

**DEFINITION, EXPLANATION, AND
SCIENTIFIC METHOD IN ARISTOTLE'S *DE
SOMNO***

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Article info

CDD: 185

Received: 16.04.2019; Accepted: 14.08.2019

DOI: <http://dx.doi.org/10.1590/0100-6045.2019.V42N4.AF>

Keywords

Aristotle

Scientific Method

Natural Science

Sleep

Explanation

Abstract: Exploring the systematic connections between Aristotle's theory and practice of science has emerged as an important concern in recent years. On the one hand, we can invoke the theory of the *Posterior Analytics* to motivate specific moves that Aristotle makes in the course of his actual investigation of the natural world. On the other, we can use Aristotle's practice of science to illuminate the theory of the *Posterior Analytics*, which is presented in a notoriously abstract, and at times also elliptical, way. I would like to contribute to this interpretative tradition with a study of how Aristotle explains the phenomenon of sleep and waking.

1. THE BIOLOGICAL ORIENTATION OF THE *DE SOMNO*

Aristotle's theoretical motivations for dealing with sleep and waking in the natural investigation transmitted to us with the Latin title *De somno et vigilia* (hereafter *De somno*) are clearly stated at the outset of the first book of his work *On the Parts of Animals* (*PA I*). There, Aristotle is quite emphatic on the need to engage in a separate, and indeed common, study of certain natural phenomena pertaining to animal life. These phenomena are to be studied separately, and in common, because they are shared by many, if not all, animals.¹ By engaging in such a study Aristotle hopes to obtain causal explanations that range across different kinds of animals. By his lights, causal explanations that are common are necessary not only to avoid tedious repetitions but also to shed light on salient explanatory features that might be otherwise missed. Surprisingly enough, Aristotle is not explicit about his second reason in *PA I*. While he stresses the importance of avoiding repetitions, he does not insist, as one might expect, on the fact that there are certain salient features that would be missed if they were not studied separately and at the right level of generality. Still, there is no doubt that this second reason is, at least for Aristotle, as important as the first one.

It is worth elaborating on this second reason, and on the motivations for treating certain features of animal life in common. An explicit discussion of this explanatory commitment is found in the first book of the *Posterior Analytics* (*APost I*). There, Aristotle introduces the methodological principle that explanations must be given at the proper level of generality. He illustrates this principle with the help of the property of having the internal angles equal to two right angles. Since this property belongs to all triangles, it belongs to equilateral, isosceles, and scalene

¹ *PA I* 639a15-29.

triangles. But it does not belong to these triangles in virtue of the fact that they are equilateral, isosceles, or scalene triangles. Rather, it belongs to them because they are triangles. This geometrical example helps us see that there is a common explanatory level beyond that of equilateral, isosceles, and scalene triangles. We reach this common explanatory level by ignoring those facts that are specific to equilateral, isosceles, and scalene triangles. More to the point: we ignore those facts by treating equilateral, isosceles, and scalene triangles insofar as they are triangles. We can think of such a treatment of triangles as a general study of triangles.²

It is not difficult to see why sleep and waking are to be studied in common for all animals. Sleep and waking are closely related to the activity of perceiving. We know, in particular, that someone (or something) is awake or asleep based on the presence or absence of the activity of perceiving. But perceiving is the activity that, at least for Aristotle, demarcates animal life (including human life) from plant life. Aristotle has defended this claim in his study of the soul (the *De anima*). This claim is to be taken as a foundational thesis for the project attempted in the *De somno*, since it establishes the biological orientation of the entire work. More directly, even when Aristotle concentrates his attention on what happens in the case of the human body, he is committed to developing a causal account that can be extended to all animals. Aristotle focuses on the human body because he is committed to the methodological principles that all investigations ought to start from the study of that which is most developed and as such is also better in nature. An especially clear formulation of this methodological principle can be found in a fragment from the now lost *Protrepticus*:

² *APost* I 5, 74a4-6 combined with 74a16-17.

Prior things are always more knowable than posterior things, what is better in nature <is more knowable> than what is worse: *knowledge is of what is organized and more determinate than of the opposites*. (Aristotle, *Protr.* B 33 Düring (Iamblichus, *Protr.* 38.7-8 and *De comm math sc.* 81-7-11; italics are mine)³

By Aristotle's lights, the human body is the most developed, and so the most complete, living body. It can serve as a guideline, and indeed a model, for the study of the functioning of animal bodies. More specifically, and more precisely, Aristotle is confident that the results reached in the course of the study of the human body can be extended to all *blooded* animals—that is, all the animals that possess a heart. Moreover, by deploying analogical reasoning, Aristotle is able to extend the results reached in the course of the study of the blooded animals to the case of *bloodless* animals—that is, all the animals that possess something that is functionally analogous to a heart.

³ I am using the translation offered by D. S. Hutchinson and Monte R. Johnson in their still provisional reconstruction of Aristotle, *Protrepticus or Exhortation to Philosophy*, which is available online at the following address: <http://www.protrepticus.info/>. Additional passages from the Aristotelian *corpus* can be offered in which we are told that the order of explanation must follow the order of nature, with the order of nature having thus normative force over the order of exposition. See, e.g., *GA* 2.4, 737b25-27. For a recent discussion of this methodological principle, I refer the reader to Leunissen 2017: 56-74 (especially 58-66).

2. THE ὄτι-stage OF THE *DE SOMNO*

In the opening lines of the *De somno*, Aristotle sets for himself the goal of establishing what sleep and waking are, and why both have to be present in all animals. His stated goal is to achieve a scientific definition of sleep and waking that tells us why animals are affected by both sleep and waking. That the search for a definition and the search for an explanation converge toward one and the same result is no surprise. At the beginning of the second book of the *Posterior Analytics*, Aristotle has already argued that knowing the what-it-is is the same as knowing the why-it-is:

“[...] it is clear that the what-it-is (τί ἐστὶ) and the why-it-is (διὰ τί ἐστὶ) are the same. What is a <lunar> eclipse? Privation of the moon’s light by the interposition of the earth. What is the reason of the <lunar> eclipse? Or: Why does the moon suffer an eclipse? Because of the failure of light due to the interposition of the earth.” (*APost.* II 1, 90a24-27. Cf *APost.* II 8, 93a4)

But how should we proceed in our search for the explanation, and indeed definition, of sleep and waking? In the second book of the *Posterior Analytics*, Aristotle makes it clear that before embarking on the search for any explanation or definition, the investigator has first to establish what is to be explained or defined. This is exactly what Aristotle does at the outset of the *De somno*. With the exception of the opening paragraph,⁴ the remainder of the

⁴ The opening paragraph of the *De somno* makes it clear that the three short essays we usually refer to as *De somno*, *De insomniis*, and the *De divinatione per somnum* are part of one and the same explanatory project. Once we have explained what sleep is, and

first chapter is entirely devoted to identifying the scientific fact of sleep and waking. By “scientific fact” I do not simply mean an explicable fact; rather, I mean a fact that is amenable to an explanation in the context of a science. The force of this point becomes apparent as soon as we reflect on the strictures that Aristotle imposes on the scientific inquiry and reflect, in particular, on the methodological requirement that an explanation of sleep and waking should be given in common for all animals.

In outline, the argumentative strategy that Aristotle follows in the first chapter of the *De somno* consists of the following three steps.

First step: Aristotle establishes that waking and sleep are contraries, and that what receives one of the two contraries receives also the other (but it does not, and indeed cannot, receive both at the same time). This is a general point, and a point that Aristotle makes without invoking any particular principle of natural philosophy. Rather, Aristotle secures this result by invoking a logical property shared by any chance pair of contraries.⁵

why it occurs in animals (*De somno*), we need to inquire what dream is, trying to explain why sometimes one and the same person does and does not dream in sleep (*De insomniis*); last but not least, we have also to deal with the question whether it is true that it is possible to foresee the future in dreams (*De divinatione per somnum*). At the end of the *De divinatione per somnum*, we are told that all the items on the agenda outlined at the beginning of the *De somno*, namely the nature and causes sleep and dream, and in addition divination as a result of episode of dreaming, have been discussed.

⁵ In the *De somno*, Aristotle mentions the following pairs of contraries: health and sickness, beauty and ugliness, strength and weakness, sight and blindness, hearing and deafness (1, 453b30-31).

Second step: What is specific about the phenomena of sleep and waking is that they depend on the activity of perceiving. Aristotle establishes this point by means of the following observation: we know that someone (or something) is awake or asleep based on the presence or absence of the activity of perceiving. With this observation, Aristotle secures two results. The first is that, since the activity of perceiving is proper neither to the soul nor to the body but it entails both, sleep and waking are to be studied as part of the explanatory project that is concerned with “what is common to the soul and the body.”⁶ As a result, we can say that this explanatory project is clearly distinct from the one attempted in the *De anima*. While in the *De anima* Aristotle is concerned with the soul as the principle of life, in the *De somno* he is concerned with natural phenomena that are common to both the soul and the body, the explanation of which depends at least in part on the results achieved in the study of the soul.⁷ A full appreciation of the relationship between the two projects helps us understand why in the *De somno* Aristotle invokes the *De anima* for the claim that the capacity of perception belongs to animals to the exclusion of plants. This claim is enough to secure the following important result: animals alone are affected by sleep and waking.

Third step: No animal can be always asleep or always awake, but each and every one of them must alternate sleep and waking. Aristotle argues that the capacity for

⁶ The opening lines of the *De sensu* suggest that Aristotle regarded what is common to the soul and the body a discrete investigative domain. For more on the opening lines of the *De sensu* and their significance for how Aristotle conceives of his task in the *Parva naturalia*, I refer the reader to Johansen 2006: 141-164.

⁷ More on the relation between the project attempted in the *Parva naturalia* and the *De anima* in Falcon 2019: 1-15.

perception cannot be exercised continuously, and hence periods of activity (waking) must be followed by periods of inactivity (sleep). This result is secured by invoking the following general principle: if x possesses a natural function, then there is also a natural time-limit for the exercise of that function; when the function is exercised beyond that time-limit, x is incapacitated. Aristotle does not pause to elaborate on the epistemological status of this principle; nor does he try to qualify it, by saying that it is a *natural* principle, or to restrict it by adding that this is a principle that applies to the sublunary world to the exclusion of the celestial world. The overall impression is that Aristotle is invoking a general principle of natural philosophy that, at least by his lights, is empirically evident. His claim is that things such as eyes, hands, *and everything else with a determinate function*, is given a time-limit beyond which they are incapacitated.

With the help of these three steps, Aristotle has secured *the scientific fact* that he will attempt to explain in the rest of the *De somno*—namely, that all animals alternate periods of sleep and periods of waking. It should not go unnoticed that Aristotle has also achieved an initial characterization of the phenomena of sleep and waking. More directly, if the animal is defined by possession of the capacity for perception, sleep is a fettering or an immobilization of perception, whereas waking is the release and liberation of perception:

That all animals partake of sleep is clear from these considerations: for the animal is defined by the possession of perception, and we say that sleep is in a certain way an immobilization (ἀκινήσια) and like a fettering (δεσμόν) of perception, whereas <we say that> its liberation and release is waking. (*De somno* 1, 454b24-27)

Needless to say, this is just a first, preliminary account of sleep and waking. At best, this account gives us an initial grasp of what has to be studied. Armed with this initial grasp of the phenomenon of sleep and waking, we are in the position to begin our search for its causes. Our cognitive state at this stage of the investigation is not unlike the one that Aristotle ascribes to those who have non-accidental knowledge of the existence of something. Consider the following passage from *APost* II 8:

“<It> is impossible to know what a thing is when we are ignorant that it exists. Sometimes we grasp that something exists in an accidental way, and sometimes by grasping something of the thing itself (for instance, that thunder is a certain kind of noise in the clouds, that eclipse is a certain kind of loss of light, that the human being is a certain kind of animal, or that the soul is that which moves itself). [...] To search for what something is without grasping that it exists is to search for nothing. But when we grasp something <of the thing itself> it is easy to search. Thus, as we are aware that something exists, so is our awareness directed toward what it is.” (*APost* II 8, 93a20-29)⁸

In this passage, Aristotle argues that we can attempt to offer a definition of what something is only when we are aware of its existence. In addition, he claims that when we

⁸ The seminal papers on this passage, and its implications for Aristotle’s scientific method, are Bolton 1976: 514-544, and Bolton 1987: 120-166. See also Sorabji 1981: 213-219, Demoss and Devereux 1988: 133-154, and Charles 2000: 23-56.

know in a non-accidental way that a thing exists, we grasp something of the thing itself (93a22) and our awareness is directed toward what the thing is (93a28-29). In this case, our non-accidental knowledge that the thing exists comes with some provisional understanding of what it is. This understanding is conveyed by a preliminary account. Aristotle's examples are that thunder is a certain kind of noise in the clouds, eclipse is a certain kind of loss of light, and the human being is a certain kind of animal.⁹

What we are told about sleep and waking in the *De somno* (1, 454b24-27) is not unlike these other definitions in that it gives us a fix on the phenomenon under investigation by way of an initial characterization of the place of sleep and waking in animal life.¹⁰ By saying that sleep is in a certain way an immobilization and is like a

⁹ *APost* II 8, 93a23-24. The definition of the soul as self-mover is slightly more problematic. Aristotle's first and foremost concern in the first book of the *De anima* is to block the route that leads to the definition of the soul as a self-mover. In fact, one of the most important outcomes of the investigation conducted in that work is the conclusion that the soul is an unmoved mover (and hence it is not a self-mover). Perhaps it is possible to defend the example offered in the *Posterior Analytics* by saying that the definition of soul as a self-mover reflects an early understanding of the soul based, among other things, on an ἐνδοξον about the nature of the soul. This definition grasps something of the thing itself to the extent that it enables us to see that the soul is a principle of motion. But it also reflects a defective understanding of the soul. It will be Aristotle's job to correct this defective understanding in the first book of the *De anima*.

¹⁰ Bolton 1976: "the chief function of nominal definitions is to enable scientific inquiry to get off the ground. Nominal definitions encapsulate information which the scientist has about an entity before he has an account of its nature or essence. This enables the scientist to fix on a suitable object for further investigation" (521).

fettering of perception, and arguing that waking is the release and liberation of perception, Aristotle establishes a link not only between sleep and perception but also between sleep and waking. With the help of this characterization, he can now work toward acquiring scientific knowledge of what sleep is.

To the extent that the link between sleep and waking, on the one hand, and perception, on the other, is essential to our understanding of the phenomena of sleep and waking, we can say that we have grasped something of the thing itself. This is in line with the methodological requirement outlined in the *Posterior Analytics*: by establishing that something is the case, we are also grasping something of the thing itself.

The qualification that Aristotle adds to his first definition of sleep calls for a few words of elaboration. According to Aristotle, “we say that sleep is *in a certain way* (τρόπον τινα) an immobilization and is *like* (οἷον) a fettering of perception.” The words highlighted in italics are to be taken as sign of a lacuna that is to be filled in with the relevant content as the inquiry proceeds from the ὄτι-stage to the διότι-stage of inquiry. In other words, the first, still provisional, definition of sleep captures a relevant aspect of sleep while at the same time it also lacks in content.¹¹ Furthermore, I do not think that “we say” can be taken to be equivalent to “we *ordinary people* say” that sleep is in a certain way an immobilization and like a fettering of

¹¹ I believe that this is also the message conveyed by Aristotle’s examples in the *Posterior Analytics*. When Aristotle says that thunder is *a certain kind* (τις) of noise in the clouds, eclipse is *a certain kind* (τις) of loss of light, and the human being is *a certain kind* (τι) of animal, he signals a lacuna to be filled in the course of the investigation. Put differently, “to be a certain kind of . . .” is a place-holder for additional information to be supplied at a later stage. Cf. Charles 2000: 38n24.

perception. Perception is understood by Aristotle as a capacity that defines animals to the exclusion of plants. This is far from being a trivial thesis, let alone a widely shared view at the time. Rather, it is an important scientific truth that Aristotle secures in the *De anima* and applies in the *De somno*. Even if it is possible that the first and still provisional, definition of sleep captures some of the pre-theoretical intuitions ordinary people share on the nature of sleep, the fact that it is a commonly shared view, or even an *ἔνδοξον*, is not what interests Aristotle.

So far I have argued that the first chapter of the *De somno* is concerned with the *ὄτι*-stage of his investigation, and that this chapter provides valuable insights into how the relevant scientific fact is established by Aristotle. In connection with the latter point, it should be added that Aristotle is greatly concerned with the precise extension of what is to be explained. His language is reminiscent of the way in which scientific facts are established in the *Historia animalium* (*HA*). As in the *HA*, Aristotle is here looking for correlations between sleep and other features. In particular, he establishes a correlation between having eyes and undergoing periods of sleep:

“Nearly all other animals clearly partake of sleep whether they live in water, in air, or on land: fishes of all kinds and the soft-bodied animals (*μαλάκια*) are observed undergoing period of sleep, and as many as (*ὅσα*) have eyes, all (*πάντα*) undergo periods of sleep;¹²

¹² The linguistic pattern “*πάντα ... ὅσα*” is strongly reminiscent of the way in which Aristotle establishes his scientific facts in *HA*. For more on this topic, I refer the reader to Lennox [electronic resource]: “Aristotle appears to use the sentence form “as many as are X, all have Y” for quite a specific reason. It is not *just* to note a universal correlation; it is to do so while leaving the

for even the animals that have eyes made of a hard substance (σκληρόφθαλμα)¹³ and insects manifestly assume the posture of sleep, although for all these animals these periods can be very brief, which is why it may escape us whether they partake of sleep or not. As for the hard-shelled animals (όστρακοδέρμα), it is not yet perceptually clear whether they sleep. However, if one has found the foregoing argument convincing, then one will be persuaded by it.” (*De somno* 1, 454b14-23)

In this passage, Aristotle invokes—vigorously and unequivocally—the authority of observation for the claim that all, or nearly all, animals are observed undergoing periods of sleep. I say “nearly all animals” because the case of the hard-shelled animals is a difficult one. The perceptual data available to Aristotle do not suffice to establish whether these animals partake in sleep. But even in this case observation remains the necessary and ultimate authority. Still, Aristotle is willing to admit that he has built a convincing case for the thesis that all animals, including the όστρακοδέρμα, undergo periods of sleep.

extension of the correlation open—a brilliant methodological innovation. New animals with the correlation can be discovered but the generalization will not change.”

¹³ The σκληρόφθαλμα may be considered a difficult case because they do not have eye-coverings that help us determine whether these animals sleep or not. In this case, their bodily posture may be taken to be evidence that they are asleep. On σκληρόφθαλμα, see *PA* II 13-15.

3. TOWARD A DEFINITION OF SLEEP: THE PRIMARY SUBJECT OF SLEEP

The second chapter of the *De somno* marks the beginning of the διότι-stage of Aristotle's inquiry:

It is now to be investigated why (διὰ τί) one sleeps and wakes and on account of what sense—or what senses if there is more than one—one sleeps and wakes. (*De somno* 2, 455a4-5)

The passage is an invitation to identify which one of the five senses is responsible for the phenomena of sleep and waking. Aristotle does not respond to this invitation by singling out any one of the individual senses, or a particular combination of them. For one thing, all animals are affected by sleep and waking, but not all of them have all five senses. For another, when an animal is asleep, all its senses are affected in the same way. This second point can be restated by saying that sleep is conceived by Aristotle as a state of total incapacitation. When the animal is asleep, none of its senses is working.

A detailed analysis of the argument for the claim that sleep is an affection of the common sense exceeds the scope of this paper.¹⁴ Here suffice it to say that Aristotle is able to individuate the part of the perceptual system that is directly affected by sleep and waking: the incapacitation associated with sleep happens neither in any chance sense-organ nor from any chance cause but it happens in the primary sense-organ (2, 455b8-11). It should not be overlooked that the lacuna deliberately left in the initial characterization of sleep and waking—the one that gave us

¹⁴ For a recent in-depth analysis of Aristotle's argument, I refer the reader to Gregoric (2007): 163-173.

a fix on these phenomena—is being filled as the investigation progresses. Aristotle is now able to locate where the phenomena under investigation take place. He can say that sleep and waking are affections of the primary sense-organ. We can restate this last point by saying that, at this stage of the inquiry, Aristotle is able identify *the primary subject* that is affected by both sleep and waking.¹⁵ With the help of this last observation, we can perhaps rework the initial characterization of sleep and waking as follows: sleep is an immobilization or fettering *of the first sense-organ*, whereas its release is waking.

There is no doubt that we have made some progress in our search for a definition—and indeed explanation—of the phenomenon of sleep. At this stage of our inquiry, we can confidently say that sleep is not simply a state in which the senses are not being used. Rather, it is a state in which the senses cannot be used. Moreover, they cannot be used because the primary sense-organ is somehow affected. Still, we are far from having reached a satisfactory explanation of this state. We would like to know, for instance, what distinguishes this particular state from other states of unconsciousness where our ability to perceive is equally affected—for instance, fainting, or the state of unconsciousness that Aristotle calls ἔκνοια (suffocation or asphyxia). The only way to make progress on this front is to look for the cause (or causes) of sleep. It is only when we will have found the cause (or causes) of sleep that we may be able not only to say how sleep is different from these other states of unconsciousness but also to clarify what role sleep has in animal life.

¹⁵ This is “the underlier” in the triadic scheme <AFFECTION, UNDERLIER, AGENT> discussed in Code 2015: 11-47 (especially 16-23).

4. ARISTOTLE'S DEFINITION OF SLEEP

At this point, Aristotle resumes the causal investigation announced at the beginning of the second chapter of the *De somno*. He does so by promising not only a causal explanation but also a definition of sleep: *it must be said on account of what cause sleep occurs, and what sort of affection it is* (2, 455b13-14).

We have already seen that, in the first chapter of the *De somno*, Aristotle introduces the principle that no natural capacity can be exercised indefinitely but rather periods of activity must be followed by periods of inactivity. Aristotle builds on this principle by arguing that the periods of inactivity are *for the sake of* the periods of activity. More specifically, the periods of sleep are *for the sake of* the periods of waking.¹⁶ Waking is understood as the full, and indeed optimal, exercise of the perceptual capacities. As a result, saying that sleep is for the sake of waking is equivalent to saying that the optimal exercise of the perceptual capacities is contingent on having adequate periods of sleep. In other words, periods of sleep are necessary *if* the optimal exercise of the perceptual capacities is to obtain:

It is necessary for sleep to belong to every animal. I mean “necessity” in a conditional sense (ἐξ ὑποθέσεως)—namely, if the animal is to have its own nature, then certain things must belong to it of necessity; moreover, since

¹⁶ Aristotle reaches this result by applying the teleological principle that nature does nothing in vain (“*we say* that nature acts for the sake of an end, and this end is a good,” 455b17-18). For more on this principle and the function it plays in Aristotle’s search for teleological explanations, see the alternative accounts offered in Lennox 2001: 182-204 and Leunissen 2010: 119-135.

these things belong, others must belong [as well]. (*De somno* 2, 455b25-27)

Perhaps this passage can be restated in the following way: since the capacity for perception is part of the essential nature of the animal (recall that to be an animal is to be able to perceive), the presence of certain other things is necessary—in *primis* a living body equipped with sense-organs. But it is precisely because the possession, and indeed optimal use, of the capacity for perception requires such a body that sleep, understood as the periodical shut down of the sense-organs for the sake of recovery, is needed. In other words, the teleological explanation of sleep is a direct consequence of the Aristotelian insight that perception necessarily requires a materially constituted organ or tool—namely, a certain kind of living body, and that such an organ or tool cannot function without periods of rest.¹⁷ This insight is encapsulated in Aristotle's claim that sleep is for the preservation of the animals (2, 455b22).

By invoking a teleological explanation of sleep, Aristotle has made some progress toward giving an explanation of the place that sleep has in animal life. However, he has told us virtually nothing about the way in which episodes of sleep and waking occur. Still, it is clear that this question cannot be further avoided. Quite the opposite, it follows from a general feature of teleology and conditional necessity in Aristotle. Recall that, at least for Aristotle, there is more than one level of conditional necessity governed by teleology in Aristotle. Consider, in particular, the following two conditional statements:

- (1) If the animal is to perform its characteristic activities optimally, then it must take some rest (in

¹⁷ Cf. Everson 2007: 519.

the form of sleep, understood as the temporary shutting down of the of sense-organs).

(2) If the animal must take some rest (in the form of sleep, understood as the temporary shutting down of the sense-organs), certain physiological processes must take place in its body.

At this point of the inquiry, Aristotle moves from the first to the second level of conditional necessity. As a result, he turns his attention to the physiological processes required for episodes of sleep and waking to occur.¹⁸ The transition to this new task is marked by the promise to concentrate on the processes and activities that take place in the body of the animal when the latter is affected by sleep and waking (2, 455b28-31).

First, Aristotle establishes what part of the body is directly affected by sleep and waking. Aristotle is able to answer this question because he has already established that sleep and waking are an affection of the controlling sense-organ. In blooded animals, the primary sense-organ is located in the region around the heart. As for bloodless animals, they do not have a heart but something that is functionally analogous to it. If, therefore, Aristotle is able to explain what happens in the bodies of blooded animals when episodes of sleep and waking occur, he is also able to explain, by means of analogous reasoning, what happens also in bloodless animals. Aristotle states his explanatory strategy in the following passage:

¹⁸ I owe this point to Lucas Angioni. His comments helped me see how to negotiate the transition from the first to the second level of conditional necessity at this particular juncture of Aristotle's argument.

One should assume that the causes of the affection [*sc.* sleep and waking] in other animals are as they are in blooded animals—either the same or analogous—and that the causes in blooded animals are those in human beings. Hence, one should consider the entire subject starting from them [*sc.* human beings]. (*De somno* 2, 455b31-34)

Next, Aristotle turns his attention to the processes that give rise to single episodes of sleep and waking, which amounts to looking for the whence of sleep and waking (*De somno* 3, 456a30-33). This search is equivalent to a search for the *moving* (or *efficient*) *cause* of sleep and waking.¹⁹ Aristotle makes it clear that sleep and waking are causally linked to nutrition and the transformation of nourishment into blood (or into its analogous substance in bloodless animals).²⁰ A detailed account of the physiological processes involved in the assimilation of nourishment and its transformation into blood are not needed in the *De somno*. What we need to know in connection with the study of sleep and waking is only this:

When nourishment enters into the parts that are fitted for its reception, an exhalation (*ἀναθυμίασις*) arising from the nourishment

¹⁹ This is “the agent” in the triadic scheme <AFFECTION, UNDERLIER, AGENT> discussed in Code 2015: 11-47 (especially 16-23).

²⁰ The following statement from the *De somno* encapsulates how Aristotle sees the relationship between nourishment and blood: “nourishment in its ultimate form is: in blooded animals, the natural substance blood, and in bloodless animals that which is analogous to it.” (3, 456a34-36).

enters into the veins, and there it undergoes a change and is transformed into blood, which eventually reaches the source [of all blood, *sc.* the heart]. (*De somno* 2, 456b2-5)²¹

To understand the physiological process outlined in this passage we have to keep in mind the function that Aristotle assigns to the brain. The brain is the coldest among the parts of the body and exists in the body for the sake of cooling the entire organism.²² When the exhalation

²¹ The reader should compare what Aristotle says in the *De somno* with the following passage from *PA*: “as the nourishment exhales upward through the veins, the residue from it becomes cooled owing to the specific nature of this place <*sc.* the brain>, and produces fluxes of phlegm and serum. And we should be justified in maintaining that this process resembles, on a small scale, the one which produces rain-showers. Damp vapour exhales up from the earth and is carried into the upper regions by the heat; and when it reaches the cold air up it condenses back again into water owing to the cold and pours down toward the earth” (*PA* II 7, 653a1-8).

²² Here is what Aristotle says on the function of the brain in *PA*: “Everything needs something to counterbalance it, so that it may achieve proportion and the mean; [...] for this reason nature has contrived the brain to counterbalance the region of the heart and the heat in it; and this is why animals have a brain, the composition of which is a combination of water and earth. Hence, although all blooded animals have a brain, practically none of the others has (unless it be just a counterpart, as in the case of the octopus), for since they lack blood they have but little heat” (*PA* II 7, 652a20-26). Among other things, this passage helps us understand that blooded animals must have both a heart and a brain. With the exception of a few cases (most notably, the octopus), bloodless animals do not have a brain. In their case, cooling takes place in some another way. In the *De somno*, Aristotle deals with cooling in bloodless animals at 2, 456a6-21.

produced in the process of digestion enters into the veins, it becomes a warm substance moving up quickly through the veins toward the upper part of the body. When it has reached the brain, this hot substance is cooled off.²³ At that point this substance, which will at some point be transformed into blood, is ready to flow inward toward the heart. Sleep happens in connection with the sudden concentration of blood in the region around the heart. The brain produces sleeps but it is not itself affected by sleep. What is affected by sleep is the heart because the latter is the seat of the common sense-organ.²⁴

We can go further in describing what Aristotle envisions happening in the body in connection with episodes of sleep and waking. Aristotle argues that one awakes when the separation of the thinner blood from the thicker blood is completed (3, 458a12). Aristotle seems to think that an episode of sleep occurs as a result of the fact that a large quantity of blood in need of separation has flooded the region around the heart; when the separation is completed, an episode of waking ensues:

²³ Based on what Aristotle says in *De somno* 3, 458a5-10. It is suggestive to think that the brain works like a radiator, the function of which is to cool the body off. The brain is surrounded by a dense network of veins. By being forced to flow through these narrow passages, the hot substance is cooled off. Cf. *HA* 495 a 5-11: "In all animals, the brain is bloodless; there is not a single vein in it, and it feels cold to the touch [...] the membrane surrounding it is patterned with little veins."

²⁴ "It is this part [*sc.* brain] which produces sleep in animals (or if there is no brain its analogous). It cools the onflow of blood which comes from the nourishment (or else is due to other causes of the same sort) and weighs down the part where it is (that is why when a person is sleepy his head is weighed down) and causes the hot substance to escape below together with the blood" (*PA* II 7 653a11-16).

Sleep occurs because the blood after the introduction of nourishment is especially in need of separation and lasts until the thinner part has been separated off into the upper parts of the body and the thicker one into the lower parts. When this has taken place, animals awake from sleep being released from the heaviness consequent on taking in food. (*De somno* 3, 458a21-25)

We have now reached the moving or efficient cause of an episode of sleep. By Aristotle's lights, this cause is a sudden and massive²⁵ flow of blood that affects the primary sense-organ caused by²⁶ the bodily substance carried upward by the action of connate heat (*De somno* 3, 458a26-27). Although the role of connate heat was not discussed up to now, we should not be surprised to find it mentioned in the final, and indeed most accurate, description of the cause of sleep. Aristotle considers digestion to be a case of concoction (πέψις). But concoction requires a principle that acts on the nourishment by cooking it. This hot principle is connate heat (also known as vital heat).

The key term introduced in the final description of the cause of an episode of sleeping is ἀντιπερίστασις.²⁷ In this

²⁵ The Greek ἀθρόως may convey at once the notion of a "sudden" and "massive" event. Gallop 1996: *en masse*; Everson 2007: *en bloc*.

²⁶ I retain the ὑπό transmitted by all the MSS (*pace* Ross 1955, who brackets it, and Gallop 1996, who omits it). Cf. also Code 2015: 43.

²⁷ For Aristotle, ἀντιπερίστασις is a *terminus technicus*. He did not coin it (see *Phys.* VIII 10, 267a15-16). Aristotle criticizes Plato for explaining breathing and projectile motion by means of ἀντιπερίστασις (respectively in *Resp.* 6, 472b6-31 and *Phys.* IV 8,

case, ἀντιπερίστασις refers to the process of cooling off and the subsequent flowing down of what had previously moved up as a result of the action of the connate heat. If this is correct, ἀντιπερίστασις does not refer to a single thing, or to a single event, but rather to a sequence of events resulting in a temporary paralysis (κατάληψις) of the primary sense organ. This sequence of events is triggered by the action of the connate heat.

The relative complexity of the cause of sleep does not set sleep apart from the cases discussed in the *Posterior Analytics*. Let us briefly return to the example of a lunar eclipse. In this case, the διὰ τί question takes the following forms: What is the cause of a lunar eclipse? Or: Why does the moon suffer an eclipse? The answer is: Because of the failure of light due to the interposition of the earth (*APost* II 1, 90a16-18). Similar questions can be asked in

215a14-15). Plato, who speaks of περίωσις (pushing around) rather than ἀντιπερίστασις, explains a number of biological and physical phenomena in terms of ἀντιπερίστασις: in addition to breathing and projectile motion, Plato lists acoustics, water currents, the descent of thunderbolts, and the alleged attraction exercised by amber and the lodestone (*Tim.* 79 A-80 C). Aristotle narrows down the use of ἀντιπερίστασις. He invokes it to explain meteorological phenomena such as winds. It is no coincidence that both in the case of winds and in the case of sleep Aristotle envisions exhalations (ἀναθυμιάσεις) being involved in the explanation. In fact, he is happy to speak of an analogy between what happens in the human body and in the case of winds (*Meteor.* II 4, 360b22-26). In the end, however, Aristotle does not give us a definition of ἀντιπερίστασις. Simplicius supplies it for him: “ἀντιπερίστασις occurs when one body is expelled from its place by another and they exchange places and the one that expelled the other stands in the place of what was expelled.” (Simplicius, *In Phys.* 135031-33, trans. Richard McKirahan)

connection with sleep: What is the cause of sleep? Why does the primary sense-organ suffer a temporary incapacitation? The answer is: Because of the sudden and massive ἀντιπερίστασις caused by the bodily substance carried upward by the action of the connate heat (*De somno* 3, 458a26-27). What sets apart the case of sleep is that sleep, unlike a lunar eclipse (or a thunder), has a final cause and this final cause must appear in the final definition (τί ἐστι) of sleep.

It is very telling that Aristotle's investigation of sleep ends with a causal definition of sleep. This is also the most complete—indeed most precise—definition of sleep. It makes reference to both the final and the moving (or efficient) cause of sleep. It also identifies the primary subject affected by sleep—namely, the heart (or whatever is functionally analogous to the heart in bloodless animals)—with the seat of the controlling sense-organ. As such it recapitulates the progress made in the search for a definition that explains not only how sleep arises in an animal but also the role that sleep has in animal life:

Sleep is the paralysis of the first sense-organ preventing it from operating, and it occurs on the one hand (μὲν) of necessity—for it is not possible for the animal to exist should the conditions that produce it not obtain—and on the other hand (δὲ) for the preservation of the animal. (*De somno* 3, 458a28-32)

5. CONCLUSION

It has long been appreciated that Aristotle envisions the scientific inquiry as an enterprise that advances in stages.²⁸ The search for a scientific definition, and the corresponding explanation, of the phenomena of sleep and waking, is no exceptions to the rule. In fact, this search illustrates the Aristotelian strategy in an exemplary way. In addition to a pre-explanatory stage (ὄτι-stage) and an explanatory stage (διότι-stage) of investigation, the explanatory stage itself unfolds in stages.²⁹ First of all, Aristotle determines what part is primarily and directly affected by sleep and waking. While it is true that the animal as a whole is asleep and awake, a scientific explanation is expected to single out the most precise description of the phenomena. This entails finding out the primary (or proximate) subject of change. At least for Aristotle, this is the heart (or whatever is functionally analogous to the heart). It is only when this important result is secured that Aristotle is able to turn to the search for the final and the moving causes of sleep and waking. While the final cause is identified by looking at the functional role that sleep and waking have in the life of animals, the primary (or proximate) moving cause is individuated by looking at the complex physiological

²⁸ I refer the reader to Gotthelf 2012a: 394-398.

²⁹ Following Allan Gotthelf, (Gotthelf 2012b: 261-292), I speak of a *pre-explanatory* stage of inquiry in connection with the ὄτι-stage. The reason for this choice is that the collection of the data is never innocent with respect to their subsequent explanation. Quite the opposite: the relevant data are not only collected but also organized for their subsequent explanation. The study of sleep and waking is no exception to the rule. Hence, the ὄτι-stage is best understood as a *pre-explanatory* (rather than a *non-explanatory*) stage of inquiry.

process (or processes) involved in any episode of sleep or waking. It should not go unnoticed that the final scientific explanation of sleep and waking does not make reference to matter or form. The reason is that matter and form are found only in natural substances (with the caveat that their extension to celestial substances is a thorny issue). At most, our explanation of sleep and waking will make reference to something that is analogue to matter—that is, the primary subject affected by sleep and waking.³⁰

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³⁰ For more on this point, I refer the reader to Code 2015: 11-45.

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