CHAPTER 1

Aristotle and Theophrastus on plant-animal interactions

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Abstract. Aristotle and Theophrastus, the last great philosophers and scientists of Greek Classical Antiquity, are the founding fathers of Zoology and Botany, respectively; they should also be honoured as the co-founders of Biology. They were close friends and life-long collaborators who evidently decided to pursue an organized study of the living world, probably in Lesbos at 344 BC (the landmark for the creation of the Science of Biology). The product of their division of labour, the voluminous zoological and botanical works of Aristotle and Theophrastus, respectively, were actually used contemporaneously as university textbooks by the students of the Lyceum.

Besides numerous comparisons and analogies, mostly on general issues, between animals and plants, both Aristotle and Theophrastus deal with various cases of plant-animal interactions, covering virtually all aspects of the field. Their scientific approach is notable, although the barriers to knowledge imposed by their era did not permit a significant contribution on issues like plant sex and pollination. Their important accomplishments on plant-animal interactions include herbivory and poisonous plants, plant pests and use of manure, insect-repellence and gall formation, fig caprification and apiculture, seed dispersal and seed infestation.

Introduction

Aristotle (384-322 BC) and Theophrastus (371-286 BC) should be considered as the last great philosophers of Greek Classical Antiquity. They represent, in particular, the culmination of the natural philosophy of the Ionian scientific tradition which was inaugurated on the Aegean coast of Asia Minor, several centuries earlier, and reached its climax on the opposite coast, at the brightest cradle of Ionian civilization, Athens. It should be borne in mind, however, that both Aristotle and Theophrastus were not Ionians but Macedonian (Dorian) and Aeolian, respectively; accordingly, they never became full citizens of Athens. During their lifetime they experienced the decline of the City-State system of Classical Greece and its eventual replacement by a more or less unified Greek State dominated by the northern Greeks (the Macedonians), under the leadership of Alexander the Great.

Aristotle was born at Stagira of Chalcidice (Macedonia) and his father Nicomachus was a physician at the court of Amyntas C', father of Philip B'. At the age of 17, Aristotle moved to Athens where he studied and subsequently taught in Plato's Academy. Although by far the most brilliant among Plato's pupils, Aristotle was not appointed as the new director of the Academy after Plato's death (347 BC). Apparently as a result of his non-designation and with a team of colleagues and followers, he travelled to Assos of Troad (Asia Minor) and founded a new school there. Unfortunately, the venture came to an abrupt end three years later with the assassination of the patron of the school, Hermeias, the hegemon of Assos.

It is at that difficult moment in Aristotle's life that Theophrastus seems to have played a prominent role; probably, at his suggestion (Morton, 1981), the two men moved to the nearby island of Lesbos, in the North Aegean Sea. Theophrastus (his original name was Tyrtamos) was born at the Lesbian town of Eresus and his father, Melantas, was a local fuller. It is probable that at an early age (ca. 355 BC) he went to

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Athens and enrolled in the Academy, where he was acquainted and associated with Aristotle. According to Morton (1981), Aristotle evidently took to the highly intelligent, industrious and good-natured young man, who became his close friend and life-long collaborator.

After an apparent rest at Lesbos for two years (344-342 BC), Aristotle received an invitation by Philip B', king of Macedonia, to serve as a tutor for his teen-aged son, the future Alexander C' the Great. So Aristotle returned to his native country where he spent several years at the royal court, in the capital Pella, teaching the young prince 'το ευ ζην' (in free translation 'the quality of life'). Although there is no direct information, it seems highly probable that during his sojourn in Pella and afterwards in Stagira (when Alexander came of age), Aristotle was accompanied by Theophrastus.

In 335 BC, immediately after the struggle over domination of Greece was finally decided in favour of Macedonia, Aristotle returned to Athens, together with Theophrastus, and founded the Lyceum. After Alexander's death (323 BC), Aristotle had to flee Athens for Chalcis, Euboea where he died a few months later. Theophrastus became the second director of the Lyceum and the Peripatetic School (the name of the school was derived by the habit of lecturing while strolling around the gardens of the Lyceum) which reached its apogee of success during his 37 years of administration. The function of this institution was to train the leaders, officials and experts of the new era (Morton, 1981). Like its rival Academy, the Lyceum was a true University of its epoch: an up-to-date curriculum emphasizing the observational sciences, numerous lecturers, as many as two thousand students and a spacious, well designed campus with buildings and open-air facilities, a very important library, a museum and the first botanical garden.

Aristotle is generally considered one of the greatest Ancient Greek philosophers and during his rather short lifespan he wrote on virtually everything (in possibly as many as 400 works). Besides his philosophical treatises, he has left a number of voluminous works on natural history, the most important among them being the following (all of them fortunately extant): *Περί τα ζώα ιστορίαι, HA* (Historia Animalium, History of Animals, in 10 Books), *Περί ζώων μορίων, PA* (De Partibus Animalium, Parts of Animals, in 4 Books), *Περί ζώων κινήσεως, MA* (De Motu Animalium, On the Movement of Animals, 1 Book), *Περί πορείας ζώων, IA* (De Incessu Animalium, Progression of Animals, 1 Book), *Περί ζώων γενέσεως, GA* (De Generatione Animalium, Generation of Animals, in 5 Books). The first work could be compared to what is currently considered a General Zoology text, whilst the second is the earliest treatise on Animal Physiology (the latter works covering more specialized fields). The also extant work *Περί φυτών* (De Plantis, On Plants, in 2 Books) that is included in Aristotle's minor works, is definitely not by him. It was almost certainly written more than 3 centuries later by Nicolaus of Damascus (1st century BC) and according to Morton (1981) reflects the level to which Peripatetic science was later reduced.

Theophrastus, though not admired as a major philosopher (of the stature of Aristotle, Plato or Democritus), was also a voluminous writer and is credited by Diogenes Laertius (3rd century AD) with 227 treatises. Apart from his well known Characters, his only other extant works are: *Περί φυτών ιστορίας* (Historia Plantarum, Enquiry into Plants, *HP*, in 9 Books) and *Περί φυτών αιτιών* (De Causis Plantarum, Causes of Plants, *CP*, in 6 Books). These works are the first, truly scientific botanical writings and correspond roughly to modern textbooks of General Botany and Plant Physiology, respectively. Among his non-extant works, 6 Books on the behaviour of animals are also included.

Peck (in his 1965 Introduction to *HA*) discusses all the relevant bibliography (in particular Thompson, 1910) concerning the dates of the treatise and concludes that Aristotle's natural history studies were carried out, or mainly carried out, between his two periods of residence in Athens, and especially during the 2-year stay at Lesbos (344-342). A similar conclusion is reached by Morton (1981) who suggests that Aristotle had not studied animals systematically until 344 BC when he moved to Lesbos. Kiortsis (1989) cites as writing dates the following: for *HA* 347-342 BC, for *PA* 330 BC and for *GA* 330-322 BC. Mitropoulos (in his Introduction to *HA*) believes that Aristotle's zoological works have been written

in collaboration with several colleagues and disciples (Theophrastus, Strato, Eudemus and other Peripatetics). In his opinion, Theophrastus may have contributed much and, in particular, the spurious 10th Book of *HA* may belong exclusively to him. On the other hand, Balme (in his 1988 Introduction to the third volume of *HA*) concludes that there seems to be no compelling reason to believe that *HA* was written before the other biological treatises. In his opinion, all the available evidence suggests that Aristotle wrote *HA* I-IX as a study of animal differentiae; he collected the data initially from other treatises and then proceeded to complete the study from new reports, a process which was still unfinished at his death. The likeliest period for the bulk of his work is his stay at Lesbos (344-342 BC) and subsequent years (until 336 BC). Such a suggestion of course conflicts with the assumption that the *HA* was the collection of data which were to become the subject of further investigation in the other treatises. According to Balme, even Book X of *HA* is a genuine work of Aristotle, which nevertheless would possibly not belong to *HA* (it is probably the book listed in older catalogues as 'On failure to generate'). Concerning the dates of the works of Theophrastus, there exists only a suggestion by Morton (1981) that they were written in their final version around 300 BC. Hort (in his 1916 Introduction to *HP*) notes that the style of Theophrastus in his botanical works suggests that, as in the case of Aristotle, what we possess consists of notes for lectures or notes taken from lectures; there is no literary charm while the sentences are mostly compressed and highly elliptical, to the point sometimes of obscurity.

In my opinion, 344 BC may constitute the landmark of the creation of the Science of Biology in general and of its main constituents, Zoology and Botany, in particular (Thanos, 1992). A critical mass of technical and social changes in the Greek World (explicitly illustrated by Morton, 1981) motivated Aristotle and Theophrastus and resulted in their joint decision to pursue an organized study of the living world. Therefore, a rough division of labour was mutually agreed, Aristotle choosing animals and Theophrastus plants as their respective fields of interest. It should be no surprise that this decision was taken in the charming natural environment of Lesbos. As well, the origins of the two men must have played a role in that decision. Aristotle's father was a physician and he himself had some medical knowledge; Theophrastus, on the other hand, was closer to agriculture and forestry and evidently was aware, from his father, of many technical aspects of handling clothes and leather. I assume that the outlines of their major biological treatises had been thoroughly discussed and worked out during their stay in Lesbos; the bulk of their work would be already completed within the following decade, just in time for the inauguration of their Lyceum. If we accept that all these natural history books are simply University textbooks for the use of the Lyceum students, it is obvious that such treatises would continually be updated and corrected (and this would account partially for the confusion about their dates of composition, described previously). Therefore it may be deduced that concerning their biological works, the productive period for Aristotle was during his forties whilst for Theophrastus, it was during his thirties and forties. An interesting and relevant point is that although both pay full tribute to the earlier natural philosophers and naturalists (whom they cite in many instances: Alcmaeon, Anaxagoras, Empedocles, Democritus, Hippon, Menestor, Androtion, Chartodras, Diogenes of Apollonia, Cleidemus, Androkydes, Thrasyas of Mantineia, Leophanes) they never cite each other. Aristotle is never mentioned by name in Theophrastus although he is mostly prominent throughout *HP* and *CP*; the same holds true for Aristotle's works. The reason is that during this particular period it was considered good form not to mention a contemporary by name; this is, incidentally, solid proof that Theophrastus had already written the core of his works while Aristotle was still alive.

Aristotle is generally acknowledged nowadays as the founder of Biology in general and of Zoology in particular (e.g. Kiortsis, 1989). Theophrastus, on the other hand, although an extraordinary scientist, has only recently been recognized, internationally, as the founder of the science of Botany (e.g. Morton, 1981; Evenari, 1984). In my opinion both Aristotle and Theophrastus should be considered the co-founders of Biology.

The decision to split their study for 'academic'

reasons may explain why both refrained from penetrating, in their writings, into each other's specific field. Nevertheless, overlapping and casual references to comparisons and interactions between plants and animals were obviously inevitable. Along with the discourse of Aristotle-Theophrastus interaction and integration, the principal aim of this study has been the compilation and the critical analysis of the passages where animals and plants are cited in common. For this reason the previously mentioned major biological works of both men have been appropriately screened.

Textual references to plant-animal interactions

Aristotle, particularly in *GA*, and Theophrastus to a lesser extent are repeatedly attempting comparisons and analogies between animals and plants, though mainly on basic or general issues; as, for instance, in their discussions of general form and basic functions such as growth, nutrition and reproduction. According to Aristotle, plants are living creatures as well, but of a 'lower' level. Nature proceeds from the inanimate to the animals by small steps; the first step is plant life: it seems alive compared to inanimate things and inanimate compared to the animals (*HA* 588b). Plants lack locomotion (*PA* 656a) and have no power of sensation, or 'sensory soul' (like sea-squirts, sea-lungs and sponges, *PA* 681a, *GA* 741a; during sleep animals live like plants, *GA* 778b-779a). Nevertheless, in both plants and animals the principles ('souls') of growth, nutrition and generation are present (*GA* 735a, 740b). Plants do not have any excrement (*PA* 650a, 655b; similar to lower animals like sea anemones, *HA* 531b and ascidians, *PA* 681a), do not have real sexes (*GA* 731a), do not impregnate (like testaceans, *HA* 538a), accomplish their reproduction according to seasons (similar to certain sea animals: testaceans, sea-squirts, sea anemones and sponges, *HA* 588b) and can survive when dissected (like certain insects, *PA* 682b). A well-known assumption of Aristotle is that plants are like animals upside down (*PA* 650a); plants, like all living things have a superior and an inferior part but their superior part is in an inferior position (*IA* 705a-b, 706b). Because the superior part of plants is the roots which have the character and value of the mouth and head, the seed is the opposite, being produced at the top (*PA* 686b). After discussing similar subjects (*HP* 1.1.1.-1.2.6.), Theophrastus concludes: 'We should not expect to find in plants a complete correspondence with animals' (*HP* 1.1.3.), 'since plants, in contrast to animals, have no behaviour or activities' (*HA* 1.1.1.). Both Aristotle and Theophrastus draw the analogy of the leaf shedding habit in plants to the shedding of horns in stags, feathers in hibernating birds and hair in four-footed animals (*GA* 783b; *HP* 1.1.3.). Aristotle also compares blood vessels to the veins of broad leaves (*PA* 668a) and the umbilical cord through which the embryo receives its nourishment to the analogous structure (funicle) that connects the developing seed with the pericarp, as is nicely observed in pods (*GA* 752a, 753b).

Although Theophrastus was emphatically teaching botany instead of providing a local flora or a treatise on crop cultivation, the great economic importance agriculture had already gained during his time is obviously reflected to a certain degree in his works. Therefore, in numerous passages one finds discussions about manuring, particularly that concerning the effect of the various animal sources of manure to the growth of plants of various important crops (e.g. *HP* 2.2.11., 2.6.3., 2.7.3.-4., 6.7.6., 7.5.1., 8.7.7.; *CP* 3.6.1.-2., 3.9.1.-5., 3.17.5., 5.15.2.-3.). In addition, there are numerous references to animal pests and animal-caused diseases of plants, particularly crops (e.g. *HP* 3.12.8., 4.14.1.-10., 5.4.4.-5., 7.5.4., 8.10.1., 8.10.4.; *CP* 2.11.6., 3.22.3.-6., 4.14.4., 4.15.4., 4.16.1.-2., 5.9.3.-5., 5.10.1., 5.10.3., 5.10.5., 5.17.6.-7.). Considerable attention is devoted to seeds that are consumed by the larvae of beetles - thought to be produced by the seed itself - (e.g. *HP* 7.5.6., 8.10.5.; *CP* 5.18.1.-2.); this is a common case in legume seeds which are infested by larvae (today identified as the larvae of bruchid beetles), with the exception of chick pea (*Cicer arietinum*), bitter vetch (*Vicia ervilia*) and lupin (*Lupinus albus*) seeds which do not engender any creatures (*HP* 8.11.2.; *CP* 4.2.2.). In the case of chick pea, Theophrastus argues that it is a particular saltiness in the seed coat that prevents infestation (*CP* 6.10.6.).

As an obvious result of the great importance of

galls as a tannin source, Theophrastus deals with them in detail and describes the external morphology of ten different types of galls produced by oak trees (*Quercus* spp., *HP* 3.7.4.-5.). He further reports several additional ones occurring in kermes-oak (*Quercus coccifera*, the well known scarlet 'berry' gall, *HP* 3.7.3., 3.16.1.), terebinth (*Pistacia terebinthus*, *HP* 3.15.4.), elm (*Ulmus glabra*, *HP* 3.7.3.) and laurel, in particular the male tree (*Laurus nobilis*, *HP* 3.7.3.). Although the general belief of his time was that the galls were formations of the plant itself, Theophrastus had noticed the presence of insects (resembling mosquitoes and flies, respectively) within the hollow bag-like gall of terebinth (*HP* 3.15.4.) and in the transparent, watery gall of the leaf rib of oak (*HP* 3.7.5.).

In discussing herbivory, Theophrastus makes a strong point that no general rule can be reached (*HP* 1.12.4.). Some parts of the plant may be edible and other inedible (*CP* 6.12.9.-11.); also some animals seem to prefer the tender parts while others prefer dry parts (*CP* 6.12.12.). He further states that it is usual that leaves are not edible while the fruits of the same plant can be consumed by both humans and animals. Less usual is the case of lime (*Tilia europaea*) with edible leaves but inedible fruits (*HP* 1.12.4.). Some plants are not touched by animals when they are green but are edible only when dried (after the sun has eliminated the 'bitterness'), as with sesame (*Sesamum indicum*), lupin (*Lupinus alba*) and possibly hedge-mustard (*Sisymbrium polyceratium*) and red-topped sage (*Salvia viridis*) (*HP* 8.7.3.; *CP* 6.12.12.). Another interesting observation is that animals find legumes a pleasure to digest (*CP* 4.9.1.), whilst legumes and fruits are part of the diet of the bear (*HA* 594b). According to Aristotle, sheep and goats are herbage eaters but, when foraging, the sheep graze intensively and stay in one place, while the goats quickly move on and only browse the tops; sheep are fattened on young olive shoots, wild olive (*Olea europaea* subsp. *oleaster*), tare (*Vicia sativa*) and any kind of brand (*HA* 596a). Cattle eat both grain and herbage, but are fattened on legumes such as bitter vetch (*Vicia ervilia*) and broad beans (*Vicia faba*). Horses, mules and asses eat grain and herbage (*HA* 595b); pigs are most inclined to eat roots and they are fattened on barley, millet, figs, acorns, wild pears and cucumbers (*HA* 595a). Some pasture species, such as lucerne (*Medicago sativa*), cause a failure of milk production, especially in ruminants; other pasture species, like cytisus (probably *Medicago arborea*) and bitter vetch (*Vicia ervilia*), increase the milk, although cytisus, when in bloom, causes burning and bitter vetch makes parturition more difficult (*HA* 522b).

Theophrastus mentions several examples of specific plants that produce toxic compounds and which may cause poisoning or death to the animals that might consume the particular plant parts. Examples furnished include black hellebore (*Helleborus cyclophyllus*), fatal to horses, cattle and pigs (*HP* 9.10.2.), the deadly root of wolf's bane (*Aconitum* sp.) which is not touched by sheep or other animals (*HP* 9.16.4.), the leaf and the fruit of the 'spindle-tree' (*Rhododendron luteus*), fatal to both sheep and especially to goats (*HP* 3.18.13.), the leaf of yew (*Taxus baccata*), fatal to beasts of burden but not to ruminants (whilst its red 'fruit' is sweet and harmless to humans, *HP* 3.10.2.). Even three exotic plants (*Scorodosma foetida*, *HP* 4.4.12.; *Nerium odorum* and an unnamed plant, *HP* 4.4.13.) are cited as toxic. Aristotle also provides certain peculiar accounts: when a turtle has eaten some of a viper it eats oregano as well; when a weasel fights a snake it eats rue (*Ruta graveolens*) for its smell is inimical to snakes; storks and other birds apply oregano to a wound caused by fighting; when a snake eats fruit, it swallows the juice of 'bitter-wort' (*HA* 612a) (vipers are also said to take rue after eating garlic, *CP* 6.4.7.). An interesting example is the highly poisonous root of *Thapsia garganica* which was never touched by the cattle indigenous to Attica, where this plant was particularly abundant. Imported cattle, on the other hand, fed on it and perished of diarrhoea (*HP* 9.20.3.). Fish are killed by the juice of black mullein (*Verbascum sinuatum*); hence people poison them in rivers and lakes whilst Phoenicians even used this poison in the sea (*HA* 602b). The Cretan dittany (*Origanum dictamnus*) is a fine example of healing properties. The plant is described by Theophrastus as being endemic to Crete and useful for many purposes, especially against difficult labour in women (*HP* 9.16.1.). The plant is both rare and with a very narrow distribution, attributable to the fact that

goats are fond of it and graze it out. Theophrastus (*HP* 9.16.1.) adds also, somewhat sceptically though, the story of the arrow (cited by Aristotle as well, *HA* 612a) according to which a wounded wild goat (*Capra aegagrus cretica*) seeks to eat dittany and as a result the arrow drops off. This impressive story inspired the Flemish engraver Dapper, who illustrated it in 1703 (Baumann, 1982). In a comparable case the leaves and the stalk of silphium (*Ferula tingitana*) are said to be pleasant eating to sheep; it is also said that when a sick sheep is driven to graze in the silphium district it is quickly cured (*HA* 6.3.6.).

Another chapter concerns the repellant action of certain plants or plant products. In particular, hulwort (*Teucrium polium*) is good against moth in clothes (*HP* 1.10.4.). Furthermore, all insects find olive oil oppressive, for they avoid the mere smell of it (*CP* 6.5.3.) due to its pungency, just as with oregano (*Origanum* spp.) and the like (evidently, other aromatic labiates) (*CP* 6.5.4.). Ants will be made to abandon their nests if the entrances are sprinkled with oregano whilst most animals will flee if gum of storax (*Styrax officinalis*) is burnt (*HA* 534b). A strong insect-repellant action is reported for both species of *Inula* (*I. graveolens* and *I. viscosa* – recently renamed *Dittrichia viscosa* -, the former - considered the 'female' kind - being more pungent, *HP* 6.2.6.); in addition, octopuses hold on so fast to the rocks that they cannot be pulled off unless they smell fleabane (*I. viscosa*) (*HA* 534b). As an example of mutually beneficial 'collaboration' radishes (*Raphanus sativus*) are reported to be interplanted with bitter vetch (*Vicia ervilia*) in order to prevent the latter from being eaten by flea-spiders (*HP* 7.5.4.; *CP* 2.18.1., 3.10.3.).

In the field of pollination one has to admit that no great contribution to our knowledge could be expected during Theophrastus' era. The real nature of flowers as sexual organs eluded Aristotle and Theophrastus. This comes as no surprise, since plant sex was suggested only two millennia later, in 1672, by the English physician Thomas Millington and the first experimental proof was furnished subsequently, in 1694, by Rudolf Jacob Camerer, a German professor of medicine at Tübingen (Bristow, 1980). Nevertheless, Aristotle and Theophrastus unconsciously distinguished the two sexes in certain dioecious plants on the basis of their fruiting ability, the 'female' being of course the fruit-bearing type; this same discrimination was generally extended on various domesticated plants as opposed to their wild relatives (e.g. olive - wild olive and fig - caprifig, *GA* 715b). Both Aristotle and Theophrastus believe that plants have no real sexes; Aristotle, in particular, is puzzled by the Testacea for which he states in several instances that having no sexes (and being sessile as well) they stand midway between plants and animals (*HA* 537b; *GA* 715b, 731b, 761a,b). According to Theophrastus the nature of seeds is close to that of eggs since they both contain in themselves a certain amount of food which is consumed with 'birth' (*CP* 1.7.1.). Aristotle similarly believes that in the living creatures where male and female are not separate, the 'seed' is as it were a foetus (*GA* 728b); he further states that animals with separate male and female parts seem to be just like divided plants: as though you were to pull a plant to pieces when it was bearing its seed and separate the male and female present in it (*GA* 731a). Thus things are alive by virtue of having in them a share of the male and of the female, and that is why even plants have life (*GA* 732a).

The case of the date palm (*Phoenix dactylifera*) has been well known since at least 1500 BC, as illustrated in the bas-reliefs of Nimrud in Mesopotamia (Meeuse & Morris, 1984). There is strong evidence that even the ancient Assyrians were familiar with the practice of artificial pollination of date palm. Theophrastus, after describing this procedure (*HP* 2.8.4.; *CP* 3.18.1.), advances further to the point of comparing (*CP* 2.9.15.) the dusting of the female flowers by the male inflorescence to what was observed with fish, when the male sprinkles his milt on the eggs as they are laid (*GA* 755b). Another very interesting case is fig caprification, the fig tree (*Ficus carica*) being a close companion of man for many millennia in the Eastern Mediterranean area. Concerning fig caprification, Theophrastus devotes two lengthy and quite exhaustive passages (*HP* 2.8.1.-3.; *CP* 2.9.5.-14.) and Aristotle a short but comprehensive one (*HA* 557b). In certain cultivated fig varieties (considered the 'female' fig trees), caprification is the necessary procedure to promote proper maturation of the syconium, the

complex fruit of fig. Thus wild figs (produced by so-called 'male' fig trees) were hung on the cultivated fig tree or wild trees were planted on eminences near the fig orchard to ensure the insects an easy flight down wind (*CP* 2.9.5.). For it is certain particular insects that after having grown inside the developing seeds of the wild figs will pierce the pericarp tissues, to seek another fig to get in (*HP* 2.8.1.; *CP* 2.9.5.) and spend the rest of their life (having carried the pollen from the first to the latter while at the same time laying their eggs). These insects are the 'psenes' of Theophrastus, the presently called fig wasps, Agaontidae (the particular one being *Blastophaga psenes*). Theophrastus also describes another type of wasp which never gets out of the fig and is sluggish like a drone (*HP* 2.8.2.). These are actually the wingless male wasps that fertilize the females before the latter make their trip to their second fig-host. (For a modern account of fig biology the reader is referred to Galil, 1977.)

Aristotle appears to be in possession of both accurate and deep knowledge in regard to apiculture, although he was obviously ignorant of the role of pollen and nectar. After sceptically mentioning that, according to some, bees are generated spontaneously from the flowers of a broom, reed or olive (*HA* 553a), he correlates a heavy crop of olives with frequent bee swarming (*HA* 553b) since wax collecting had been observed on the olive trees (*HA* 624b). It is from the flower of thyme (*Coridothymus capitatus*) that the bees get the honey and according to the abundance of its flowering the beekeepers can forecast a rich or a poor yield (*HP* 6.2.3.). Thyme honey is outstanding for its sweetness and consistency and can be distinguished immediately (*HA* 554a). Besides thyme as a source of food (*HA* 626b), during blossom periods bees collect from the following plants: 'atraktyllis' (*Carthamus* sp.), honey-lotus (*Trigonella graeca*), asphodel (*Asphodelus* sp.), myrtle (*Myrtus communis*), 'phleos' (*Saccharum* sp.), chaste-tree (*Vitex agnus-castus*) and broom (*Spartium junceum*) (*HA* 627a). It is also beneficial to plant around the hives wild pears (*Pyrus amygdaliformis*), almond (*Prunus amygdalus*), myrtle (*Myrtus communis*), broad beans (*Vicia faba*), lucerne (*Medicago sativa*), Syrian grass (probably a legume), winged vetchling (*Lathyrus ochrus*), poppy (*Papaver rhoeas*) and herpyllus thyme (*Thymus* sp.) (*HA* 627b). In Pontus (Black Sea) there exist white bees which produce honey twice per month but only during the winter because they collect honey from the abundant ivy (*Hedera helix*) (*HA* 554b). Aristotle had noticed that on each individual flight the bee visits only plants of the same kind (*HA* 624a) and the wax (i.e. the pollen) is carried on the legs (*HA* 554a); the bees pick it up by scrabbling at the blossoms busily with their front feet and subsequently wiping it off to the middle and hind ones (*HA* 624a). The honey is gathered with their mouth from all flowers whose blossoms are in a calyx and from all others which contain sweetness (nectar?), without any injury caused to the fruit; finally the honey is vomited in the cells of the comb (*HA* 554a). Bees were observed to sicken when they worked on mildewed plants and the best honey was made from young wax (pollen) and 'moschos' (nectar?) (*HA* 626b). The comb comes from flowers and is sealed with tree gum whilst the honey is made from what falls from the air (*HA* 553b), an unfortunate conclusion due to the fact that no direct correlation with flowering could be drawn: the hives were found filled with honey within one or two days (and not for instance in the autumn, although there was blossom enough) (*HA* 553b).

In the field of seed and fruit dispersal, numerous accounts are furnished, especially by Theophrastus. The cormlets of the corn-flag (*Gladiolus segetum*) are found in the runs of moles (*Talpa europaea*) 'for this animal likes them and collects them' (*HP* 7.12.3.), this habit leading, unintentionally of course, to dispersal of the plant. A similar case of accidental dispersal and regeneration is in oaks (*Quercus* spp.), through the caching of acorns by jays (*Garrulus glandarius*) and other birds (*HA* 615b; *CP* 2.17.8.). An example of epizoochory is the fruit of goosegrass (*Galium aparine*) which sticks to clothes (*HP* 7.14.3.). Endozoochory is represented by ivy (*Hedera helix*) fruits reported to occur either as bitter or sweet and consumed by birds only in the latter state (*HP* 3.18.10.). An interesting example of removal of hardseededness by the passage through the digestive tract is furnished by the pods of *Cytisus aeolicus*: they are described as a wonderfully fattening food for sheep whilst best seed germination is obtained by

using the sheep-droppings (*HP* 3.17.2.). A final fine example of zoochory is the case of the mistletoe; it is at the same time a masterly treatise by Theophrastus (*CP* 2.17.1.-10.), which, incidentally, has escaped the attention of mistletoe specialists such as Calder & Bernhardt (1983). In this discourse, Theophrastus, after having identified the two species occurring in Greece (*Loranthus europaeus* and *Viscum album*) (*CP* 2.17.1.), asks questions and provides answers concerning the peculiar habit of these plants not to grow on the ground but only on a host tree (*CP* 2.17.3.) of various species: *Abies* spp., *Pinus* spp., *Pistacia terebinthus* and *Quercus* spp. (*CP* 2.17.1.), even *Q. coccifera* (*HP* 3.16.1.). He concludes that mistletoes are dispersed by birds in the seed state since it is the birds that consume the mistletoe berries (*CP* 2.17.5., 2.17.8.); incidentally, Aristotle, in describing the three species of thrush he had observed, mentions that one of them (most probably the mistle thrush, *Turdus viscivorus*) eats only mistletoe berries (*HA* 617a). The seeds pass unharmed through the digestive track of the bird and are able to establish their new seedlings only when the droppings happen to fall on a host plant (*CP* 2.17.5.).

Besides (or maybe due) to the rough division of labour into two main, scientific domains, most scattered references to plants in Aristotle and a considerable number of references to animals in Theophrastus are of a general type and follow a very consistent pattern of principled comparisons between animals and plants. The overall impression is the conception by both men of a single natural kingdom of living organisms, a profoundly scientific view derived from the naturalism of the Ionian philosophers and in marked contrast to the idealism of Plato (Morton, 1981).

The extent of the greatness of Aristotle and Theophrastus as scientists will be additionally illustrated by the striking passages that follow. According to Aristotle it is not the size of the body that determines the size of the brood; and it is not only among the animals that walk but also among those that fly and swim that the big ones produce few offspring and the small ones produce many. Similarly too it is not the biggest plants that bear the most fruit (*GA* 771b). Theophrastus also notes that plants with smaller seeds produce more of them and, similarly, certain animals (especially the oviparous and larviparous ones) bring forth small but numerous progeny (*CP* 4.15.2.). In prolific birds, nourishment is allocated to the semen; some fowls after having lain excessively, die. Similarly many trees wither away when they have borne an excessive amount of fruit since no nourishment is left for them. Annual plants (legumes, cereals) experience the same thing. Their kind produces a great deal of seed and they use up all their nourishment for seed. The birds and plants alike become exhausted (*GA* 750a). Theophrastus observes that the most prolific animals are the quickest to age and die whilst, similarly, the plants that age earlier are those that bear many crops and abundant fruit (*CP* 2.11.1.), or too large a crop (in both trees and annuals) (*CP* 2.11.2.-3.). These remarks should be considered as the earliest hints of *r*- and *K*-selection strategies as well as of the principle of allocation and reproductive effort. These important concepts have only recently been established in the fields of reproductive biology and evolution; in particular the rapid death of monocarpic plants following reproduction may simply be a consequence of exhaustion, because of excessive reproductive effort (for a comprehensive account of these concepts the reader is referred to Fenner, 1985).

A final point is that although Aristotle and Theophrastus were by any standards great philosophers and scientists, their works reflect to a great extent the overall attitude towards nature, at the end of Classical Antiquity, as well as the level of accumulated knowledge of Greek society in general at that time.

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