AN ARISTOTELIAN PHILOSOPHY OF BIOLOGY: FORM, FUNCTION AND DEVELOPMENT

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1. Preface

In metaphysics and philosophy of science, a significant movement is making inroads, under the banner of 'neo-Aristotelianism'.[1] The ideas at the core of this movement are that causality is rooted in the natures, powers or capacities of entities and that these are the ideas that should be at the core of accounts of scientific explanation, rather than laws that represent relations among events. A significant sub-set of those who think of themselves as neo-Aristotelians are also in favor of reviving some version of hylomorphism, the idea that natural entities should be thought of as unities of material and formal aspects.[2]

This movement has so far been focused primarily on the physical sciences, especially chemistry[3] – which raises an obvious question. Given that Aristotle the natural scientist was above all a biologist, what would a neo-Aristotelian philosophy of *biology* look like? In this paper, I will begin a discussion on precisely that question, and begin to suggest an answer. One interesting result is that the fact that biology is now permeated by evolutionary ways of thinking is all but irrelevant to answering that question.

2. Aristotle's Philosophy of Biology

My title mentions three concepts central to Aristotle's approach to the study of life: Form, Function and Development. I chose those three terms partly for anachronistic reasons – they are central to the reformation currently tak-

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[1] Cartwright 1992; Groff and Greco 2012; Ellis 2001, 2002; Molnar 2003; Oderberg 2007; Tahko 2012.

[2] Koslicki 2008; Johnston 2006; Lowe 2006, 2008; Walsh 2015.

[3] Oderberg 2007 is a partial exception.

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ing place in contemporary biology; and as corresponding classical Greek concepts were certainly central to Aristotle's study of animals, one might be encouraged to think that, after a century of biology dominated by Darwinian/neo-Darwinian concepts like random variations, gene pools, fitness differences, and selection co-efficients, biology is returning to its Aristotelian roots. I will address this possibility directly in the closing section of the paper – but preliminary to doing so, my aim is to reflect on Aristotle's *metaphysics* of life, and how it leads him to his unique approach to living things, an approach in which an integrated view of biological form, biological function and biological development (or generation, as for most of biology's history it was called) is central. At the heart of that integration are three key insights:

1) The conception of the form of a natural entity as activity (ἐνεργεία) or realizaton (ἐντελέχεια),[4] and of soul, the form of a living being, as its *first* realization

2) The living body as *instrumental*, that is, constituted of the precise parts it is, organized in the precise ways they are, *for the sake of* performing the activities that constitute *the way of life* of the animal whose body it is, and

3) Generation (or as it is referred to today, development) as a process *irreducibly for the sake of being* – even for the sake of «being eternal as far as possible, i.e. eternal in form».[5]

Though anchored in some key texts, I will characterize Aristotle's approach to life broadly enough that it should be possible to look at any figure in the history of biology, including *recent* history, and determine whether, at such a fundamental level, they share an Aristotelian view of life. His extremely detailed and highly organized investigation of animals takes place within a unique and unprecedented metaphysical and epistemological framework, so it is not unlikely that an Aristotelian biology will need to be accompanied by an Aristotelian *philosophy* of biology.

It is, then, time to reflect in a different way on the *lasting* impact of Aristotle's way of inquiring into the nature of life and his unique way of understanding the living world in all of its rich, complex, ever-active diversity.

[4] As will come up later, these two concepts are intimately related, but are not synonyms. In *Metaphysics* IX.3, Aristotle says: «The name 'activity' (ἐνεργεία) which has been connected with 'realization' (ἐντελέχεια), has been extended to other things from motions, to which it most of all refers» (1047a30). Once he introduces its extended use, to the activity of substance, he explains: «For the function of a thing is its goal, and activity is function. That is why the name 'activity' is applied according to function and extends to 'realization'» (*Metaph*. IX.7, 1050a22-4). As applied to substantial beings such as organisms, 'activity' does not just mean 'motion' but refers to the functions through which an organism expresses its way of life.

[5] *De anima* II. 4.

2. 1. *Aristotle on Diversity, Form and Activity*

A fitting place to begin is with Aristotle's attitude and approach to *diversity*. Aristotle's predecessors, on his telling (and he was there, after all), looked at that world of rich, complex and ever-active diversity and either dismissed it as deceptive appearance, hiding the real, simple, unchanging unity which is the true object of the philosopher's quest; or accepted it as a realm of unknowable flux and chaos, either a poor reflection of the real, simple, eternal, unchanging world, or its accidental by-product.

Aristotle looked at this rich diversity and smiled – or so I imagine. Consider how he chooses to open his *Metaphysics*:

«All human beings by nature desire knowledge. A sign of this is our affection for the modes of perception; for even apart from their usefulness they are enjoyed for themselves – and most of all visual perception. For not only in order that we may act, but even when there is no plan to do anything, we enjoy seeing, so to speak, above all others. This is because it, most of all the modes of perception *allows us to know things and reveals many differences*».[6]

Aristotle points to our delight in sensory experience provided by our eyes as evidence of our desire to know. Why the eyes over all other modes of perceiving? Because, he explains, they, more than any other sensory organ, give us knowledge of *many differences*. Keeping in mind that these are the very opening lines of his inquiry into the highest form of wisdom, the science of being *qua* being, it is both a powerful rejection of Plato's views about the relation of sense perception to knowledge and a statement of the importance of perceiving *differences* in coming to know things.

That is theory – but it is reflected in practice in myriad ways. Note, for example, how he characterizes his plan for organizing data about animals in his *Historian animalium*:

«The *differences* among the animals are in accordance with their ways of life, their activities, their habits and their parts; *we will first discuss these differences* in outline, and later, aiming at understanding, we will discuss them in connection with each kind».[7]

I will return to the fact that two out of the four modes of difference referred to here are *activity* and *way of life*. But I want to stay with the centrality of *difference* per se first. Aristotle tells us that animals can be different to a greater or lesser degree: they may differ *in form* from one another while being *the same in kind*; and they may be *different in kind* while being the same "by analogy". But the complex, ever-active diversity of life was not to be swept under the rug or explained away, it was to be celebrated, carefully studied and explained,

[6] *Metaph.*, A.1, 980 a 22-27.

[7] *Historia animalium*, 487 a 10-13. Emphasis added.

for therein lies *knowledge* of animals – a point he stresses at the opening of his famous encomium to the study of life in *Parts of Animals* 1.5:

«Among beings constituted by nature, some are ungenerated and imperishable throughout all eternity, while others partake of generation and perishing. Yet it has turned out that our studies of the former, though they are valuable and divine, are fewer. … We are, however, *much better provided in relation to knowledge about the perishable plants and animals*, because we live among them. […] The perishable beings *take the prize in respect of understanding because we know more of them and we know them more fully*. Further, because they are nearer to us and more of our own nature, they provide a certain compensation compared with the philosophy concerned with divine things».[8]

While the eternal beings are, at least in some senses, ontologically superior, it is the animals and plants around us that are epistemically superior. And, provided we approach the study of living things in the appropriate way, there are things at which to marvel, even in the most lowly of creatures:

«[…] for the nature that crafted them provides extraordinary pleasures to those who are able to know their causes and are by nature philosophers».[9]

In urging us to move forward in the inquiry into each of the animals without disgust, he insists that in all of them there is something natural and beautiful (φύσικος καὶ κάλος, 645a23); and he grounds *that* claim teleologically:

«For what is not haphazard but rather for the sake of something is in fact present most of all in the works of nature (ἐν τοῖς τῆς φύσεως ἔργοις); the end for the sake of which each animal has been constituted or has come to be takes the place of the beautiful (τὴν τοῦ καλοῦ χώραν)».[10]

When I translated these passages for the Clarendon Aristotle Series in 2001, I was so concerned to counter the rather 'romantic' tendencies of earlier English translations that I resisted various natural translations of καλόν here and simply translated it as 'good', leaving it to the commentary to note its moral and aesthetic connotations. I now believe that was a mistake. Aristotle is making a rhetorically powerful move here: if one engages in an inquiry into the most ugly animal in the appropriate way – as a philosopher – you will see *beauty* and something akin to *nobility*. And that appropriate, philosophical form of inquiry is inquiry focused on "the end for the sake of which each animal has come to be". He spells out this point in some detail as this encomium closes:

«If someone has considered the study of the other animals to lack value, he ought to think the same thing about himself as well; for it is impossible to look at that from

[8] *Parts of Animals*, 644 b 23-645 a 4, selections. Emphasis added.
[9] *Parts of Animals*, 645 a 9-11.
[10] *Parts of Animals*, 645 a 24-27.

which mankind has been constituted – blood, flesh, bones, blood vessels, and other such parts – without considerable disgust. […] One should consider the discussion of nature to be referring to *the composite and the overall substantial being* rather than to those things [e.g. the parts listed above] which do not exist when separated from their substantial being».[11]

Aristotle, then, embraced the diversity of the living world as an *explanatory* project – and at the center of the explanatory project is a fundamental principle of natural inquiry: «nature does what is best for the substantial being of each kind of animal»[12]. An *Aristotelian* biology will be robustly teleological. The 'overall substantial being' on which the philosophical naturalist should focus, is *that for the sake of which* each animal has come to be, its 'final cause', which is its soul or 'principle of life'. In an Aristotelian investigation of the living world, that cause takes precedence over material and efficient causes. But it also 'takes the place of the beautiful/noble' – for after all, as he tells us early in *PA* I: «That for the sake of which and the beautiful is more present in the works of nature than in the works of art»[13].

The works (ἔργα) of nature! "Works" is a good translation, for it harbors precisely the same ambiguity as the Greek word it translates, ἔργα – both can refer either to the end product of productive activities or to the productive activities themselves. Think of the *work* of the artist and his *works* of art!

But it is often, and equally appropriately, translated "function", and in Aristotle's biology the word most commonly refers to what the parts of animals do, their characteristic activity. What the translation 'function' stresses is that the activity of a part plays a role within the overall life of the organism. A part's function is what it is *for*, the reason why the animal has precisely the part that it does. This brings us, via slightly different but closely related routes, to the relationship between two of our key concepts: Form (εἶδος) and Function (ἔργον).

2. 2. *Form*

For the last 30 years I have been insisting that it is multiply misleading to translate the Greek word εἶδος as 'form' in certain contexts and 'species' in others[14] – if key metaphysical terms are 'said in many ways', Aristotle goes out of his way to tell us so. He does not do so for εἶδος. Kinds (γένη) are differentiated (or divided, if we are doing the differentiating) into forms; and Aristotle's occasional association of kind with matter and form with final or complete differentia(e) gives us a hint of a different way of thinking about these two

[11] *Parts of Animals*, 645 a 25-36, selections. Emphasis added.
[12] *IA* 2.704b16-17.
[13] *PA* 1, 639 b 19-21.
[14] See especially Lennox 2001b [1987]; Lennox 2001a, pp. 122-23.

concepts, rather than the comfortable 'genus' and 'species' – forms of a kind are something like *variations on a common theme*.[15]

When discussing identity and difference of form and kind in his biology, there was a notion of kind that took on special importance for him. Only rarely does he explicitly designate animal groups as great or extensive kinds (μέγιστα γένη),[16] and even when he does so he is not thinking in terms of what post-Linnean biologists might call a particular taxonomic level. Rather, he is thinking of *groups of animals that share an overall body plan, way of life, and parts with corresponding functions that, while identifiably the same, differ along various perceptible axes in ways that he sometimes designates as «more and less" or "excess and defect»*.[17] In introducing his discussion of the cephalopods in *Historia Animalium* IV, for example, he reviews the parts they all share and their shared, distinctive, body plan:

«Among the animals called 'soft-bodies' these are the external parts: 1. the so-called feet; 2. the head, continuous with the feet; 3. the sac, containing the internal organs, which some mistakenly call the head; 4. the fin, which encircles the sac. In all of the soft-bodies the head turns out to be between the feet and the belly. Moreover, *all* have eight 'feet', and *all* have two rows of suckers, *except* for one kind of octopus. The cuttlefish, and the large and small calamary have a *distinctive* feature, two long tentacles, the ends of which are rough with two rows of suckers, by which they capture food and convey it to their mouth and fasten themselves to a rock when it storms, like an anchor».[18]

Parts of Animals IV. 9 is devoted to explaining, in both material and functional terms, all of these differences, in a rich discussion that is constantly drawing upon comparisons and contrasts with the crustaceans and mollusks.[19]

A key concept in understanding shared differences such as these from an Aristotelian point of view is "way of life" (βίος) – one of his four major categories of difference around which the *History of Animals* is organized. A rich discussion of this concept for our purposes is to be found, interestingly, in his *Politics*.

[15] For the association of kind with matter and form with differentia, see *Metaph*. Z.12, 1033a5-9, 1033a25-26; I.8, 1058a17-28.

[16] *PA* I. 4, 644a13-23, 644b1-16. *HA* I.6, 490b7-491a6; II.15, 505b24-32; *HA* IV.1, 523a31-b21; *PA* IV.8, 683b-684a1. Notice that the last text referred to discusses *megista genê* of the soft-shelled animals, or crustaceans. That demonstrates the 'extension neutral' nature of this term. What underwrites its application is a kind with many forms that differ by more-and-less, i.e. continuous, differences, *not* a particular taxonomic level.

[17] *PA* I.4, 644 a 18-23, b8-16; *HA* I.1, 486 a 15-b22.

[18] 523 b 21-33.

[19] Aristotle describes in brilliant detail similarities in overall morphology between his 'soft-bodied animals' (cephalopod mollusks) and 'hard-shelled animals' (testaceous mollusks).

«But furthermore, there are many forms (εἴδη) of nutrition, for which reason there are also many ways of life (βίοι) both among animals and among human beings; for it is not possible to live without nutrition, so that differences in nutrition have produced differences in the ways of life of animals. For among the wild animals some are nomadic and some are solitary, whichever is best suited to their nutrition, on account of some of them being carnivorous, some frugivorous and some omnivorous. So nature distinguishes their ways of life in relation to their preferences and inclinations. But since what is by nature flavorful is not the same for each animal but different for different animals, even among those that are carnivorous or frugivorous ways of life are divided relative to one another».[20]

Here the contrasting ways of life are tied closely to nutritive activities, but elsewhere he makes precisely the same points about reproduction. Aristotle rightly thinks that most animal activities, and therefore most of an animal's anatomy and physiology, are oriented around these two activities, which in the end, as we will see in the next section, are the activities of self-maintenance and, as he would put it, *form*-maintenance – for the processes involved in generation or development, including mating, nest or den building and maintenance, and the raising of young after birth are all, as Aristotle sees it, engaged in the process of formal replication, the producing of off-spring who are like the parents in form. More on that later.

Aristotle was deeply insightful to recognize the importance of these groupings – an insight which provides a student of life with a clearly marked path from what is given in perceptual experience to what is causally fundamental.[21] Fish *are* all the same when you compare them with birds – and it was Aristotle's brilliance to figure out how to capture that sameness philosophically, so that it could be applied across the animal kingdom. He tells us, in essence, that the Greek language already recognizes this kind/form structure in the case of fish and birds. But he notes that Crustacea too *are* all the same, when compared to Cephalopods… and vice versa.[22] Track all those more and less

[20] *Pol.* I 3. 1256a20-29; emphasis added.

[21] It is the same sort of insight that inspired Georges Cuvier to identify four embranchments of animals, Geoffroy St. Hilliare to identify his types, and Richard Owen to introduce the concept of homology.

[22] The groups he most often uses in practice as μέγιστα γένη fall into two even broader categories, blooded and bloodless (roughly equivalent to our vertebrate/invertebrate distinction). The blooded kinds are [i] four legged live bearing animals (land mammals), [ii] four legged egg laying animals (reptiles and amphibians, [iii] cetaceans, [iv] birds and [v] fish; the bloodless kinds are [i] insects, [ii] crustaceans, [iii] cephalopods, and [iv] testaceans. But as discussed in the previous note, the term 'great kind' can be used of groups of narrower extension (e.g. sub-kinds of crustacean), provided they meet the criteria of having many forms within them varying by more-and-less differences. And as a moment's reflection on these categories shows, Aristotle is not at all interested in a set of categories that ex-

differences down from those shared features and you get distinct *forms of crustacean*, and then *forms of lobster or crab*, and then *individual forms* of lobsters or crabs, always just *more and more determinate forms of their shared crustaceous nature*. Near the end of *PA* 1.4 he sketches how this method works for parts:

«Roughly speaking, it is by the figures of the parts and of the whole body that kinds have been defined, when they bear a likeness – e.g. members of the bird kind are so related to each other, as are those of the fish kind, the soft-bodied animals [cephalopods] and the hard-shelled animals [testaceous mollusks]. For their parts differ not by analogous likeness, as bone in mankind is related to fish spine in fish, but rather by bodily affections, e.g. by large/small, soft/hard, smooth/rough, and the like – speaking generally, by the more and less».[23]

In the next chapter, after reminding us of what he said about parts in the previous chapter, he insists that we should think about animal *actions* in the same way, for they too can be common to all, differ in kind, or differ in form:[24]

«Therefore one should first discuss actions – those [actions] common to all, those [actions] according to kind, and those [actions] according to form. I call 'common' those [actions] that belong to all the animals, and 'according to kind' those [actions] whose differences from each other we see are in degree […]».[25]

As we are about to see, the notion of 'action' (πρᾶξις) here is, at least when applied to an animals organs, equivalent to the concept of function. We have come to the point where Aristotle has told us that there is a parallel 'kind/form' structure in animal activities and animal parts; we are about to see that this parallelism underwrites one of the explanatory projects at the heart of an Aristotelian biology: using the differences in an animal's functional activities to explain the differences in an animals morphological features – in effect the project of functional morphology, as we will see in the final section of this paper.

As an example of Aristotle putting this network of concepts to use I will look very briefly at his discussion of the external parts of birds in his *Parts of Animals*. He begins by noting the centrality of this pattern of differentiation:

«Among birds, differentiation of one from another is by means of excess and deficiency of their parts, i.e. according to the more and less. That is, some of them are long-legged, some short-legged, some have a broad tongue, others a narrow one, and likewise too with the other parts».[26]

hausts the animal kingdom – he notes repeatedly that there are many organisms that don't fit into these categories (including human beings) and they need to be treated as distinctive forms (cfr. *PA* 1.4, 644b1-7).

[23] 644 b 8-14. [24] 645 b 20-27. [25] 645 b 20-23.
[26] *PA* IV, 12. 692 b 3-6.

And in explaining the coordinated nature of these differences between one form of bird and another, differences in ways of life are the key:

«those that are long-legged have a long neck, while those that are short-legged have a short one…for if the neck were short in those with long legs, the neck would not be of service to them for eating food off the ground; nor if it were long in those with short legs. Again for those that eat flesh a long neck would be contrary to their way of life (βίος) […]».[27]

The key insight here, on display in an earlier passage explain different kinds of mouths in different animal kinds, is recognizing that continuously varying traits vary as they do as *coordinated* adaptations to distinctive ways of life.

«The beak differs according to the use to which it is put and the protection required. For all birds called crook-taloned have their beak hooked *because they are carnivores* and eat no seeds*; such a beak is by nature useful for mastering prey and is more powerful. But their strength lies both in this part and in their talons, which is why they also have their talons more curved. And in each of the other birds the beak is useful for its way of life* (βίος); for example, for the woodpeckers, crows and crow-like birds the beak is strong and hard, while for the small birds it is hollow for collecting seeds and grasping mites».[28]

And while Aristotle does not emphasize this sort of explanation as much in his discussion of the internal parts, he makes it clear that he is committed to doing so as part of his overall research program.

«Moreover, just as the use of the external parts is not the same for all animals, but has been provided in a particular way to each of them in relationship to their ways of life and movements, in the same way too the internal parts are by nature different in different animals».[29]

Consider those organs that we think of as supplying the blood with oxygen and which Aristotle thought of as cooling it: lungs and gills. Aristotle tells us that animals have lungs on account of being land dwellers (διὰ τὸ πεζὸν εἶναι) while fish have gills because they are water dwellers – that is, cooling must be performed in a way that fits the animal's life. Yet cetaceans, though water dwellers in all other respects, have lungs and breathe! And there is an even stranger case than the cetaceans:

«[…] There are also water animals of a different sort [than fish], on account of the blend of their body and their way of life, namely those that, though they take in air, live in water, as well as those that, though taking in water and having gills, progress to a dry environment and eat there. Up till now only one such has been observed, the

[27] *PA* IV, 692 b 19-693 a 6.
[28] *PA* III 1. 662 a 34- b 9; emphasis added.
[29] *PA* III 4. 665 b 1-5.

one called 'kordylos';[30] for though it has not a lung but gills, yet it is four-legged as if in fact it had developed naturally to walk».[31]

This is an even more serious puzzle that cetaceans. We have here a creature that is, from a locomotive standpoint, clearly a land dweller. Yet it is adapted to cooling by gills rather than by lungs. His understanding of an animal's way of life must accommodate such cases – an animal's way of life is explanatory pay-dirt. His only attempt to offer a deeper explanation for an animal's way of life – and he does so only rarely – is by a study of the animal's material make up which may suggest that there is a match up between where they search for food and their "bodily blend".

2. 3. *Function*

Recall Aristotle's introduction of the idea that there are variations in animals' activities that parallel the structure of variation in their parts:

«Therefore one should first discuss actions – those [actions] common to all, those [actions] according to kind, and those [actions] according to form. I call 'common' those [actions] that belong to all the animals, and 'according to kind' those [actions] whose differences from each other we see are in degree…».[32]

This passage begins with the word 'therefore' (ἄρα), which is followed by a prescription: one *should* first discuss actions, τὰ πράξεις. The 'therefore' suggests that this prescription follows from what was just said previously – and what *was* just said? Why *should* we first discuss actions?

«Since every instrument [ὄργανον] is for the sake of something, and each of the parts of the body is for the sake of something, and what they are for the sake of is a certain action [πρᾶξίς τις], it is apparent that the entire body too has been constituted for the sake of a certain complete action.[33] For sawing is not for the sake of the saw, but the saw for sawing; for sawing is a certain use. So the body too is in a way for the sake

[30] In correspondence with me, Dr. J. W. Arntzen of the Netherlands Centre for Biodiversity in Leiden has suggested that Aristotle is most likely referring to a so-called *paedomorphic* newt (semi-aquatic salamander), that is, a newt that has retained some of its immature characteristics into adulthood. Such a newt would be full-grown but would retain its gills. He reports that in Southeastern Europe there are three newt species in which paedomorphic individuals appear regularly: *Lissotriton vulgari*, *Ichthyosauara alpestris*, and *Triturus macedonicus*. These three species vary considerably in size and color, but since Aristotle says nothing about either the size or color of his *kordylos*, this information is of no use. Dr. Arntzen reports that the phenomenon of paedomorphosis is more regularly found in mountain populations of *Ichthyosauara alpestris* than in the other two species. Aristotle would have every reason to believe that the paedomorphic members of a population were a different kind of newt.

[31] 589 b 22-28.

[32] 645 b 20-23.

[33] Τὸ σύνολον σῶμα συνέστηκε πράξεώς τινος ἕνεκα πλήρους (645 b 17).

of the soul, and the parts are for the sake of the *functions* [τῶν ἔργων] in relation to which each of them has naturally developed».[34]

We should first study actions because the similarities and differences in parts and bodies as a whole are *for the sake of* performing certain activities or functions and living certain kinds of lives. Let us focus in this passage on the connection between body and soul, on the one hand, and parts and functions, on the other. The first sentence embeds a teleological conception of the organism within a wider, instrumental teleology: Aristotle often explicitly invites us to think of non-uniform parts as 'instrumental', ὀργανικὰ.[35] The claim that the parts are what they are *for the sake of* certain activities is a pervasive theme in Aristotle's investigation of animals – but here he immediately infers *a teleology of the entire body* from the fact that each of its parts is for the sake of a specific action. That is not an obvious inference either in Aristotle's context or our own. A quite typical approach to adaptation within a Darwinian framework is to see each trait as an independent response to an independent selection pressure – it has been a bone of contention throughout the history of biology whether such an inference is licit or not.

One might think of this inference in a sort of 'additive' way – something like: each part is for the sake of an activity, the whole body is the sum of its parts, hence the whole body is for the sake of the sum of its activities.

In fact to see the passage in this way would be deeply mistaken. In his *De anima* (*On the soul*) he first identifies soul as the *form* of a living body, but then notes that in the case of living beings, form is to be understood as first realization (πρῶτη ἐντελεχεία), and then provides a general definition of soul as 'the first realization of a natural, organic (or instrumental) body'.[36] By 'first realization' he has in mind, as he makes clear, the distinction between an organism with a fully developed, integrated set of living *capacities*, *poised* for action, and the organism fully in action (the cheetah sitting on a rock surveying a herd vs. actually running down its prey, the caterpillar sitting on a leaf vs. actually spinning its cocoon).[37] That is, for Aristotle the idea of the whole organism as a functional unity is bedrock in much the same way that the idea of a way of life is. That the performance of its living activities requires distinguishable parts with their own specific functional capacities come second. As we will see presently, this is a way of thinking about organisms that motivated the organismal biologists (at least some of whom realized its Aristotelian roots) in the first half of the 20th century, and is reemerging in the 21st century, as people have realized the centrality of the self-organizing and self-maintaining powers

[34] 645 b 15-20.

[35] 646 b 26, 647 a 3-5, 656 a 2, 687 a 10, 19.

[36] *De anima* II.1, 412 a 20 – b 1.

[37] Of course when surveying the herd the cheetah is actively using her senses, and when sitting on the leaf the caterpillar might well be actively eating or digesting.

of organisms in accounting for the integrated nature of the physiological and biochemical processes associated with their organ systems, organs, cells and sub-cellular processes.[38]

To re-orient biology in that direction is to steer it in the direction of a neo-Aristotelian biology – but only if this idea is integrated with some equivalent of Aristotle's concept of a way of life that itself serves to explain the *coordination* among the more and less differences in both structure and function in the different forms of animal.

2. 4. *Development*

One major debate, taking place in biology today, is over the need to integrate evolutionary and developmental biology, and among those who agree on the need exactly how to accomplish that integration. Aristotle wrote the first really great treatise on developmental biology, his five book long treatise, *On the Generation of Animals*. He had no idea that this subject would ever need to be integrated with evolutionary thinking, of course – but he did feel a powerful need to justify the study of biological generation as a distinctive aspect of the scientific study of animals, and that need turns out to be philosophically relevant to the concerns of this essay.

There are two levels to Aristotle's felt need to defend the study of animal generation as an autonomous part of zoology. At the most abstract level, the shadow of the Eleatic denial of *any sort* of coming to be still cast a dark shadow over Greek natural science, a fact about which any student of Plato's would be deeply concerned. Parmenides begins with the axiom that what is, is and what is not, is not; he adds to that the equally axiomatic thought that nothing can come to be from nothing. But if what is, is, and nothing can come to be from what is not, it would seem that coming to be is simply impossible.

Aristotle's abstract response to the Eleatic denial of change begins in *Physics* I: after reviewing the failed attempts of his predecessors to come to grips with the problem in its first six chapters, chapter 7 distinguishes the continuously existing subject undergoing a change from the opposing 'contraries' at either end of a process of change and acknowledges that the way in which we talk about change often confusingly masks this distinction from us. This analysis provides a basic framework within which *what is X* may come to be from *what is not-X*.

However, Aristotle acknowledges that while this analysis works well for cases in which an entity undergoes a change of place, size or quality, e.g. a cheetah *running* from one place to another, or a *growing* cub, or a cub *changing its color* as it matures, it does not obviously accommodate the case of a new

[38] See Nicholson 2014; Walsh 2015; Russell 1924.

cheetah coming to be. He *asserts* that this framework will also accommodate such cases – but how this framework will apply to a fertilized egg becoming a fully developed cheetah, butterfly or a dolphin he gives not the slightest clue.

His intentional avoidance of this problem in the *Physics* accounts for the fact that there is a separate treatise *On Generation and Corruption*, defending these opposed changes as irreducibly different forms of change, changes in the category of substantial being, i.e. the coming into being of that which *is* the substratum of all *other* changes. There are three categories of such change for which he owes the reader of the *Physics* an account: [i] elemental transformation, [ii] the production of uniform bodies defined by emergent properties/powers not instantiated in the elements (elasticity/rigidity, hardness/softness, compressibility/density, etc. – and [iii] the generation of organisms, which «we say are most of all substantial beings».[39]

In this last category, as Aristotle explains as he opens his explanatory account of animal parts in *PA* II, we find *all three forms of unqualified generation in one process*. Priority in order of coming to be does not reflect teleological or conceptual priority, however:

> «Thus the matter of the elements [by which he means their four primary powers, hot, cold, moist, dry] is necessary *for the sake of* the uniform parts, since these are later in generation that the elements, and later than the uniform parts are the non-uniform parts; for these have already attained their end and limit, have achieved a constitution of the third sort, as often happens when generations are completed».[40]

It is here that Aristotle realizes one of his greatest philosophical achievements. All of his predecessors responded to Parmenides by accepting that Being, the Real, does not change and by treating the world of changing things as either illusory, a accidental by product of chance or a realm of chaotic flux utterly devoid of being. Aristotle responded by seeing substantial beings, principally living beings, as the culmination of a complex, orchestrated, goal-directed process of coming to be.

How does he understand this process?

In *De anima* II.4 he makes the provocative claim that nutrition and generation are manifestations of «the same capacity (or power; δύναμις)»[41], and that this is the «primary and most common capacity of soul»[42]. The thought behind that provocative assertion is that the very capacity that in the fully mature organism *maintains* its being as the kind of organism it is, is transmitted, during copulation, from the male parent to the female seed[43] – at which point

[39] «…ἅ μάλιστα λέγομεν οὐσίας εἶναι» (*Metaph.* Z.7, 1032 a 19-20).
[40] 646 b 5-10. [41] 416 a 19-20. [42] 415 a 23-26.
[43] Which Aristotle imagines as a worked up portion of the menstrual fluid (or some analogue in non-menstruating animals).

it begins producing another fully mature organism of the same kind.[44] Aristotle imagines that a special kind of heat – special in what way will be explained momentarily – is the bearer of this capacity, both in the metabolic processes of a mature organism and in the generative process. He presents evidence that, though that heat is conveyed to the female seed by means of semen, its active component is the warmth of its *pneuma* (a sort of air that is produced within the organism), and it is only that warmth that plays an active, causal role in development. But that warmth has a *logos* (not unlike a developmental program), which represents the form of the kind, transferred from the male.[45] The fact that this psychic heat has a *logos* is definitive of its being the nutritive/generative capacity it is, and as the following passage makes clear, it controls all of the sub-generative activities insuring that they are appropriately ordered.

«Now the uniform parts and the instrumental parts come to be simultaneously. And just as we would not say of an axe or any other instrument that it was made only by fire, so too with foot or hand – and in fact in the same way with flesh, for it too has a function. Now hard, soft, toughness or brittleness, and any other affections that belong to ensouled parts, heat and cold might produce these; but not the *logos* by which one part is flesh and another is bone – rather it is the motion from the generator, being in full realization (ἐντελέχια) what that out of which the offspring comes to be is potentially».[46]

He goes on, by way of analogy, to note that while heating and cooling play a very important role in softening and hardening the iron, it is the motion of the iron-worker's instruments, guided by "the *logos* of the craft" that make the sword; and that it is the craft that is the source and form of the sword, while it is the motion derived from the nature of an actual animal of a certain form that is the true source of biological generation.[47] Aristotle is impressed enough with this process, by which biological forms – souls – are endlessly replicated, that he even claims that it permits a living thing to «participate in the eternal and divine» – but in the same breath says that it is the "most natural" of an organism's formal capacities.[48]

[44] *De anima* II.4, 416b18-32. If one sought a modern analogue, recall that the very same genetic machinery that is operative in the cells of mature organisms is combined in the fertilization of an egg and is operative in the process of development period.

[45] It is the power or capacity of this special heat that Allan Gotthelf aptly dubbed 'an irreducible potential for form' (Gotthelf 2012, chapter 1, esp. 24-29). Compare: «Species-specific genomic programs consist of large networks of interacting regulatory genes that directly control the spatial and temporal gene expression in the developing animal. Evolutionary changes in animal morphology reflect changes in these *encoded genomic regulatory programs for development*» (Davidson and Erwin 2010).

[46] *GA* II.1, 734 b 28-35.

[47] 734 b 36-735 a 9.

[48] Cfr. *De an.* II.4, 415 a 26-415 b 7; *GA* II.1, 731 b 18-732 a 1.

3. Aristotle and a 21st century Philosophy of Biology

It should now be clear that the advent of an evolutionary understanding of the world has very little to do with whether biology is or is not Aristotelian in outlook – though some were critical of Darwinism, none of the organismal biologists had any doubts about evolution. It was not an evolutionary perspective *per se* that led philosophers such as David Hull or biologists such as Ernst Mayr to see an enormous gulf between Aristotle and evolutionary biology; it was the sort of evolutionary biology that emerged from the synthesis of Mendelian genetics and mathematical selection theory, an evolutionary biology that disintegrated whole organisms into a collection of independent traits clustering in design space;[49] that thought of populations of organisms as 'gene pools'; and that treated generation as ultimately irrelevant, since evolution was simply shifts in the frequencies of genes in gene pools due to selection acting on independent phenotypic traits.

And in fact, as Daniel Nicholson and others have recently been pointing out, there is a renewed interest among certain theoretical biologists and philosophers of biology in conceiving of the organism as an irreducible locus of explanation, and in concepts like 'self-organization' and 'self-maintenance', and a robustly teleological concept of biological function and development associated with these concepts. These thinkers are of the view that the processes associated with evolution will only be well understood once biologists return to a focus on the living, active organism as the explanatory center of biology. As Nicholson recently put it:

«This more nuanced characterization of *the organism as a self-organizing and self-maintaining autonomous system* far from thermodynamic equilibrium can be used to elucidate a number of features associated with life. Specifically, it may hold the key to naturalizing rather elusive notions like *function, normativity, and agency*. Let us begin with function. A number of authors have recently articulated an *organizational* account of biological function according to which the attribution of functions to parts of an organism is deemed to be determined by the means in which each of the parts individually contribute to the realization of the systematic organization that generates and maintains them»[50]

Denis Walsh makes a similar point while focusing, not on function, but on development:

«The most remarkable feature of organismal development that has come to light in the past twenty years is its supple, self-organizing adaptiveness (Kitano 2004). The

[49] In fairness, this was one aspect of the Synthesis of which Ernst Mayr was a staunch critic. See Mayr 1963, pp. 162-185.

[50] Nicholson 2014, p. 355; emphasis added.

processes of development respond to perturbations in ways that preserve and maintain the organism's viability across a wide array of circumstances».[51]

These scholars[52] are in part reminding us of an alternative research program to neo-Darwinism in the first half of the 20th century, that of the *organismal* biologists.[53] While a number of these biologists, particularly those in Great Britain associated with the 'Theoretical Biology Club', took their philosophical inspiration from Alfred North Whitehead, there was also a shared conception of living beings that was distinctively Aristotelian. In the view of these organismal biologists, the capacities (or powers) of organisms for highly organized, adaptive activity are not what living things *have* and *do* – they are what living things *are*, at different stages of realization. Focused on the functional unity of the organism, E.S. Russell expresses the organismal point of view as follows:

«From the point of view of function, the unique character of the living individual as the fundamental unit of biology stands out unmistakenly, for the individual is essentially a functional unity, whose activities are co-ordinated and directed towards the development, maintenance, and reproduction of the form and modes of action typical of the species to which it belongs».[54]

Shifting his focus to development, Russell stresses the goal directed nature of biological generation:

«That in development there is a definite progression to an end or goal, i.e. a reference to the future, cannot be denied. That the course of development is essentially influenced by the past history of the race is likewise difficult to deny [summed up] in the laws of heredity and recapitulation».[55]

In one central passage, Russell does a fine job of giving unified expression to

[51] Walsh 2015, p. 124.

[52] See Esposito 2013, pp. 165-180; Walsh 2015; Nicholson 2014; Nicholson and Gawne 2015.

[53] Though there was no uniform set of doctrines that all of the following list of people accepted (any more than there was with the neo-Darwinians), people who were happy to designate themselves 'organismal' and who formed a network of communication and support were E.S. Russell, Yves Delage, Joseph Needham, H.J. Woodger, Paul Weiss, W.E. Ritter, F.R. Lillie, L. von Bertalanffy, C.H. Waddington, and (interestingly) J.S. Haldane -interestingly, because he is the father of J.B.S. Haldane, who is often listed as one of the founders of "the neo-Darwinian synthesis". Russell credits W.E. Ritter for coming up with the term 'organismal', which was self-consciously formed in opposition to both mechanism and vitalism. (Cfr. Esposito 2013, for a full discussion of this network.)

[54] Russell 1932, p. 166. It should be noted that the second chapter of *Interpretation* is devoted to an interpretative reading of Aristotle's *Generation of Animals*. Russell was close friends with D'Arcy Wentworth Thompson, author of *On Growth and Form* and translator of Aristotle's *History of Animals* for Oxford University Press.

[55] Russell 1932, p. 169.

all of the Aristotelian aspects of the organismal point of view, on which I have focused:

«…all [an organism's] functions are directed to one or other of three great ends, namely the *development* of specific form and activities, the *maintenance* or restoration of such typical form and activities, and the reproduction of specific type. None of these broad characteristics of living things is shared by any machine».[56]

Notice that Russell nearly always conjoins 'form' with 'activities' in characterizing the unity of the organism. For Aristotle, as we've seen, form would be the organized capacities for those activities, and the *unity* of an organism's activities would ultimately be accounted for by the organism's distinctive way of life.

Nevertheless form as it is used in biology today typically refers to morphology or structure – albeit with the underlying assumption that biological structures are loci of capacities for various functions. For Aristotle the organizing principle behind the integrated structures and activities of living things was the concept of a 'way of life'. The area of contemporary biological research in which I find an echo of this particular aspect of Aristotle's approach to biology is *ecological morphology*. Research in this field seeks to develop an understanding of the overall bodily organization of an organism as a function of its complex relationship to its environment.[57] As the authors of a volume of essays in this area of research note,

«Such a holistic approach to studying organismal form and function clearly requires the integration of information from what are normally considered to be separate disciplines of biology».[58]

What is key here is the study of each organism's distinctive activities interacting with its environment, that is, integrated around its distinctive way of life.

4. Conclusion

The goals of this paper have been two: [i] to present a rich enough picture of Aristotle's philosophy of biology, including his metaphysical understanding of life and living beings, to construct a picture of an Aristotelian Philosophy of Biology and [ii] to consider recent developments in philosophy of biology and theoretical biology that suggest what a neo-Aristotelian philosophy of biology might look like. In working toward this second goal I have noted that historians and philosophers of biology have found it helpful to look back to the organismal biologists who were active in the first half of the 20th century – some of whom were well aware of the echoes of Aristotle reverberating in

[56] Russell 1932, p. 6.
[57] See the papers in Wainwright and Reilly 1994.
[58] Wainwright and Reilly 1994, p. 1.

their work. What I have made *no* attempt at here is to consider how this point of view might be integrated with the undoubted accomplishments of evolutionary biology and molecular genetics. That is a task for others and for the future.

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Abstract: *In metaphysics and philosophy of science, a significant movement is making inroads, under the banner of 'neo-Aristotelianism'. This movement has so far been focused primarily on the physical sciences; but given that Aristotle the natural scientist was above all a biologist, it is worth asking what a neo-Aristotelian philosophy of biology would look like. In this paper, I begin a discussion on precisely that question. One interesting result is that the fact that biology is now permeated by evolutionary ways of thinking is all but irrelevant to answering that question. Far more important is how central are concepts of organic form, function and development to biology. Given recent developments, there are reasons to think at least some areas of the biological sciences would welcome a neo-Aristotelian philosophy of biology – i.e. a critical exploration of these concepts from an Aristotelian perspective.*

Keywords: *Aristotle, biology, neo-Aristotelian philosophy of biology, philosophy of science.*