Chapter 2
The *Mohist Canon* and Alternative Origins of Theoretical Science

Abstract Proceeding from the theoretical considerations presented in Chap. 1, the chapter provides an overall interpretation of the scientific sections of the *Mohist Canon*, which are presented in Chap. 3. We start with a discussion of the theoretical character of the text as it ensues from textual structures. We then discuss the ways the text reflects on different domains of pre-scientific knowledge pertaining to concepts such as spatial and corporeal extension, duration, motion, measurement, model, image and weight, thereby including what has sometimes been referred to as Mohist geometry, mechanics and optics. We compare these reflections to other historical instances of theoretical thinking, mostly from ancient Greek science and philosophy. We conclude the chapter with considerations, following from our textual analysis and intercultural comparisons, on the place of Mohist science in a long-term, global history of knowledge and what it tells us about structural necessities and historical contingencies in the rise of theoretical science.

In the Introduction we have argued that the selected parts of the *Mohist Canon* presented in this book document a particular type of theoretical thinking, that they represent rationalizations of aspects of the perceived world, natural and technical, that bespeak an origin of theoretical science that can be seen as an alternative to and independent of the widely recognized Greek case. In this interpretative chapter we will substantiate this claim by a comprehensive analysis of Mohist science based on the translations and discussions of the sections of the *Mohist Canon* that we set out in Chap. 3 and on the structure of the text overall. In particular, we will make use of comparisons between the Chinese and the Greek case in order to address the question of cross-cultural commonalities and historical and cultural contingencies in the origin of theoretical science. The *Mohist Canon* can be understood as reflecting this kind of theoretical thinking in two complementary ways, through the hierarchically structured nature of the text itself and through the knowledge evident in the sequences of individual sections as they are presented in this work. Our analysis of these two features of the *Mohist Canon* taken together suggests an origin of theoretical science different from and entirely independent of what we know from the classical West.

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2.1 Structure and Theoretical Character of the Scientific Sections in the *Mohist Canon*

The most obvious structural feature of the *Mohist Canon*, as we have sketched in the Introduction, is the division into Canons proper and matching Explanations. The Canons either provide a definition or state a proposition. Sections A1 to A 75 comprise the definitions; sections A 88 to B 82 comprise the propositions. All definitions start with a *definiendum* of one or two characters in length, followed by a short *definiens,* sometimes as short as a single character, and end with the particle *yě* 也. Sections A 76 to A 87 constitute a kind of "lexical appendix" to the definitions, exemplifying not just the different meanings of words with more than one usage, but also drawing attention to the semantic scope of words that play a central role in the whole Later Mohist enterprise (see Graham 1978, 323–336). They may thus be counted to belong to the group of definitions, but because their content is chiefly lexical, not scientific, we have not included the sections in the main part of our study, but dealt with them separately in the Lexical Appendix (Chap. 4).

The prominent role of definitions in the text is a clear indication of its theoretical character. The attempt to delineate meaning is an act of reflection on the meaning of the terms. Even though modern deductive systems such as Hilbert's axiomatic formulation of Euclidean geometry completely dispense with explicit definitions, still we may argue that definitions are the most crucial ingredient in the emergence of deductive thinking seen in ancient texts (Lefèvre 1979, 301). While at first sight the presence of proofs may seem more crucial to the emergence of deductivity than that of definitions, to be part of a deductive system, proofs have to be closed, *i.e.*, they have to be anchored in statements that are also part of the deductive system and that are not themselves amenable to proof. This closure is thus achieved by definitions, and, when present, axioms or postulates.[1]

The Explanations, which match the Canons, are a structural element of the text that further underlines its theoretical character. One function of the Explanations is to introduce conceptual distinctions beyond those stated in the Canons. For example, in B 25a the Canon says simply "Bearing but not being deformed." The Explanation expands on this and explains the different behavior of beams and ropes under a weight (*zhòng* 重) by introducing the concept of *jí* 極 'rigidity', thus refining the conceptual tools to describe the varying effects of a weight (極勝重也 "the rigidity prevails over the weight"). There are particularly interesting cases where the new concept is expressed as the negative mode of a term already defined and becomes an independent technical term. For example, Canon A 44 始 says: "*shǐ* 'beginning' pertains to time." The explanation recapitulates the association of 'time' with 'duration' seen already in A 40 久 and introduces further the distinction between 'duration' and 'lacking duration' 無久. Up to now the term 'lacking duration' has not been introduced in the text. Here it is used as a concept in its own right,

[1] The importance of anchoring scientific proof in non-demonstrable premises is emphasized in Aristotle's *Posterior Analytics*, 72b; Aristotle 1989, 37–41.

not merely as the absence of duration. The last line of the explanation, “The ‘beginning’ corresponds to [the case of] not having duration,” (始當無久) shows this clearly. The importance of the concept ‘lacking duration’ is further highlighted by its use in A 50 止 discussing motion and rest in relation to ‘duration’ and ‘lacking duration’, and its use in B 15 as the concept that when paired with ‘spatial extent’ is of the ‘hard-and-white’ type (無久與宇堅白 “The relation between ‘being without duration’ and ‘spatial extent’ is of the hard-and-white type”). A parallel case occurs in the definition of ‘having a limit’ A 42 窮 where the Explanation introduces the term ‘lacking a limit’ 無窮, which is then further used as a concept in B 61, where it refers to the temporal limitlessness of the fact of something having happened (有之而不可去 “having had it, then it cannot be disposed of”), and in B 73 which argues that the elements of unbounded sets can be exhausted (無窮不害兼 “being without limits is not detrimental to being a composite whole”).

Very often the Explanation provides an elaboration on the statement of the Canon. For instance, the Canon of A 46 損 defines *sŭn* ‘lessening’ as “partially removing.” The Explanation then elaborates on what ‘partially’ means by stating that “to be ‘partial’ is to be an element (*tǐ* 體) of a composite whole (*jiān* 兼),” thereby making the section a part of a systematic concern with sets. It further identifies what remains, after having had some elements removed, as the ‘lessened’ object. It therefore makes clear that the partialness in question pertains as much to what remains as to what is removed. The Canon A 51 必 defines *bì* ‘being inevitable’ straightforwardly as “being unstoppable.” The Explanation introduces logical inevitability with the example of the pair ‘elder brother/younger brother’, thus showing a further understanding, to wit, the existence of an elder brother logically means there is a younger brother (*more sinico*). Secondly, it sets out the complementary pair of either ‘being this’ or ‘not being this’ as a case of the inevitability that arises from the law of the excluded middle. Later in the text, *bì* 必 is further used in relation to empirical inevitability. In B 25b, for example, it says that if you add a weight to one side of a beam, that side will inevitably drop down (必垂).

For propositions the Explanation often expands on the cross-reference term (the X of the *shuō zài* 說在 X summing up phrase of the Canon). Thus, the Canon of B 64 reads: “Traveling a long distance takes a long time. The explanation lies with ‘earlier and later’”(行脩以久, 說在先後). The Explanation then explicitly expands on the meaning of ‘earlier and later’ by stating that the pair of terms has to do with temporal duration, and that “when people travel a long distance they inevitably take a long time” (民行脩, 必以久也).

In the sections on optics and mechanics (B 17–29) the Explanation often provides an exposition of the physical arrangement and behavior involved, but typically fails to describe in detail the apparatus that accounts for these things. The Canon of B 19, for example, states somewhat vaguely that a shadow will turn upside down at some point in conjunction with which it elongates. The Explanation lays out a specific arrangement referring to light emanating “like arrows shot from a bow” (入煦若射) and casting shadows above or below, depending on where it enters. It then identifies the point at which the shadow turns upside down, but does not include any information on the physical set-up that produces this effect, leaving the description overall somewhat wanting.

Graham (1989, 138) speculates that the Canons were learned by heart while the Explanations "were probably jotted down from teachers' oral explanations" of the Canons. While this must remain a speculation, it is undeniable that the division into Canons and Explanations shows a systematicity that clearly underlines the theoretical character of the text. Because the Explanations elaborate, differentiate and substantiate the statements in the Canons, they deepen and widen the conceptual network and scope of Mohist science, which in many cases would remain obscure if we had to rely on the Canons alone. The language of the Explanations remains as succinct and as formal as that of the Canons proper. There are no extant texts known from the Warring States period with language that can readily be recognized as "jottings," that is, as informal notes casually appended to a text. It is difficult to see how the Explanations could have arisen in their present form simply as teachers' notes "jotted down" to serve a passing didactic or disputational purpose. If Graham is right about their origin, then what we have in the text is likely to be a very much revised form of those jottings. And to the extent that revision implies reconsideration and re-thinking, the Explanations would represent a kind of concise analytical commentary.

The definitions provide a basis for consistent use of words in reasoning. The defined terms often but not necessarily figure in the propositions. The Mohists seem to have thought of establishing definitions as a virtue in itself. The fact that about half of all sections are definitions indicates that they are not merely preparatory with respect to the propositions, but constitute a contribution to the later Mohist dialectical endeavor in their own right. If the whole text is understood as providing a basis for consistent reasoning, the definitions form an important part of this. That they are also of use in the propositions formulated in the text is a consequence of and evidence for their overall import.

The propositional sections chosen here for translation display some of the terms defined in the first half of the canons, namely *gù* 故 'basis' (A 1), *tǐ* 體 'element' (A 2), *zhī* 知 'knowing' (A 5), lì 力 'force', *jiǔ* 久 'enduring' (A 40), *yǔ* 宇 'spatial extent' (A 41), *qióng* 窮 'reaching a limit' (A 42), *jìn* 盡 'to be exhaustive' (A 43), *yùn* 運 'rotating' (A 48), *zhǐ* 止 'remaining fixed' (A 50), *bì* 必 'being inevitable' (A 51), *zhōng* 中 'center' (A 54), *zhí* 直 'to be straight' (A 57), *duān* 端 'end-point' (A 61), *yíng* 盈 'filled out' (A 65), *jiān bái* 堅白 'hard-and-white' (A 66) and *fǎ* 法 'model' (A 70). In some cases, the propositions offer further considerations on terms defined in the first half of the text, *e.g.*, in B 13, where the term *yǔ* 宇 'spatial extent', already defined in A 41, is elaborated on by use of the terms *xí* 徙 'shifting about' (宇或徙 "'spatial extent', [allows for] a shifting about somewhere") and *zhǎng* 長 'expand', (說在長 "the explanation lies with 'expanding'"), neither of which has been defined but that recur in a number of other sections. Sometimes the elaboration involves explicitly relating these terms to further defined terms, *e.g.,* in B 14 where *yǔ* 宇 'spatial extent', *jiǔ* 久 'duration' and *jiān bái* 堅白 'hard-and-white' are all used in conjunction with one another: 宇久不堅白 "(The relation between) 'spatial extent' and 'temporal duration' is not of the hard-and-white type."

B 15 immediately following uses the same technical terms in very much the same way in connection with *wú jiǔ* 無久 'being without duration', which is itself established as a technical term in A 44 as we have mentioned above.

Besides these few cases in which the understanding of some defined terms is directly elaborated on, the propositions mainly introduce new topics. In this, they may clarify the relation between terms not previously defined, *e.g.*, B 26, which contrasts *qiè* 挈 'pulling up' and *shōu* 收 'letting down':

C: 挈與收反 …

C: Pulling something up in conjunction with letting something gradually down are the reverse of each other. …

E: … 挈: 長重者下, 短輕者上。上者愈得, 下者愈亡。繩直, 權重相若, 則止矣。收:上者愈喪, 下者愈得。上者權重盡, 則遂。

E: … Pulling something up: The long and heavy is below, the short and light is above. The more the one above gains, the more the one below loses. When the cord hangs straight and the effectiveness and the weight match each other, then it would remain fixed. Letting something down gradually: The more the one above loses, the more the one below gains. If the effectiveness and the weight of the one above are exhausted, it drops.

As the text is handed down to us there is no formal proof of any proposition anchored solely in the definitions, and there probably never was. At the same time there are central technical terms used to explain phenomena described in the propositions that are not found in the definitions. Examples are *quán* 權 'effectiveness' (B 25b and B 26) or *jí* 極 'rigidity' (B 25a). There are also defined terms that are not made use of in the propositions, *e.g.*, *lú* 櫨 'king-post' (A 64). But defined terms are used in propositions, in some places so systematically, that the respective Explanation comes close to formal proof. The Explanation of B 73: 無窮不害兼 "being without limits is not detrimental to being a composite whole," is probably the best example. Both the Canon and the Explanation explicitly include the formal feature of claiming a statement and its negation with no possibility of a third option (*tertium non datur*). At the same time the explanation of B 73 also includes an explicit rebuttal to the ostensible *tertium-non-datur* claim that had been made. The argument is expressed in terms previously defined in the text, *viz.*, *qióng* 窮 'reaching a limit' (A 42), *jìn* 盡 'to be exhaustive' (A 43), *zhī* 智 [*sic*] 'knowing by direct contact' (A 5, 知), *yíng* 盈 'filled out' (A 65), and *bì* 必 'inevitable' (A 51). In particular, the use of the word *bì* 必 'inevitable' is consistent with the definition in A 51, indicating logical necessity. Additionally, the first part of the Explanation presents a claim, using the term *bèi* 誖 'self-contradictory, fallacious', intending to refute a Mohist tenet, a claim that is then successfully rebutted by the Mohist. As we mentioned in the Introduction (fn. 13), the use of the term *bèi* 誖 suggests a philosophical, or logical rigor not often found in other texts from this period.

Among Graham's proposed matchings of sequences of definitions with sequences of propositions (Graham 1978, 30 and 229–30), the set of propositions B 13–16 paired with definitions A 40–51 seems to show the clearest relation between definition and proposition generally. Propositions B 13–16 follow closely the topic of the co-ordinated definitions on spatial and temporal contingency and inevitability seen in A 40–51. B 16 in particular introduces a distinguishing criterion related to time by which a statement is true in one case and false in another, thus fitting the topic of temporal contingency neatly. Although the propositions B 17–29 do not directly build upon the terms defined in A 52–69, Graham, all the same, argues for a match between these two parts of the text. The category under which both of these sets of definitions and propositions are subsumed he calls "explaining objects (the sciences)" (Graham 1978, 30). He labels the definitions A 52–69 "geometry" and the set of propositions B 17–29 "problems in optics [and] mechanics" (Graham 1978, 230).[2] Although these passages all deal with situations in the material world that in many cases come about through the use of instruments, Graham's matching is imperfect and not without some question in that the definitions relate to instruments of measurement and construction (measuring rod, compass, carpenters' square, gnomon), but the propositions deal with optical instruments and arrangements (pin hole, flat, convex and concave mirrors, and possible shadow theaters) or material arrangements with ropes, beams, and stones, involving mechanical devices such as levers and probably pulleys.

In view of the above it is clear that the *Mohist Canon* is not a fully-fledged deductive text. While there clearly are the rudiments of deductive argumentation, unlike in most parts of Euclid's *Elements* or in Archimedes' *On the Equilibrium of Planes*, there is no strict deductive buildup here. This absence should not be allowed to suggest that the text does not in fact have a genuinely solid theoretical structure. The separation of the text into definitions and propositions is only the first of a hierarchical structure of subdivisions that reaches down to the level of pairs of sections. (See the hierarchical tree of topics in the Introduction; Figs. 1.1 and 1.2.) The ordering, grouping and sequencing of sections renders the *Mohist Canon* a very finely structured text, even if this structure is only very partially a deductive one. By way of ordering, grouping and sequencing, definitions and propositions are put in thematic contexts, their similarities and distinctions are highlighted, and novel relations established that otherwise would have likely gone unnoticed. First of all, the overall ordering of the groups of sections appears not to be random. These are what we identified as thematic sequences in the Introduction and according to which we grouped our translations and discussions, beginning with *Epistemological foundations* and ending with *Sets of indeterminate or unknown extent*. That the discussion of spatial extension and duration as general terms precedes that on the corporeal aspects of extension, for instance, is likely to be a deliberate choice, because the former is a reflection of intuitive knowledge, while the latter reflects on the knowledge obtained in the use of certain instruments, a development that builds upon intuitive knowledge. By the same token, the placement of the fundamental epistemological definitions at the very beginning of the entire work seems to be

[2] Graham 1978 includes sections B 30 and B 31 ("economics") in the sciences section of propositions. We have omitted this part of his label.

deliberate, given the obvious overall concern with the basis for knowledge and its relation to rigorous reasoning.

Thematic sequences of sections can be further subdivided. The first five of the optical sections (B 17–21) are on shadows, the last three (B 22–24) on mirror images. ‘Shadows’ and ‘mirror images’ are both designated by the same character 景 (which may have been read [in modern pronunciation] *yǐng* or *jǐng* depending on which meaning was intended; the writing system is ambiguous in this respect), formally grouping all eight optical sections together. Similarly, the first six sections on epistemological foundations can be seen to fall into two subgroups, A 1 故 *gù* ‘basis’ and A 2 體 *tǐ* ‘element’ deal with basic structures in reasoning, and the following four, A 3 知 *zhī* ‘knowing’, A 4 慮 *lǜ* ‘thinking’, A 5 知 *zhī* ‘(acquired-) knowing’, and A 6 𢜔 *zhì* ‘wisdom’, describe types of knowing. Sections A 44–50 all deal with change; sections A 47–50 deal in particular with motion as change of place or position, and with rest as the absence of motion. Subdivisions can be identified down to the level of pairs of contrasting or parallel sections. Temporal and spatial extensions, for example, are defined in precisely parallel language, A 40: 久, 彌異時也 “*jiǔ* ‘enduring’ is spanning different times,” A 41: 宇, 彌異所也 “*yǔ* ‘spatial extent’ is spanning different places.” In the same way it seems not to be a coincidence that A 47 and A 48 occur in sequence, the first defining revolving and the second defining cyclical rotating, A 47: 儇, 稘秪也 “*xuán* ‘circling around’ is coiling and curving,” A 48: 運, 易也 “*yùn* ‘rotating’ is switching from one to another.”[3] Graham points out that the two Canons A 47 and A 48 “make a pair with contrasted definitions” and that “phonologically” 運 *yùn* < ***N-qʷins** ‘rotate’ is related to 圓/員 *yuán* < ***ɢʷren** ‘round’ (Graham 1978, 297, using earlier OC reconstructions). To these two we can add the A 48 word 儇 (旋/還) *xuán* < ***s-gʷen** ‘circling around’. In the everyday language of Warring States period texts 儇/旋/還 *xuán* means ‘revolve, circle, turn or whirl around’ and 運 *yùn* means ‘rotate, spin’, as *e.g.,* of a potter’s wheel (*cf.* 均/鈞 *jūn* < ***qʷin** ‘potter’s wheel’). It seems that the juxtaposition of these two sections here, in view of the explicit sense of ‘switching’ expressed by the definition 運, 易也 in A 48, is intended to bring the difference between these two kinds of circular motion sharply into focus, ‘revolving and curving around’ on the one hand *vs.* ‘rotating about an axis or in a fixed cycle’ on the other.[4]

Often the overall succession of sections proceeds through different aspects or levels of abstraction and varies a certain theme accordingly. Thus, the theme of

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[3] The text of the Canon of A 47 is reconstructed and speculative, see the discussion in the textual notes to A 47.

[4] If the three words 運 *yùn* < ***N-qʷins** ‘rotate’, 圓/員 *yuán* < ***ɢʷren** ‘round’ and 儇/旋/還 *xuán* < ***s-gʷen** ‘circling around’ are in fact related, we then have a “word family” characterized by a phonological archetype {labio-velar or uvular initial, **–in** ~ **–en** rime}. Whether the words are cognates or morphologically derived from an underlying word root is difficult to say, but we can recognize that the word family itself includes many more members, *e.g*., 淵 *yuān* < ***ʔʔʷin** ‘whirlpool’, 渾 *hún* < ***N-qqʷən** ~ 混 *hùn* < ***N-qqʷəns** ‘roiling, swirling’, 圍 *wéi* < ***ɢʷəj** ‘to encircle’, 衛 *wèi* < ***ɢʷəjs** ‘to circumambulate, circle around, revolve’ and 回 *húi* < ***ɢɢʷəj** ‘return’.

change is varied from A 44 through A 51. Change is regarded first with respect to something beginning, emphasizing its punctual character (A 44 始當無久 "The 'beginning' corresponds to [the case of] not having duration"), then with respect to the features of something being transformed (A 45 化徵易也 "'transforming' is when the set of identifying features switches from one to another"), and next with respect to the amount in something being lessened (A 46 損偏去也 "'lessening' is partially removing"). Sections A 47–50 treat change in place or position, as mentioned above. Finally, the sequence turns to the logical realm, discussing inevitability (A 51 必). From this last move it becomes clear that the discussion of change is to be understood as an exploration of what may vary over time and space, while certain inferences are inevitable and therefore apply invariably. Since every section contributes to the immediate context of a sequence, a single section can bring into focus an unexpected connotation for a whole series of sections, as happens with the section on 'inevitability' readjusting the meaning of the whole sequence on space, time, motion and change (A 40–51).

One feature of the ordering of definitions that does play into the deductive aspect of the text is that when defined terms are used in the definition of another term, they are, as a rule, defined *before* such use. Among the sections selected for translation the only violations of this rule, in fact, pertain to defined terms used in the Explanation of a definition, but never in the Canon. Thus, *duān* 端 'end-point', defined in A 61, is used in the Explanations of A 1 故, A 2 體 and A 60 倍 (and by conjecture in that of A 55 厚), but not in their Canons; *dòng* 動 'moving' defined in A 49 and *zhǐ* 止 'remaining fixed' defined in A 50 are used in A 43 盡, but only in the Explanation. Use of a previously defined term in a later definition, by contrast, occurs 25 times in the selected sections, and in 12 of these cases the term is used in the Canon. In some cases we see clear instances of a systematic progression of definitions. Thus, *jìn* 盡 'to be exhaustive', defined in A 43, is used in the definition of *tóng cháng* 同長 'of the same length' (A 53): "'of the same length' means that by being laid straight (next to each other) each exhausts the other" (同長, 以正相盡也). This in turn is used as the definition of *zhōng* 中 'center' (A 54): "'center' implies being of the same length" (中, 同長也), *i.e.*, being of the same length from a common starting point. The pair A 53 and A 54 are then the basis for the definition of *yuán* 圜 'circle' in A 58: "'circle' implies being of the same length from a single center"(圜, 一中同長也).

If we allow ourselves to interpret the first two sections (A 1 故 and A 2 體) as an indication of the Later Mohists' reflection on their own methods, we could say that the first implies establishing a basis by defining certain terms and formulating conditions under which something may come about, and then, on this basis, being able to argue for further definitions and propositions, as is the case generally in deductive reasoning. This is consistent with the idea of a *gù* 'basis' as "what must be the case before something will be achieved" (A 1 故). The second section, by contrast, emphasizes the holistic aspect of knowledge, "*tǐ* 'element' is a part of a composite whole" (A 2 體). Each Canon can be viewed as an element in a larger set, and sets of Canons can be viewed as elements in even larger sets, thus reflecting the hierarchical grouping of sections in the text. These two sections taken in tandem may suggest alternative, but not necessarily mutually exclusive, approaches to structuring knowledge; A 1 reflects a form of argument based on premises and precedents, A2 reflects reasoning on the basis of compositional relations.

All these relations among the sections reveal a complex network of interrelated concepts. This network character of the text turns words taken from everyday language or from the more specific language of particular practices into theoretical terms.[5] While the terms inherit part of their meaning from their original everyday use and practical contexts, the meaning is modified by being detached from concrete action and being relocated within the conceptual structure making up Later Mohist theoretical thought. Theoretical demands such as consistency, comprehensiveness, and the resolution of paradoxes give rise to differentiations and specifications of terms alien to their everyday counterparts. In particular, certain aspects of the original meaning of the terms may be abstracted or made absolute. Thus, while in everyday usage *duān* 端 denotes an extremity or a tip of something, which may be regarded simply as a very small thing, the *duān* 端 'end-point' introduced in the *Mohist Canon* is infinitely small: it is explicitly defined in A 61 as having no dimension, "'end-point' is the element that, having no magnitude, comes foremost" (端, 體之無厚而最前者也). This meaning is clearly a consequence of theoretical understanding of the term, a theoretical "artifact," so to speak. It is often employed with exactly this sense. For instance, in the definition of *cì* 次 'contiguous' (A 69) as "having no interstice but yet not overlapping," it is stated that this is only possible "because the end-point has no magnitude" (端無厚而後可). The meaning of the theoretical terms is thus closely related to the specific forms of knowledge involved: the forms of knowledge reflected upon and the theoretical knowledge generated in this reflection. This is what will be discussed in the following section.

2.2 Theoretical Knowledge in the *Mohist Canon*: Foundations and Elementary Structures

As we discussed in the Introduction, the scientific sections in the *Mohist Canon* represent theoretical reflections on elementary and instrumental forms of knowledge, *i.e.*, knowledge attained through everyday experiences in the natural and technical environment. But the first six sections of the text (A 1–6), which we have included in our selection, present us with reflections of a different kind. They are meta-reflections on the structure and typology of knowledge itself. They thereby constitute a set of "starting points" for the processes of reasoning and argument that underly the subsequent individual passages. Above we have explained how the first two sections, defining a 'basis' (*gù* 故, A 1) and an 'element' (*tǐ* 體, A2), can be understood as describing the two fundamental structural features of the text, the anchoring of arguments in a basis, in previously established statements, and the

[5] See Schemmel 2019.

hierarchical grouping of sections, turning them into elements of thematic sets. But at the same time they describe fundamental structures of human reasoning broadly.

The *gù* 故 'basis' can be understood to refer to any knowledge from which further knowledge can be derived. This may pertain to logical argument, as with inferences drawn on the basis of certain established knowledge. But it may also pertain to the experiential world, where the basis would designate a cause or condition necessary for something to come about. That both meanings are implied is suggested by the usages later in the text of *bì* 必 'inevitable', a term central to the Explanation of A 1. According to that Explanation, a basis can take either of two forms, *viz*., a minor basis, which recognizes an element occurring in an argument without entailing any inevitability of the conclusion, or a major basis, where having a particular element guarantees a certain outcome. The basis as something that must be obtained before a certain thing can come about is thus immediately differentiated with respect to inevitability. The term *bì* 必 'inevitable' may refer to empirical consequences as well as to logical implications, as highlighted in our discussion of section A 51. The causal interpretation of the 'basis' is further corroborated by section A 77 of the lexical appendix, in which *gù* 故 is explicitly listed as a kind of *shǐ* 使 'causing': "being moist is a 'basis'; one inevitably expects the completion of what it brings about" (濕, 故也。必待所為之成也), even if that completion is not inevitable. The 'basis' may therefore be understood as indicating a 'precedent', in the sense of something that must come first, logically or causally.

The second fundamental structure of reasoning introduced at the very beginning of the text is that of identifying an 'element' (*tǐ* 體) as a single component of a multicomponent structure. The important point is that an element is not simply a single item in isolation, but is understood fundamentally as an item in some relation with other items, a part in a composite whole. The basic insight that individual things can be put together to obtain composite things, or can be decomposed into building blocks appears to be a very elementary knowledge structure. Yet, the examples given in the Explanation of A 2 point to a more technical understanding, presupposing arithmetics and some type of geometry. The first example, "one of two" (二之一) may simply refer to the fact that either one of two things that make a pair can be considered an element. But it may also refer to the unit, which is contained in the number 'two', and thereby point to the composite character of the natural numbers as aggregates of the unit, as they are defined in definition 2 of book VII of Euclid's *Elements*:

> A number is a multitude composed of units. (Euclid 1956, Vol. 2, 277)

The other example is that of the end-points on a measuring rod (尺之端). Having end-points has just been used in A 1 as an example for an element being a 'minor basis', probably because having end-points is a necessary precondition for something to be a measuring rod, but that alone does not necessarily imply being a measuring rod. The use of the end-point as an example in A 1 as well as A 2 shows that the basis-consequence structure of A 1 and the element-whole structure of A 2 are not mutually exclusive, but complementary aspects of relations. The use of the end-point as an example, which is a theoretical entity as we have argued above, makes clear that the term ‘element’ not only refers to components that may be taken apart in the real world, but also to the elements resulting from intellectual analysis, thus underlining the theoretical character of the concept. We will come back to the particular type of geometrical and set-related knowledge documented in the *Mohist Canon* later. Here we want only to point out that the way these examples, which in some respects can be seen as mathematical, are used in the Explanations of the first two sections shows that this knowledge serves the Mohist as a tool for his wider analysis of reasoning and language and as a model for rational discourse in general.

In our translation we inevitably have recourse to theoretical terms that come with their own semantic history. While the term ‘element’ in its mathematical connotations appears strikingly appropriate to translate *tǐ* 體, another connotation of that term, closely related to the first one in ancient Greek philosophy, namely that of an immutable building block of the natural world, something everything is made of, such as atoms or the ‘four elements’ of Empedocles and Aristotle, appears to be absent from the Mohist concept. This is a first indication of a deep-lying difference between Mohist and ancient Greek science to which we shall come back.[6]

The four sections A 3 through A 6 identify four specific kinds of ‘knowing’ and ‘thinking’, one building on another: innate knowledge; thinking (on the basis of one’s previous knowledge); experiential knowledge (acquired on the basis of one’s previous knowledge); and a kind of knowledge that comes about from the first three coupled with discussion and reflection. The sequence of sections shows that the Mohists were not only concerned with reflections on certain concrete parts of knowledge, but with a meta-reflection on knowledge itself. Within this four-part buildup of the semantic field of ‘knowing’ and ‘thinking’, the *Mohist Canon* generally seems to represent the discursive, reflective type of knowledge described in A 6, based on the innate and experiential knowledge described in A 3 and A 5. The passages thus document a reflective awareness of the epistemic function of the text, a function that we describe as theoretical. The fact that the entire *Mohist Canon* opens with the considerations set out in these six sections suggests that the purpose was an effort at a systematic reflection on what can be known about how to use language, about how to act and about behaviors in the natural and technical world.

It may be tempting to further identify the *Mohist Canon*’s description of innate and experiential knowledge with our categories of elementary and instrumental knowledge, respectively, explained in the Introduction. But it is important to note that both elementary and instrumental knowledge draw from experience, even though large parts of elementary knowledge are built up early in ontogenesis, and there is usually no awareness of their experiential origins. While for instrumental knowledge the experiential origin is often obvious, because it is only acquired when handling certain cultural artifacts, only modern developmental psychology is able to investigate the role of experience in the construction of our elementary structures of knowledge. For this reason it may be that in some instances what we here describe

[6] On the relation between the mathematical and philosophical use of ‘elements’, see Damerow and Lefèvre 1981, 127–132.

as elementary knowledge is what the Mohists would have conceived of as innate knowledge; see A 3 知 材也 "*zhī* 'knowing' is an innate capacity".

This applies in particular to the concepts of time and space. Fundamental structures of our temporal and spatial cognition, such as extendedness or the existence of motion, clearly form part of our elementary knowledge structures. The human ability to form sequences of actions and events in one's mind, the ability to comprehend motion, and the ability to coordinate sequences and motions with each other are all developed in the process of growing up. More complex aspects of the concepts of time and space, in particular concepts of duration and of simultaneity, are constructed from these basic abilities. Elementary knowledge structures are closely linked to action and perception and usually remain unconscious. Yet, they may become externally represented in language or other human means of expression. To begin with, the everyday terms are confined to the concrete contexts of action from which they originate. But under specific societal circumstances they may become the starting point for systematic reflections.[7]

We see this documented in the *Mohist Canon*, A 40, where *jiǔ* 久 'duration' is defined as "spanning different times" (彌異時也), thereby rendering explicit the extendedness implied by the everyday term *jiǔ* 久 'lasting a long time'. By using the verb *mí* 彌 'to span, spread (over, out, through)' to correlate different times, the extendedness of duration is indicated unambiguously. The term *shí* 時 'time' itself can have either punctual or extended meaning. In the following section A 41, this concept of duration is immediately complemented by that of *yǔ* 宇 'spatial extent'. The extendedness of space is made explicit by defining *yǔ* 宇 as "spanning different places" (彌異所也), again using the verb *mí* 彌, perfectly parallel to the temporal case.

The definitions of duration and of spatial extent thus not only document a reflection on the extendedness of time and space, but also show the Mohists' awareness of a close relation between spatial and temporal concepts. The use in both cases of the verb *mí* 彌 clearly indicates that the Mohist conceives of space and time as comparable entities in that both are extended.[8] What is the origin of seeing a parallelism between duration and spatial extent? In fact, a certain parallelism between spatial and temporal concepts appears to be a universal aspect of elementary knowledge.[9] Thus, spatial metaphors used for temporal designations in everyday language are a

[7] Pioneering empirical and theoretical work on the ontogenetic development of these fundamental structures of cognition has prominently been pursued by Jean Piaget and his collaborators, see for instance Piaget 1959, and more specifically Piaget 1969 on the concept of time and Piaget and Inhelder 1956 on the concept of space. The role of external representations in processes of reflection on these knowledge structures and the significance of these processes for a historical understanding of knowledge development has been worked out and discussed by Peter Damerow, see for instance Damerow 1996. This historical-epistemological approach as applied to the concept of space is further developed and discussed, with more references to the literature, in Schemmel 2016.

[8] The use of the verb *zài* 在 'to be located' in a temporal context later in B 14 and B 16 further underlines this parallelism.

[9] See the literature cited in Boltz and Schemmel 2016.

cross-linguistic phenomenon.[10] Extension, which functions as the unifying aspect of space and time in the Mohist sections under consideration, is probably the most basic structural similarity between space and time (Galton 2011). While on the level of elementary knowledge, such unifying aspects remain implicit, enabling, among other things, spatial metaphors for temporal ideas, it is a typical aspect of theoretical knowledge that such structural parallelisms become explicitly addressed on the level of technical terminology. The universal character of the underlying cognitive structure explains why we can find parallel cases of its expression in theoretical texts from other historical societies. Such a parallel case can be found in Aristotelian discussions of space and time. In his *Categories* (4b, 24–25; Aristotle 1983, 36), for instance, Aristotle describes time and place, which we may take to mean space in the respect under discussion, as quantities related by the fact that they are both continuous, an attribute that presupposes extension.

In A 40 and A 41, the Mohists address the parallelism between time and space by explicit juxtaposition of similarly constructed definitions. In later sections they further establish explicit argumentative connections between the defined terms for duration and spatial extent, in particular connections relating to motion. Thus, the Canon of B 13 establishes a relation between motion and space, "'Spatial extent' allows for a shifting about somewhere" (宇或徙), and the Explanation describes expansion as a kind of motion that implies the further occupation of space, "expanding is shifting about and thus occupying further spatial extent" (長徙而又處宇). The phrase *huǒ xǐ* 或徙 'shifting about somewhere' used in that context, is exactly the one by which *dòng* 動 'moving' has been defined in A 49. In B 14 the discussion of the relation between spatial extent and duration is then elevated to a more abstract level, when it is stated that this relation is not of the hard-and-white type (宇久不堅白). We understand *jiān bái* 堅白 'hard-and-white', defined in A 66, as a technical term for the separate recognition of independent, but mutually pervasive properties. While in earlier sections it is applied to attributes of extended bodies (see the discussion below), it is here applied to the fundamental concepts of temporal duration and spatial extent themselves. To answer the question why this relation is not of the hard-and-white type, the Mohists first assert in B 14 that spatial extent, referred to by the phrase 'south and north', exists in connection with the period of the dawn, and again separately in relation to the period of dusk (南北在旦又 在暮). They are thus not mutually pervasive. Furthermore, spatial extent is defined as that which allows for a shifting about (explained in B 13), and because shifting about entails temporal duration (explained in B 14), spatial extent has a dependent relation to temporal duration. This dependent relation is also implied in the statement in B 64 that traveling a longer distance takes a longer time (行脩以久). So 'spatial extent' and 'temporal duration' are not independent attributes, but are inherently linked. Thus they are not of the 'hard-and-white' type.

[10] See, for instance, the recent discussion in Evans 2013. For evidence that the parallelism between space and time is not only a linguistic, but a cognitive, phenomenon, see, for instance, Boroditsky 2000 and Casasanto and Boroditsky 2008.

There is a pair of spatial and temporal concepts that are, by contrast, of the 'hard-and-white' type. As stated in section B 15, the relation between 'lacking duration', *i.e.*, a point in time, and 'spatial extent' is of that type. The Explanation states that the hard-and-white relation presumes that each attribute fills out the other, *i.e.*, is co-incident with the other. This implies that a single point in time is conceived of as filling out the whole of space, and in this respect the basic condition of being mutually pervasive is met. Yet neither of the two is contingent on the other; there is no dependent relation between spatial extent and a moment in time. This proposition in effect implies an abstract notion of simultaneity; a point in time exists throughout all of space.

While the particular form of the argument is specific to its cultural context, exemplified by the central role of the analytic tool 'hard and white', the argument has structural features in common with the spatio-temporal reasoning documented in the Western tradition. The idea that spatial and temporal magnitudes are related by motion, for instance, is also found in ancient Greek philosophy. For example we may refer to Aristotle's discussion of the speed of local motion, in which the time of a motion is related to the space traversed (*Physics* 232a, 23–232b, 15; Aristotle 1995, 103–115; see further *Physics* IV, 11; Aristotle 1993, 379–395). At the same time, there are obvious differences to the two approaches; Aristotle is concerned with defining velocity, while any explicit concept of velocity is absent in the *Mohist Canon*.

There is evidence that the connection of temporal and spatial measures via motion precedes theoretical thinking. In fact, according to Piaget's study of a child's development of the concept of time, the distinction between temporal and spatial order in regard to motion is only gradually achieved in the course of ontogenesis (Piaget 1969, Chapter 3). The same holds for the idea of universal simultaneity. The concept of simultaneity, for instance when comparing two independent motions or actions, is only gradually built up in ontogenesis.[11] And it is only in theoretical contexts that there is an incentive and possible need to spell out the notion that simultaneity pertains to all of space. Another such theoretical context in which universal simultaneity emerges, besides the one at hand, is classical mechanics, for which Isaac Newton postulated a kind of universal time.[12]

Despite the parallelism between space and time, there is an asymmetry in their relation as described by the Mohist. The Mohist claims the relation between spatial extent and lack of duration to be of the 'hard and white' type, but he does not claim the same for the relation between duration and lack of spatial extent. Thus, while one instant in time fills out all spatial extent, the inverse seems not to be the case, *i.e.*, there is no claim of a spatial point filling out all of time. There is in fact no term *wú yǔ* 無宇 which would mean 'lacking spatial extent', as we will discuss below. The asymmetry may be a reflection of the elementary knowledge structure that

[11] See Piaget 1969, in particular chapter 4.

[12] See, for instance, Newton's discussion of space and time in his Scholium to Definition 8 of his *Principia*; Newton 1999, 408–415.

within spatial extent, motion as well as rest is conceivable, but in time, by contrast, there is nothing comparable to rest. This attribute of time, which is not an attribute of space, has been described as ‘transience’ (Galton 2011).

A 40 and A 41 define *jiǔ* 久 ‘duration’ and *yǔ* 宇 ‘spatial extent’ in terms of *shí* 時 ‘time’ and *suǒ* 所 ‘place’, not in terms of events and extended bodies. Such abstraction of time and space from what they may contain in any particular circumstance is a further consequence of theoretical reflection. In practical contexts there is usually no need and no incentive to introduce a separation between times and spaces from the things that fill them. But how then is the relation between spatial and temporal extension on one hand and corporeal and processual extension on the other conceived of in the *Mohist Canon*?

2.3 Theoretical Knowledge in the *Mohist Canon*: Corporeal Extension

Sections A 52–69 are key to understanding the match between spatial and corporeal extension. This sequence documents a reflection on instrumental knowledge, *viz.*, on knowledge acquired in the use of ruler, compass, gnomon and other basic tools for measurement and construction. It seems that it is the context of measurement then, in which corporeality becomes crucial for the Mohists. This is in stark contrast to ancient Greek geometry. Euclid’s *Elements* clearly stem from the reflection on the figures that can be constructed with compass and ruler. At the same time, it is precisely the abstraction from the corporeality of physical objects, and even of real drawings, that characterizes the knowledge of Euclidean geometry. So while with respect to the reflection on instrumental knowledge, the Mohist sequence is comparable to ancient Greek geometry, as Graham points out, the argumentative context, *i.e.*, the relation between the material and the spatial aspects of extension, is a very different one.

The first nine sections (A 52–60) of the Mohist sequence all relate to measurements or constructions, although the instruments that must have been employed—measuring rod, leveling device, gnomon, sighting device, compass, and carpenter’s square—are only in some cases mentioned. A 57, for instance, defines *zhí* 直 ‘being straight’ as *cān* 參 ‘being in alignment’. The underlying idea appears to be derived from the practice of sighting. While two points define a straight line, in the simplest sense ‘alignment’ is understood as having a third point in a line with the other two. ‘Alignment’, in other words, allows for an opposite, *viz.*, unaligned. Using the line of sight to define straightness is also found in Greek antiquity (see the discussion of Def. 4, *Elements* Book I, Euclid 1956, Vol. 1, 165–6). The Mohist defines the circle in A 58 with the phrase “being of the same length from a single center” (一中同長). The ‘same length’ and the ‘center’ having been defined earlier (A 53 and A 54, respectively), this definition is, despite its brevity, strikingly reminiscent of the parallel definition of a circle in Euclid’s *Elements*, as

> a plane figure contained by one line such that all the straight lines falling upon it from one point [later called the center] among those lying within the figure are equal to one another[.] (Euclid 1956, Vol. 1, 153)

The similarity between these two definitions of a circle, which were certainly arrived at independently, may be explained by the similarity of the underlying practical knowledge. In both societies, Warring States China and Classical Greece, the compass, to which the Explanation of A 58 makes explicit reference, was a well- known instrument. The definitions translate the material working of a compass—fixing a center and keeping the distance to it constant—into the respective formalized languages.

The theoretical concept of a dimensionless point can also be found in both the Euclidean and the Mohist traditions. Compare the Mohist definition of ‘end-point’ in A 61 as “the element that, having no magnitude, comes foremost” (體之無厚而最前者) with the Euclidean definition of a point as “that which has no part” (*Elements* I, Def. 1; Euclid 1956, Vol. 1, 153). Both definitions emphasize the elementary character of a point and either state or imply its lack of magnitude. In the *Elements* this definition applies to any point on a line; the Mohists appear to have no notion of a point apart from an end-point. The latter fact is not surprising given the intuitive recognition that any line segment has end-points by virtue of having tips, *i.e.*, ends. But the notion of a point within a line segment is a much less intuitively obvious concept and gives rise to all sorts of theoretical problems, in particular how a collection of dimensionless entities can bring about an object with measurable dimension. The same concern is seen in ancient Greek discussions of whether or not only end-points of a line can be considered points. Aristotle in his *Metaphysics* describes Plato’s position as rejecting the existence of points on lines within geometrical figures, calling them “a geometrical fiction.” He seems to have accepted “the beginning of a line” as a point (Aristotle *Metaphysics* 992 a, 25; Aristotle 1933, 75). The Explanation of B 60 in the *Mohist Canon* explicitly states: “With respect to what is in front, the mid-point does not constitute a half-way point, rather it is like a (new) starting point” (前則中無為半, 猶端也). This clearly shows that the Mohists recognize that what was a mid-point of an original measure becomes an end-point when the original measure is divided at that point. In the Mohist case the notion of an end-point has a crucial function in comprehending different arrangements of measuring rods (A 67–79), the origin of the abstract concept of an end-point in the practice of measurement is clear-cut. Yet, as argued at the end of the previous section, the theoretical concept is only formed when a term such as *duān* 端, designating a ‘tip’ or an ‘extremity’ in everyday language, becomes part of a network of technical terms, as happens in the Mohist text. The end-point’s lack of magnitude is conceived of as absolute, which shows that the concept does not reflect an elementary experience or a concrete perception, but is instead a reflection on the linguistic representation of instrumental actions.

Notwithstanding these similarities between Mohist and Euclidean geometrical definitions, there is no counterpart found in the Mohist text to the propositions of the Euclidean *Elements*. The *Mohist Canon* documents theoretical reflections on the linguistic representations of instrumental knowledge, but not on constructions of complex figures that can be drawn with straightedge and compass or other diagrammatic representations of instrumental knowledge. In contradistinction to Euclidean geometry, the Mohist geometric definitions relate to the corporeal aspect of extension. A 60 explains linear 'doubling' (*bèi* 倍) as putting two measuring rods end to end in a straight line (尺與尺俱去一端 "a measuring rod together with another measuring rod both extending [linearly] away from a single end-point"). Although the term 尺 *chī* 'measuring rod' taken by itself can be understood to mean something non-corporeal, a 'measure' or a 'measured length', *i.e.*, a 'line', the immediate context implies that the idea of extension is always thought of as corporeal. Along the measuring rod you always get a co-occurrence of spatial magnitude and material filling out (A 65, 於尺無所往而不得二 "on the measuring rod there is no place to which it extends such that you do not get both [filling out and magnitude]"). It therefore appears to be no coincidence, if you think of an end-point to be the end-point of some physical object such as a measuring rod, that the end-point's lack of dimension is expressed as *wú hòu* 無厚 'lacking magnitude'. Spatial magnitude is an inherent feature of physical objects and cannot occur without a material filling out, as we see from A 65, which states that "[w]here there is no filling out there is no magnitude" (無盈無厚). The pair of concepts, *hòu* 厚 'having magnitude' and *yíng* 盈 'filling out' consistently differentiate the material and the spatial aspects of bodies. These are the terms defined in sections A 55 and A 65. While the distinction between spatial and material aspects of bodies emerges in elementary knowledge, the systematic differentiation of the two and the reflection on their relation to each other is clearly an aspect of theoretical thinking.

Sections A 62 and A 63 differentiate *yǒu jiān* 有間 'having an interstice' and *jiān* 間 'interstice' by giving complementary descriptions in the respective sections. "Having an interstice" is described in the Canon (A 62) as "not reaching to the center" (不及中也); in the Explanation it is said that this "refers to what flanks it" (謂夾之者也). Conversely, the 'interstice' itself is described in the Canon (A 63) as "not reaching to the sides" (不及旁也), and in the Explanation it is said that this "refers to what is flanked" (謂所夾者也). This Explanation clearly demands that the flanking things that frame the interstice be material. This excludes the end-point itself of a measuring rod as part of an interstice's flanking framework (尺前於區穴而後於端, 不夾於端與區穴 "measurements starting from an outline and ending at an end-point should not be considered as flanked by the end-point and the outline"). Section A 64 on the *lú* 櫨 'king-post' then relates the 'interstice' to the concept of emptiness, stating that the interstice being empty refers to the absence of the material of the flanking framework. A 62 and A 63 taken together seem to allow for the possibility that the interstice may be filled with a material other than that of the flanking objects, but A 64, by virtue of using the word *xū* 虛 'empty', seems to exclude that possibility.

The Mohist statement (A 65) that being filled out is a necessary precondition to having magnitude is reminiscent of Western theories of space and matter that claim that extension is a property of bodies alone, not of an alleged space independent of bodies. In a certain way, all theories that hold that space is nothing but an aspect of body maintain this view. Aristotle, for instance, discusses the idea of the void as a place from which all bodies have been removed and concludes that a void cannot exist, thereby refuting ideas about space formulated by the atomists Leucippus and Democritus (Aristotle *Physics* IV, 8; Aristotle 1993, 343–361). A particularly radical version of this view is found in Descartes' claim that body and space are only two aspects of the same thing and that the walls of a vessel would be contiguous if the vessel were empty in the philosophical sense, since between its walls there would be nothing (Descartes, *Principles of Philosophy*, Part 2, § 18; Descartes 1983, 47–48).

But is the Mohist statement actually referring to such a world view, denying extension where there is no bodily filling? The every-day meaning of the term here translated as *hòu* 厚 'magnitude' and defined in A 55, is 'to be thick'. It suggests that 'magnitude' is really about material objects, not about whether or not a concept of extension abstracted from bodies in general has any meaning. In other words, it appears that the Mohist text is actually concerned with the clarification of the use of words, but does not make any claim about the existence or non-existence of space as an entity independent of bodies. If this interpretation is correct, A 65 merely states that the word 'magnitude' applies only where there is body ('filling out'). This interpretation is corroborated by the fact that a term potentially referring to spatial extension unrelated to bodies filling space is given elsewhere in the text, *viz.*, in the sections on temporal and spatial concepts, specifically section A 41, *yǔ* 宇 'spatial extent'. After all, this 'spatial extent' is defined as spanning different places, not spanning over bodies. It therefore appears amenable to a concept of space abstracted from all bodies, although such an abstraction is nowhere made explicit in the text.

It seems that there was no need for the Mohist to position himself in an argument about whether the world was a plenum or whether a perfect void existed. Canon A 65 on 'being filled out' seems not so much to introduce a universal material plenum, than to clarify that the term 'magnitude' designates a spatial extension always accompanied by some material 'filling out'. We know nothing of debates in Warring States China about physical world views involving the question of the existence of a vacuum. The *Mohist Canon* shares with Aristotle's *Physics* a concern with the consistent use of terminology, and both texts particularly deal with spatial terms in this framework. Accordingly, in both texts we can discern elementary structures of spatial knowledge, such as that differentiating the materiality of a body from its extension. In Aristotle there is the additional doctrinal concern with natural philosophy. Aristotle explicitly argues against not only what he considers errors of reasoning, but also world views that he holds to be untenable, such as the atomism of Leucippus and Democritus. In the Mohist case there are no such world views either advocated or rejected. To be sure, B 43 (not included in our translation) mentions the Five Agents *wǔ xíng* 五行 and seems explicitly to reject the prominent Han period thesis entailing a cyclical domination of one agent over the other, "the Five Agents are not possessed of a regular dominance [one over the next]" (五行毋常勝). Yet, not only does this brief mention not allow for a claim that the Mohists recognized a Five-Agent world view of the kind that later became popular in the

Han, there is in fact no clear indication that such a world view had arisen at this time (Henderson 2010, 182).

The discursive content of the *Mohist Canon* does not reflect intellectual traditions dealing with systems of natural philosophy, but rather a concern with rules for consistent reasoning in general. This shows up not only in the sections on knowledge, reasoning, and conduct and government, but also in those on spatio-temporal, mechanical, and optical matters. In the case of spatio-temporal terminology this relation becomes particularly clear from the central role of *jiān bái* 堅白 'hard and white', used as a technical term in Warring States disputations. This establishes a connection between the logical and spatial aspects of reasoning by conveying both spatial coincidence and logical compatibility of attributes. Its definition in A 66, "neither excluding the other" (不相外), in particular, reflects the tight entanglement of logical and spatial arguments when the term *wài* 外 'excluding' is used in a spatial and a logical sense at the same time. Attributes are said to be of the 'hard and white' type when they fill out each other and are compatible, *i.e.*, while being independent, they spatially coincide and do not logically exclude each other. In the Aristotelian tradition attributes pertain to bodies, or substances, and these bodies or substances then occupy a certain place.[13] Logical and spatial exclusion are discussed separately. No substance can have mutually exclusive attributes, and no two substances can be in one and the same place at the same time.[14] In the Mohist text the argument appears to be that contradictory or incompatible attributes cannot be in the same place. Section A 66 thus reflects the elementary knowledge structure of the schema of an object, *i.e.*, no two objects can be in the same place at the same time, but it does so not by referring to some notion of an impenetrable body, but by the observation that contradictory attributes cannot co-exist unless in different places: "When attributes are at odds with each other, this means they exclude each other" (相非是相外也).

Beyond the central use of *jiān bái* 堅白 'hard and white' as a technical term, the *Mohist Canon* often shows multiple connections between spatio-temporal and logical concepts and arguments. Spatial examples may figure in the explanation of logical or set-related canons, as in A 2 體 where the end-points on a measuring rod are taken to illustrate the relation between individual elements and the composite whole. In the sequence of sections on spatial and temporal contingency and inevitability (A 40–51) there is a constant going back and forth between the spatio-temporal and logical realms. It is probably no co-incidence that the consecutive sections A 42 窮 and A 43 盡 both describe instances of exhausting, first in the spatial sense of reaching a limit, and then in a logical sense of any kind of depletion. The Explanation of A 43, *jìn* 盡 'to be exhaustive', involves spatio-temporal concepts, stating that things are either in motion or at rest (俱止動), a *tertium non datur* situation. This kind of situation falls within the scope of 'being inevitable' (A 51 必). Introducing

[13] Thus, according to Aristotle's *Categories*, for instance, quality and place are two different ways of predicating that which exists; see Rapp 2001, 82.

[14] This becomes clear from Aristotle *Physics* IV, for instance at 209a, 7–8 (Aristotle 1993, 282).

the concept of inevitability at the end of this sequence highlights the role of contingency in the foregoing sections. Inevitability and contingency underpin the fundamental questions of what is necessarily implied and what may change or vary, what inference or judgment is inevitable, and what is dependent on the circumstances and may apply in one case and not in another. But this is never explicitly expressed in these definitions. The definitions appear rather to anticipate the illustrations of these things in subsequent propositions.

The match between temporal and processual extension is already expressed in the Canon of A 50 by a definition of *zhǐ* 止 'remaining fixed' as *yǐ jiǔ* 以久 "thereby enduring," which shows that for the Mohist *zhǐ* 止 has an inherently durative sense. The Explanation of A 50 elaborates that, while rest necessarily entails duration, its opposite, *bù zhǐ* 不止 'not remaining fixed', *i.e.*, motion, may come with or without duration. The first is exemplified by a person crossing a bridge, the second by the idealized punctual image of an arrow passing a pillar. So, while resting is compatible only with duration, motion is compatible with both, duration and lacking duration.

While the concept of an instant or a "now" has a clear enough sense in elementary thinking, in the realm of theoretical reflection it may become problematic when related to the concepts of motion and rest. In Zeno's famous paradox of the flying arrow (!), the problematic relation between the theoretical idea of an instant and the question of rest or motion is exploited when it is argued that an arrow cannot move during an instant, and therefore cannot move at all. Aristotle tries to resolve this paradox by arguing that, in the "now", there is neither motion nor rest (*Physics* 239b, 1–2; Aristotle 1995, 175). In the Mohist case, the discussion of the instant, *wú jiǔ* 無久 'lacking duration', implies that it is compatible with *bù zhǐ* 不止 'not remaining fixed', which, for the Mohist, is equivalent to being in motion. It is incompatible with *zhǐ* 止 'remaining fixed', since, for the Mohist being fixed demands duration. While Aristotle responds to the problem by denying instantaneous motion and rest, the Mohist responds otherwise. This shows that, while the elementary knowledge underlying the problem appears to be the same cross-culturally, the theoretical solution is not determined by this knowledge base and may diverge between different theoretical traditions. As we know today, the paradox of motion in an instant was consistently resolved only much later in history with help of the calculus, which introduced the concept of infinitesimal magnitudes.

The problem arises from the theoretical concept of a point in time, which in the Mohist text is expressed by *wú jiǔ* 無久 'lacking duration'. This, in some respect, is the temporal counter-part to *duān* 端 'end-point'. But the parallel is not complete. In A 61 *duān* 端 'end-point' is defined as having no corporeal magnitude (*wú hòu* 無厚), but there is no matching term expressing the lack of purely spatial extent, which presumably would have been *wú yǔ* 無宇. A further asymmetry between the temporal and spatial concepts pertains to the position of the infinitely small in relation to the overall situation under consideration. The end-point is defined only at the limits of a measure, but a point in time is described such that it can be considered as any instant during a motion. The more restricted case is the word *shǐ* 始 'beginning', which is the temporal match to *duān* 端 'end-point', only if 'end-point' is understood as ‘starting point’, as is explicitly said in its definition in A 61. In contrast to what is the case for ‘end-point’, which is defined in corporeal terms, the definition of ‘beginning’ in A 44 refers to time alone, *i.e.*, duration and non-duration, rather than to some kind of processual extension, *i.e.*, what fills time out and would be comparable to corporeal extension in its relation to space. Not surprisingly, the term ‘beginning’ is introduced in the sequence on spatio-temporal concepts (A 40–51) reflecting on elementary knowledge, while the term ‘end-point’, which pertains to measurement, is introduced in the corporeal sequence (A 52–69), which for its part reflects on instrumental knowledge.

B 14 states spatial extent and duration are not of the hard-and-white type. One of its arguments for this claim is that moving about in space entails duration. B 15 states that spatial extent and lacking duration are of the hard-and-white type. Given that according to A 50 motion can occur in an instant, this would seem to contradict the argument of B 15. This apparent contradiction could be resolved by saying that motion in an instant is thought of as traversing no space within that instant, so that there is no dependent relation between an instant and spatial extent. All the same, the argument highlights the delicate nature of the theoretical discussion of instantaneous motion.

In B 16 it is pointed out that the validity and applicability of a statement depends on its appropriate placement in time. The section does not explicitly use the terms ‘time’ or ‘duration’ but refers instead to *jīn* 今 ‘present’ and *gǔ* 古 ‘past’ and seems to give a slightly different perspective on the Mohists’ notion of time generally. In couching a statement in terms of past and present, time is now understood a providing a historical context that may be either appropriate or inappropriate in connection with a given event. The event specified in B 16, Yao being good at keeping order, is said to be appropriate in regard to the past but incompatible with reference to the present. And in B 53 Yao serving as a paragon is said to be viable in the present, while having been factually located in the past. Both of these observations are regarded by the Mohists as examples of differentiating times, in B 16 implicitly and in B 53 explicitly with the phrase *yì shí* 異時. This phrase in turn connects this perspective on time with the more abstract notion of *jiǔ* 久 ‘duration’, which was defined in A 40 as “spanning different times” (彌異時). In fact, the Explanation of A 40 matches *jīn* 今 ‘present’ and *gǔ* 古 ‘past’ with the concrete observable temporal events of ‘dawn’ and ‘dusk’. B 61 points out an asymmetry of the passage of time, stemming from its directedness. Things that occurred in the past may have ended, their duration thus being limited. But the fact, or experience, of having occurred cannot be undone, and in this respect their duration is limitless.

Reviewing the Mohist sections on corporeal extension and its relation to spatio-temporal concepts, we see that they are of limited mathematical character. While there are sections strikingly reminiscent of Euclidean definitions, their context is not a deductive theory of the properties of geometrical figures, but rather appears to be aimed at providing a solid foundation for judgments about the physical (and social) world. There is another fundamental line of argument in the *Mohist Canon* that on the face of it fits well with the Mohist worldly concerns, but at the same time can be related to intellectual constructs that are today perceived of as mathematical. This is what we have referred to as the Mohists' systematic concern with sets. They become most obvious when the second section of the *Mohist Canon* (A2) is seen to be devoted to the definition of a *tǐ* 體 'element' as "a part of a composite whole" (分於兼), thus introducing the relation of element and set as one of two fundamental structures of reasoning about the world. The other presented in A1 is that of logical inferences and causal relations. A concern about sets that we would describe as mathematical is particularly addressed in sections B 73–74, which are all about the applicability of the concept *jiān* 兼 'composite whole, set' in the case of lacking knowledge. B 73 in particular states that the concept of a set can be applied even when the number of elements is unlimited. The argument employs the concept of *jìn* 盡 'exhausting' and uses the logical inference that if the limitlessness of a collection is conceived of as that collection filling out (and thereby exhausting) a limitless space, then asking about the limitless already implies its exhaustibility, *i.e.*, the applicability of the set concept to the collection. The topic of the example in the Explanation of B 73 (and, for that matter, those of B 74 and 75) is the possibility of *jiān ài* 兼愛 'comprehensively caring fondly for', a fact that may be taken as an indicator of some continuity between the specifics of the *Mohist Canon* and earlier Mohist social and political doctrines. At the same time, the focus of these sections in the *Mohist Canon* lies on consistent reasoning, whereby they document a concern with a kind of thinking that would in modern terms be described as dealing with set-theoretical structures.

2.4 Theoretical Knowledge in the *Mohist Canon*: Images and Weight

In the propositions, just as in the definitions, we see elementary and instrumental knowledge becoming the object of reflection, leading to the development of theoretical terms and abstract concepts. While in the definitions this came about as a result of discriminating, classifying and interconnecting the meanings of words, in the propositions such terms and concepts typically arise in the context of explaining unexpected behaviors encountered in everyday circumstances. The sequence of sections B 17–24 does this for shadows and mirror images. Optical technology such as flat, concave and convex mirrors, pinhole constructions, and probably also some kind of shadow theater, revealed behaviors inconsistent with the kind of common assumptions that inevitably arise from elementary experiences. This sequence of sections of the *Mohist Canon* appear to be an attempt to account for these disparities between observations and expectations.

Section B 17 says that "a shadow does not shift about," *i.e.*, does not move (景不徙). Elementary experience clearly suggests that shadows move, and at the same time that movement is typically attributed to physical bodies. Taken together these two things would imply that a shadow is a physical body, and that would in turn presuppose such features as three-dimensionality, tangibility, and requiring a mover.

The Mohists recognized that a shadow does not fit these criteria and therefore cannot naturally be regarded as a physical body. This then for the Mohists calls for an explanation. The Explanation says "When light reaches a place, the shadow disappears" (光至景亡); this is tantamount to saying that light causes the shadow to vanish, "as if its existence has been exhausted and its past extinguished" (若在盡古息), thereby denying the shadow any shred of bodily reality. Its apparent motion is only the result of shiftings of light source or occluding object, and the shadow being "re-cast" (改為) in every instant.

The complementary terms *guāng* 光 'light' and *yíng* 景 'shadow' reflect a dichotomy between light and shadow that arises from elementary experience. B 18 describes an arrangement of light sources in which an area illuminated by one light is at the same time in the shadow resulting from the occlusion of two other lights. This arrangement cannot be explained by the simple dichotomy of light and shadow. It requires the recognition of multiple shadows in the presence of multiple light sources and multiple occluding objects (which in the section at hand are the light sources themselves). In elementary experience, a shadow has the same orientation as the object casting it, but in pinhole projections, the shadow is inverted, violating this expectation. This is described in section B 19. The inverted shadow is explained as resulting from light proceeding along a straight path and crossing at the pinhole. The shadow cast by the foot of the object ends up as the top of the image, and that cast by the head as its bottom. This explanation entails a geometrical argument by assuming light to propagate along straight lines and to cross at a specified point. Both B 20 and B 21 explain further behaviors of shadows that go against elementary expectations, in one case relating to the direction into which a shadow is cast, in the other relating to its shape and size.

In the sections on mirrors (B 22–24) the phenomena to be explained mostly relate to the size and orientation of the images. All sections make use of a systematic distinction between (i) the thing mirrored (鑒者), (ii) the image itself (景), and (iii) what it is mirrored on, *i.e.*, the area on the surface of the mirror that the image occupies (所鑒). This distinction, which is only implicit in B 22, allows the Mohist to explain that an image may become smaller in mirror area (寡區) yet represent a larger part of the mirrored object: "it becomes more, but seems as if fewer," (多而若少). It further allows for the observation of a strict symmetry of mirrored object and image in position and motion towards and away from each other, as centered on the plane of the mirror (Sect. B 22). In B 23 this systematic distinction is used to explain the size and orientation of images in concave mirrors, depending on the position of the mirrored object. Two further concepts are needed for the Mohists' explanation of this variation: The concept of a 'center point' (*zhōng* 中), and the concept that the light skirting the mirrored object proceeds along straight lines (長其直). The center point is either conceived as the origin of the straight light rays that skirt the object and proceed to the mirror (object between center point and mirror) or as the point in which the light rays that skirted the object converge before they proceed to the mirror (center point between object and mirror). From this geometrical arrangement, the Mohist can deduce the size of the area on the surface of the mirror that the image occupies, which he appears to take as a measure for the size of the image itself. While this construction is wrong from the perspective of geometrical optics, if we identify the Mohist 'center point' with the focal point, it describes qualitatively correctly the size and orientation of an image in a concave mirror in regard to its dependence on the position of the mirrored object relative to this point. Section B 24 treats the case of a convex mirror, stating the correct qualitative relation between the distance of the mirrored object from the mirror and the size of the area on the surface of the mirror that the image occupies and thus the size of the image, but no explanation for this relation is offered.

Taken together, the sections on shadows and mirror images show the emergence of a theoretical understanding of optical phenomena. Sections B 19 and B 23 are of particular interest in this regard, because they explicitly assume that light travels along straight lines, and further they introduce points (*wǔ* 午 'crossing-point', *duān* 端 'end-point', *zhōng* 中 'center-point') to describe geometrical constructions on the basis of which the phenomena at hand are explained. We are thus presented here with a geometrical treatment of optical phenomena that is independent from the origins of geometrical optics in ancient Greece. The sections on mirror images, in particular, can be compared to the Euclidean *Catoptrics*, which mainly discusses reflection in flat, concave and convex mirrors.[15] As was the case for the Mohist definitions of geometrical entities when compared to Euclid's *Elements*, the Mohist sections here on mirror images do not constitute a deductively structured presentation or cover as broad a variety of arrangements as their Greek counterpart. But they do display striking similarities with the Euclidean text as concerns certain central results. Definition IV of the Euclidean *Catoptrics* may be understood as stating that the image of an object in a flat mirror is not seen on the surface of the mirror, but at a certain depth beyond the plane of the mirror (Euclid 1959, 99, see in particular fn. 2), an observation made by the Mohists in section B 22. And the inversion or non-inversion of the image in a concave mirror treated in B 23 is dealt with in Proposition XII of the *Catoptrics* (Euclid 1959, 107–8). Nevertheless, there are marked differences in the Mohist and the Euclidean explanations. Instead of the light rays described in the *Mohist Canon*, the Greek tradition of optics and catoptrics refers to visual rays, *i.e.*, rays that are thought to emanate from the eyes and reach to the perceived objects. The object's position at which its image in the concave mirror flips from upright to upside down, which in the Mohist case was referred to as the 'center point', in the Greek case is the crossing point of the visual rays that, emanating from the eyes, are reflected in the mirror and then skirt the object.

In modern optics there are no visual rays but only light rays. While there are considerations of light proceeding along straight lines in the Greek tradition, for instance in the Pseudo-Aristotelian *Problems* (Problem 15, 911b 5 ff.: Aristotle 2011, 463) or when sun rays are considered in Proposition XVIII of the Euclidean *Optics* (Euclid 1959, 13), the geometrical treatment of optics and catoptrics was mostly done in terms of visual rays. Only much later was the geometrical treatment

[15] Euclid's authorship of the *Catoptrics* has long been disputed. Even if Euclid produced a book on the topic in the third century B.C.E., the received text is generally thought to contain later material; see Smith 2015, 55, fn. 89.

of optical phenomena generally combined with the idea of light rays. In this respect the Mohist text might appear to be "ahead" of its Greek counterparts. It must be pointed out that, while visual rays can reach the perceived object at any place facing the mirror, the Mohist considerations are limited to the light rays skirting the object. Such treatment appears fully legitimate in the case of a shadow, but in the case of a mirror image as in B 23 it would appear to constitute a problematic limitation, because it only explains the silhouette of the image. It is worth noting that a "Mohist mirror," i.e., a Warring States period mirror generally, is a polished bronze surface, and that bronze mirrors have much less reflective quality than later silver or glass mirrors. This might mean that for the Mohist shadows, silhouettes and reflected light are not as sharply distinguished one from the other as we would assume on the basis of modern mirrors.

The sequence on shadows and mirror images is followed by a sequence that similarly examines unexpected behavior, this time dealing with the vertical tendency of weights. The overall argument of this sequence (B 25a–29) proceeds as follows. The general idea that weights descend vertically and in accordance to their magnitude has to be modified in view of different possible arrangements provided by various devices and practical situations and by the materials involved. The different behavior of weights is accounted for in the text by qualifying the term *zhòng* 重 'weight' with further terms such as *jí* 極 'rigidity' (B 25a), *quán* 權 'effectiveness' (B25b, 26), and *zhù* 柱 'pillar-quality' (B 29). In this context, the concept of 'weight' is itself to be understood theoretically, the term being not only applied to heavy objects but also to the abstract quality that causes their downwards tendency, as can be seen in statements such as "This is due to the rigidity not prevailing over the weight" (極不勝重也, B 25a), where the 'weight' must clearly refer to the weight of the rope itself, since no other weights have been applied.

The elementary experience that heavy bodies fall vertically downwards or, if hindered in their fall, press on their support, and that an effort is needed to lift them up, makes the vertical structure of space an elementary knowledge structure that has every indication of being independent of particular cultural circumstances. In section B 27 this general behavior of heavy objects is explicitly described:

> 凡重, 上弗挈, 下弗收, 旁弗劫, 則下直。扡, 或害之也。
>
> Weights, in principle, when you are not pulling them from above, and not letting them down gradually, and not exerting any force on them from the side, then they will come straight down. If they shift sideways, it is because something has interfered with them.

The last sentence indicates the topic of all these sections; this is deviation from the expected behavior of heavy objects. Either they deviate, as indicated here, by departing from the vertical direction (apparently the case for B 27 and B 28). They may also deviate from expected behavior by showing different effects according to further circumstances, *i.e.*, a deviation from another elementary knowledge structure, *viz.*, the assumption that equal causes have equal effects (B 25a and b, 26, 29).

The effect of weights placed on length-wise objects depends on the *jí* 極 'rigidity' of the material the objects are made of (B 25a). That of weights on the two sides of a beam depends on the *quán* 權 'effectiveness (of the weight)', which increases with the length of the side measured from the fulcrum of the beam (B 25b). Similarly, the behavior of a curtain hung over a pulley or pole depends on the length of the cloth hanging on either side, which determines the side's 'weight' and 'effectiveness' (B 26). But the vertical descent of weights may be modified by devices and arrangements not only with regard to magnitude, but also with regard to direction. In some devices a deliberate interference with direct descent produces a desired result (B 27). In dragging or pushing as well, a deviation from the vertical is essential, just like a ladder leaning against a wall needs to be inclined and cannot be perfectly vertical (B 28). In construction, the fact that weights descend vertically is taken advantage of to create stability. Objects such as stones in a wall are fixed by being piled up, so their being fixed may be attributed to the *zhù* 柱 'pillar-quality' of the arrangement. This fixedness is not equally obtained by means of suspension from a string, which may be drawn out, thus demonstrating the close connection between 'pillar-quality' and vertical descent (B 29). The sequence of sections is thus generally concerned with the vertical order of the world as defined by gravity. This distinction of the vertical from all other directions is also expressed in B 62. There a ball is described as something vertical that cannot be put crosswise. This statement implies that the vertical direction is taken as a default. The basis for that is undoubtedly the behavior of weights.

The unexpected behaviors thus become explicable and the apparent paradoxes resolved at the level of theoretical knowledge where the practical modifications and differentiations of the elementary knowledge structures are systematically reflected. The sequence B25a–29 just discussed also shows a recognition of underlying common structures in apparently different practical operations and an effort to establish a technical terminology to account for this, amounting in effect to a theoretical program.

This program is reminiscent of that documented in the Aristotelian *Mechanical Problems*, the earliest theoretical text on mechanics that has come down to us in the Western tradition.[16] In the text, 35 problems are formulated, which in most cases open with the phrase "Why is it that …?" They address consequences of the use of devices that may appear counter-intuitive or paradoxical or at least demand an explanation. The paradoxes are then resolved and the phenomena explained by identifying a lever-like arrangement. The functioning of the lever is in turn traced through reference to a balance back to the circle. This entails an identification of the fulcrum with the circle's center point and a balance arm as its radius. The program of the *Mechanical Problems* is intended to resolve the apparent contradiction between the functioning of mechanical devices and Aristotelian natural philosophy. By ultimately tracing the functioning of mechanical devices back to the circle, which is a central element of Aristotelian natural philosophy, the task is achieved.

[16] The authorship of the *Mechanical Questions* is disputed, which is why it is often referred to as Pseudo-Aristotle. For an interpretation of the *Mechanical Problems* along these lines, see Renn and McLaughlin 2018. For the parallel with the mechanics sections in the *Mohist Canon*, see Renn and Schemmel 2006.

The *Mechanical Problems* thus documents a constellation of types of knowledge very similar to that of the mechanics sections in the *Mohist Canon*. As is the case for the Mohist text, fundamental structures of elementary knowledge, such as equal effects from equal causes, are challenged by practical experience with instruments and devices. These challenges are then addressed by careful reflection on language and the development and consistent use of technical terminology. The similarity becomes particularly striking in the case of the Mohist section involving weights on a beam, B 25b, because the experience reflected in this section relates to the lever principle that is central in the *Mechanical Problems*. The statement that

> The farther the mover of the load is away from the fulcrum the more it always moves the load[17]

in the *Mechanical Problems* and the statement in B 25b that when

> the base is short and the tip is long [and you] add equal weights to both sides, then the tip will inevitably go down.

in the *Mohist Canon* both describe behaviors that from the viewpoint of classical physics we would associate with the law of the lever, and their similarity is without doubt related to this fact. There are several different kinds of instruments and concrete experiences, ranging from simple levers for lifting loads via carrying beams and shoulder poles to quantitative instruments like balances, all one way or another reflecting the law of the lever, that could underlie this similarity. In the case of the *Mechanical Problems* the invention of a type of balance with unequal arms is known to have preceded the composition of the text. Such a type of balance is described as an artifact whose functioning is to be explained in Problem 20 of the text itself. While the Mohist section B 25b has been repeatedly interpreted as involving weighing instruments, this understanding is mistaken.[18]

The device in question is a beam where weights can be added to both ends. Its fulcrum can be moved so that the beam becomes balanced by virtue of its own weight. If this were a weighing apparatus, the fact that weights can be added to both ends would suggest an equal-arm balance, while, at the same time, the fact that the fulcrum is movable would suggest a bismar-type balance. A weighing apparatus combining these two features is unknown and does not appear to be a particularly practical device. For this reason it is highly unlikely that B 25b is describing an unequal-arm weighing device. Beyond this, there is no evidence, either textual or material, that would point to the existence of such a device at this time in China.[19] More probably the Mohist passage refers to another type of implement. The shoulder pole is a plausible candidate since its practical use entails exactly the kind of mechanical experience described. If something is loaded on one side, that side goes down. One naturally compensates for this movement by shifting the heavy side closer to the shoulder (in effect, the fulcrum), thus making one side shorter and the

[17] *Mechanical Problems* 850b 14–16, Problem 4 (Renn and McLaughlin 2018, 123).

[18] The misunderstanding persists in as recent a publication as Dai 2001a.

[19] For a detailed discussion of this issue, see Büttner *et al*. 2018.

other longer. Unlike the unequal-arms balance in Greece, which allows for the numerical quantification of weights, the shoulder pole or any similar device in China does not allow any means for quantifying the effect of weights or forces. This disparity in what kind of mechanical devices were available may have something to do with the development in Greece of a mathematized theory of mechanics in contrast to its absence in China.

The *Mechanical Problems* operates against a background of an encompassing Aristotelian natural philosophy. This encompassing view demands an integration of mechanical phenomena with the background natural philosophy and leads to a radical reductionist program in that all mechanical phenomena are traced back to the workings of a lever, which explains the apparent inequality between cause and effect, and ultimately to the circle, which is seen as in harmony with the natural world.[20] There is no comparable natural-philosophic background for the *Mohist Canon*. Lacking this, there is no incentive or motivation for the reduction to any central principle. Instead, as shall be laid out in the following section, it is against the background of the Mohist project of a broad theory of knowledge and reasoning that the demand for a rational explanation of seemingly paradoxical phenomena arises, and it is in the context of this theory that the rational explanation is performed.

2.5 The Place of Mohist Theoretical Knowledge in a Global History of Science

What is the *Mohist Canon* about? On the uppermost level it appears to present a theory of knowledge and reasoning, which we may call a 'logic'. This is not a formal logic, which treats thought and argument in abstraction from their relation to the objects in question, but a logic that engages with concrete subject matters. Besides a few passages that are primarily on knowledge and reasoning *in abstracto*, the text is concerned with topics from various fields of knowledge for which it delineates the meanings of terms and lays out the proper ways of reasoning. While different topics are treated in successive sequences of passages, a close interrelation among all topics is indicated, and sometimes even emphasized, by frequent links and references from passages on one topic to the other topics.

The set of topics that the text presents is most peculiar when compared to other discursive texts from the Chinese tradition, be they from about the same time or from later times, but also when compared to the textual traditions of ancient Greece. We may roughly divide the topics into three groups, corresponding to the 'ethics', 'logic', and 'science' in the title of Graham's pathbreaking book: (1) There are passages on ethics and the conduct of government, (2) passages on sophistry and logic, and (3) passages on sciences—optics and mechanics in particular. The topics around

20 Renn and McLaughlin 2018.

ethics and government, although presented in the *Mohist Canon* in a peculiar format and style, are arguably the least unexpected in the context of Chinese discursive texts of the time. For sophistry and logic there are some indications of a broader contemporaneous tradition, in particular in *Zhuangzi* and in *Gongsun Long*, but there is no comparable systematic exposition of a logic of space and time, contingency and inevitability, and sets and models, as found in the *Mohist Canon*. In its rigorous treatment of topics concerning concrete aspects of optical and mechanical phenomena, the *Mohist Canon* has no equal in the ancient Chinese literature handed down to us. We have pointed to parallel treatments of topics in mechanics, optics, geometry, and the theory of space, time and motion in ancient Greece. But these were usually found in separate texts devoted to one of these fields. It is true that many ancient Greek philosophers, or schools of philosophy, were concerned with a broad spectrum of topics ranging from ethics via theories of knowledge to natural philosophy. Aristotle is a prominent, but by far not the only example. And many works of ancient Greek and Latin philosophy, *e.g.*, Plato's *Timaeus* or Lucretius' *De rerum natura*, span from ethics to cosmology and natural philosophy. But a text integrating the various topics found in the *Mohist Canon* would be exceptional in that tradition, too.

What we see as linking the various topics in the *Mohist Canon* together is an underlying effort to set out a coherent, if inchoate, theory of knowledge and reasoning. Following Graham we may speculate that it is the Later Mohists' aim to put their ethics on firm grounds by demonstrating that—notwithstanding all sophistry and apparent paradoxes—rational argument is possible and a doctrine may be framed without reference to deities, ancient authorities, or a transcendental world. But we may also consider the text to be from a later stage of the development of logical discourse in which it has decoupled from its origins in disputes about ethics to such a degree that no direct concern for a particular doctrine is necessary to motivate its production. In any case, the perspective of a theory of knowledge and reasoning is what binds the passages on different topics together. While the sequential treatment of topics shows that they were indeed perceived as distinct topics by the authors of the text, their combination and close interconnection in the text is clear evidence that, at the same time, the authors regarded them as connected in their pertinence to the overall project. In this context it is important to note how apparently distant topics are related. In particular, as we have argued in the foregoing sections, the logic of space and time, the logic of contingency and inevitability, the logic of elements and sets and the logic of models are not presented as four or more different types of logic. They are connected in that space and time provide conditions of contingency and inevitability, that models may be corporeal or ideal, that elements and sets can be discerned at different levels of analysis, that instruments as corporeal objects extended in space can be resolved into elements and, at the same time, imply certain causal behavior, and so on.

But even if we understand the inner connections of the topics touched in the Later Mohist project, from a broader perspective of the history of theoretical knowledge the origin of this set of topics poses intriguing questions. It is particularly striking that what has been called 'science' in the *Mohist Canon*, the sections on geometry, optics, and mechanics,[21] relates to precisely those fields of knowledge that were first given a mathematico-deductive treatment in ancient Greece. Ancient Greece saw the emergence, over generations, of a particular type of mathematics, deductive geometry. This development culminated in the composition of Euclid's *Elements* in the third century B.C.E., after which the text became a model for scientific writing in the European and Near Eastern traditions for nearly two millennia. Geometrical knowledge included in the *Elements* and the presentation of knowledge in the form of deductively structured texts became the foundation of other sciences, which were first of all (geometrical) optics and mechanics (*i.e.*, statics).[22]

Geometry, mechanics and optics figure prominently in the *Mohist Canon*. Geometry is not developed into a set of propositions about geometrical figures and thus not applied to the other sciences in a way found in Greek texts. As in the case of ancient Greek mechanics, Mohist mechanics is primarily statics, and Mohist optics prominently contains the germs of a geometrical optics. Given that the differences between the two traditions corroborate the assumption of their independent emergence, how can their similarities be explained? Starting with the most obvious observation, namely what phenomena did *not* become a topic of early theoretical reflection in either culture, we point out that fields that much later became central to physics (such as those related to heat, or to electric and magnetic phenomena), demand technologies that were only developed in the context of industrialization (such as the steam engine and the battery) to become the object of rigorous treatment. Thus the cross-cultural history of theoretical thinking reflects aspects of the history of technology and society at large and underlines the fact that pre-industrial societies will not develop rigorous theoretical treatments of experiential fields beyond their technological reach. It further reflects aspects of the physical world we live in, for instance that electric and magnetic free motive forces are fringe phenomena in our natural environments, while the gravitational force is ubiquitous in the tendency of heavy bodies to move towards the earth. But electric forces do play a central, albeit hidden, role in our everyday natural environment. As we know today, electric forces are decisive for the constitution of solid bodies, and the existence of solid bodies is another universal feature of the natural environments of human societies. It is in the interaction of the individual with its environment, which displays such universal features, that the humanly universal schemata of elementary knowledge are built up. We were able to discern candidates for such universal structural aspects of this elementary knowledge through our analysis of similarities between the independent theoretical constructs of Late Mohism and ancient Greek philosophy and science. The distinction of the vertical direction is one such aspect, the extendedness that pertains to both space and time is another. But because theoretical thinking is constructive and thereby goes beyond the

[21] Graham further includes 'economics'; *cf*. Graham 1978, 53.

[22] *Cf*. Hund 1978, 36–47. Hund further discusses astronomy, which was also geometrically treated early in ancient Greece. Its absence in the *Mohist Canon* is discussed a little further below.

knowledge structures it reflects upon, we also encountered differences in the theoretical constructs based on the same elementary knowledge structures. An example is provided by the deviating answers to the question if motion can exist in an instant of time. In other instances we could see how one and the same aspect of elementary thinking becomes reflected in vastly different theoretical contexts, *e.g.*, when the idea of a spatially universal instant of simultaneity is implied in the Mohist logic of space and time as well as in the foundations of Newtonian mechanics.

The universal structures of elementary knowledge are not sufficient to explain the similarities in Mohist and Greek science mentioned above. The knowledge reflected in geometry, mechanics, and optics is only partly elementary. It is most notably instrumental. It therefore presupposes a familiarity with certain types of instruments and technology to engender that type of practical knowledge that can then be reflected upon. We discerned the geometrical compass, devices using a lever, variously shaped mirrors, and other practical artifacts as underlying the scientific texts from both traditions. The similarities may then be traced back to their shared practical roots, whereby the similarity of the material tools may be either due to parallel developments or to earlier instances of technology transfer (or a combination of both). The striking similarity of the independent definitions of a circle in Euclid's *Elements* and in the *Mohist Canon* becomes comprehensible once the definitions are understood to be translations into theory of the material working of a compass. But we have also pointed to differences in the sciences that may be related to differences in technology: the absence of a quantitative formulation of the law of the lever in the *Mohist Canon* may be due to an absence of unequal armed balances in Warring States China.[23] But even where we assume the same practical knowledge to underlie the two theoretical traditions, there may, of course, be deviations in theoretical understanding. In the optics, for instance, we have pointed to a different understanding of the straight lines that lie at the basis of the causal explanations. These lines were interpreted as visual rays in the Greek tradition and as skirting light rays (not only when discussing shadows, but also mirror images) in the Mohist tradition.

What is important in the context of our question of what topics become the object of rigorously reasoned sciences is that the objects discussed—measurement operations and graphical constructions, shadows and mirror images, and the behavior of weights in the context of using devices—are all related to spatial extension and arrangement and involve necessary dependencies between their elements. These dependencies may be of a spatio-constructive nature or of a causal nature, in many cases they are a combination of both. This is why these topics are amenable to a treatment in the framework of the Greek model of deductive geometry as well

[23] See Büttner et al. 2018, 93. One should note that a quantitative understanding of the law of the lever in the *Mechanical Problems*, with which we have compared the sections on mechanics in the *Mohist Canon*, is not undisputed; see Renn and McLaughlin 2018. Furthermore one should bear in mind that none of the sections on science in the *Mohist Canon* is quantitative or explicitly describes proportionalities.

as in the framework of the Mohist model of a logic of space, time, contingency and inevitability. Owing to fundamental differences between these frameworks, the resulting theories display fundamental differences as well, for instance when the whole point in Greek geometry is abstraction from the corporeality of its elements, while the geometric passages in the *Mohist Canon* appear in the context of a discussion of corporeal extension. All the same, the two frameworks are not incommensurable, they do not constitute mutually incomprehensible worlds. They can be compared, we can even understand them as partly treating the same topics. Both are rational, without one being reducible to the other without a loss. We can thus corroborate for the case of the emergence of theoretical science in ancient Greece and ancient China what Günter Dux has stated more generally for the history of the human mind:

> Neither is humanity confined to a universal basic pattern of conceiving the world and the self, a pattern to which all differences would just be epiphenomena, nor does each culture develop a separate world as an incomprehensible scheme.[24]

Although we are confronted with the challenge of having to compare the very limited textual material from the *Mohist Canon* in the case of ancient China with a much richer textual and intellectual tradition from ancient Greece, we can all the same use this example to approach fundamental questions about the origins of theoretical thinking and the mathematical sciences. In the introduction we raised the question of whether it constitutes a systematic necessity that deductivity first occurs in geometry and is then extended to other sciences, as the Greek example seems to suggest. The *Mohist Canon* answers with a clear “yes and no”; there does not have to be a developed deductive theory of geometry for mechanics or optics to become topics of a rigorous science. At the same time, the rigor of these sciences implies a certain kind of proto-deductivity, by which we refer to the specific differentiation between definitions and propositions and a close logical, albeit not strictly deductive, interrelatedness of the different statements. In view of the long pre-history leading up to the compilation of Euclid’s *Elements*, a pre-history to which nothing comparable is known from ancient China, we should regard the *Mohist Canon* as standing at the beginning of a parallel development rather than its end-point, as representing a possible ancient Chinese counter-model to Greek deductive science only in its inchoate state. Unfortunately it is the beginning of a development that then did not take place, or, to the degree that it did take place, of which we have no record handed down to us. But from the way the different topics are treated in the *Mohist Canon* one could envision a development in which geometrical, mechanical, and optical topics are treated with increasing rigor and breadth without one particular science pioneering the others.

Another question from the Greek perspective pertains to the role of astronomy in the rise of theoretical science. Astronomy is among the early mathematical sciences

[24] “Weder ist die Menschheit auf ein universales Grundmuster des Welt- und Selbstverständnisses festgelegt, dem alle Unterschiede nur Epiphänomene sind, noch entwickelt jede Kultur eine eigene Welt als unbegreiflichen Entwurf.” Dux 1994, 7–8.

in ancient Greece but conspicuously absent in the *Mohist Canon*. Graham discusses the possibility of a lost Mohist document on "geometrised astronomy", but there is very little evidence for such a document.[25] To be sure, there are early Han period texts such as the parts of the *Zhou bi suan jing* and the third chapter of *Huainanzi* that deal with astronomical phenomena, but there is no evidence that they have anything to do with Mohist thinking. Nor is there any evidence in the ancient Chinese record of a geometrization of astronomy in the way that the Greeks used geometry to describe celestial motions and the workings of the cosmos, as Eudoxus' geometrico-mechanical model and the geometrical models that were later systematically synthesized by Ptolemy exemplify. In fact, as we have pointed out, there is no developed geometry in the Mohist corpus that could be readily applied to celestial phenomena. The *Mohist Canon* shows awareness of astronomical instruments such as the gnomon or the sundial. Yet, it is not at all clear how, beyond this, astronomy could have contributed to the Later Mohist project as we have reconstructed it here. It therefore appears to be a projection from the Greek case to assume that the Later Mohists must have occupied themselves with astronomy and that all records of this occupation have unfortunately been lost.

Finally, looking at the Greek case alone one might get the impression that the development of non-mythological cosmologies and encompassing systems of natural philosophy would be crucial for theoretical science to come about. Greek discussions of space, time and matter took place in such a context, as the case of Aristotle prominently shows, and we even saw that the earliest theoretical treatment of mechanics in Greece, the *Mechanical Problems*, were motivated by the attempt to reconcile mechanical phenomena with natural philosophic tenets. The Mohist case demonstrates that theoretical science may come about in the absence of such philosophy. Yet, it does not affirm the naïve idea that science emerges out of sheer curiosity, once people have the spare time to think about all sorts of problems. As in the case of early Greek science, the theoretical occupation with specific topics is not driven by a practical concern about these topics, but by a broader intellectual project that, to begin with, has nothing to do with these topics. This broader project is the historical outcome of intellectual developments in the respective societies and therefore bears the marks of knowledge constellations within that society. In the Greek case natural philosophy had become an important ingredient in that mix even before the occurrence of systematic reflections on the linguistic representation of knowledge. In China, as the Mohist case reveals, this reflection occurred before the establishment of any encompassing system of natural philosophy and in the context of a search for a theory of reasoning. What is similar in both cases is that the reflection on language emerged in the context of cultures of disputation that essentially concerned political and ethical matters. Judging on the basis of these two cases alone, the development of such a culture of disputation then seems to be a key precondition for the independent emergence of theoretical science in a society.

[25] Graham 1978, 23.