas the knowledge of a specialist lexicon is less of a determining factor.

F. Schironi: Yes, this is definitely a very good point. He is a fake because he does not speak Ionic but rather Doric. Interestingly, Italian *commedia dell'arte* too characterizes a 'doctor' in dialectal terms: Dottor Balanzone speaks Bolognese dialect because Bologna was a renowned university, the most ancient one in Italy (and in the whole of Europe). So here Dottor Balanzone is not a fake doctor but rather the caricature of a doctor, with the right dialectal accent.

I wonder, however, whether this is a specific choice of Menander and not necessarily the only way to 'make fun' of doctors. I think that one could also make fun of technical language by using lexicon, just as happens in Aristophanes' *Clouds* with music and meter at ll. 638-654; I have no problem in thinking that a similar accumulation of (transparent) medical terms would have achieved a similar comic effect. Similarly, a dialogue based entirely on a distorted theory of humors, the four elements, and concoctions would also have been comical if crafted in a comic/exaggerated vein, as happens in *Clouds* with geometry/geography at ll. 202-217, with Chaerephon's research on mosquitoes at ll. 156-164, or with linguistics at ll. 658-693; in all of these passages there is little technical lexicon, but the comic pseudo-scientific target is quite evident. In other words, I think that these are two different strategies of making fun of a doctor, either using the dialect or using an excessive accumulation of technical terms, because both a specific dialect and a specific lexicon (though one more transparent to laypeople than the modern medical lexicon) were typical characteristics of medical language. In fact, in the *Aspis* too, we have a limited use of technical lexicon connected with the doctor's art (τᾶς ἐμᾶς τέχνας at l. 461): τὰν χολάν/τᾶς χολᾶς at ll. 439 and 451 and φ]ρενῖτιν at l. 446.

S.D. Olson: In contemporary English, technical terms are routinely based on Greek or Latin. You argue throughout that the Greeks had instead a far more 'visual' system for generating such terms. My own sense is that you implicitly take this way of operating to be superior to our own, because more transparent. The way they formed new words is in any case very different from how we proceed, and it has different social effects. But I wonder whether it might not be useful to borrow the idea Luuk has raised in his contribution of verbal technology, i.e., the notion that language is not merely a fixed set of capabilities (although it is that) but also a process that human beings experiment with and sometimes improve upon. What we would see with the Greeks, then, are some initial efforts to work out how to generate new words in an environment of rapid cultural and technical change, hobbled in their sense by the lack of shadow prestige languages – or perhaps an unwillingness to use what was available in older 'barbarian' tongues. If so, we might be able to characterize them as not just working in parallel with us but as our cultural ancestors in this regard.

F. Schironi: Yes, I agree. I am not claiming that a 'visual' technical lexicon is *per se* better than our scientific lexicon, in which technical words are marked out as technical because they are mostly based on Greek and Latin roots. In fact, I do not think that a visual or 'easier' lexicon is better when it comes to technical language. One of the risks of such a lexicon is the lack of precision, which indeed we know Greek technical terminology faced. I also agree with you that the lexical situation I describe is indeed a process, in which the Greeks needed to 'name' a great deal of new discoveries in several fields, and to do that they did not have any other 'authoritative' language to use to differentiate the new technical lexicon from standard Greek, as is the case with modern technical lexicons in many disciplines. So what I have briefly described here is the beginning of technical terminology (at least in the Western tradition), and we can see it as a continuum from the Greeks to us. In this process we witness a move from a monolingual, rather 'transparent' lexicon to a mostly Latin- or Greek-based lexicon, which clearly distinguishes itself from standard language.

A. Vatri: A point on your example from Aratus: the Latin versions of this text (Cicero, Germanicus, and Avienus) do not translate the name of the constellation but just borrow it from Greek (*Deltoton*); an explanation of the origin of this name is added by Cicero (who mentions the name of the letter) and Germanicus (who refers to the Nile delta – a different metaphorical use of the letter name). Can the reception of didactic poetry by Roman intellectuals educated in Greek tell us something about what would and what would not be perceived as a technical term?

F. Schironi: I think it would help in understanding how it was perceived. But I would not be surprised if in many cases the 'technical' term was borrowed and transliterated as in the case of *Deltoton*. However, there are also cases of names of constellations that are translated into Latin, for example Δίδυμοι, which becomes *Gemini* (Cic. *Arat.* fr. XXII; German. *Arat.* 148, 163, etc.), or Ἄρκτοι and Ἅμαξαι, which Germanicus translates as *siue Arctoe seu Romani cognominis Vrsae / Plaustraque* (*Arat.* 25-26), where *Arctoe* is a transliteration of Ἄρκτοι, *Plaustra* is the translation of Ἅμαξαι, and *Vrsae* is the pure Roman name. Often the choice between a transliteration, a translation, or the Roman name is also connected with an etymological reference, which the Latin author wants to maintain (e.g., German. *Arat.* 329-332, with *Sirium*) or to add (in the case of new

Roman names or literal translations from the Greek into Latin; e.g., Cic. *Arat.* 121 with *leuipes Lepus* instead of Λαγωός). These different tactics in appropriating a technical name seem to suggest that the choice often depended on purely poetical needs or stylistic choices more than on the need or desire to create a technical lexicon that was partly Greek-based and partly Latin-based. This is even more true since these texts were aimed at readers who were mostly bilingual and so would not have had any problem in enjoying the sophisticated etymological play with Greek transliterations, Latin calques, or translations.

F. Dell'Oro: Quel est le rôle des emprunts d'autres langues dans la constitution du lexique des langues techniques que tu nous as présentée?

F. Schironi: The mathematical sciences do not show any imprint from other languages. Medicine too seems to be mainly Greek-based. The one field that shows borrowings from other languages is botany, where we have Semitic-derived words such as, for example, the following ones, all used by Theophrastus: λίβανος, σμύρνα, κασία, κινάμωμον (*Hist. pl.* 9, 4, 2, etc.), and κύμινον (*Hist. pl.* 1, 11, 2). In this case, however, we are not dealing with the adoption of Semitic words by a scientist; rather the scientist uses common words, some of which happen to be borrowed from another language (for example, κασίη, κινάμωμον, and σμύρνη occur in Hdt. 3, 107, 1; 3, 110; and 3, 111; μύρρα and κασία in Sappho fr. 44, 30; σμύρνη in Eur. *Ion* 89 and 1175; λίβανος in Sappho fr. 44, 30, Hdt. 4, 75, 3, Eur. *Bacch.* 144; and κύμινον is attested even in the Linear B tablets as *ku-mi-no/na*). In other words, when Greek technical language goes for new coinages, these are always based on Greek words and roots, except in the case of common words, some of which might be loan-words from other languages, especially Semitic ones.